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Implementing Barcode Medication Administration Systems in Public Sector Medical Units

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ABSTRACT

Medication errors in healthcare have a high cost since it is one of the main causes of harming a patient; it leads to inefficient utilization of healthcare organization resources. The barcode medication administration system helps in improving the patients' safety. The purpose of this article is to determine preparatory needs for introducing a Barcoding Medication Administration System (BCMA) in the medical units in one of the largest tertiary hospital in Abu Dhabi City, United Arab Emirates. Analytical Hierarchical Process (AHP) has been employed to describe systematic decision-making by prioritizing different factors that affect the implementation of BCMA and how technology plays a role in helping to reduce or prevent human errors by promoting safety in the health care sectors. Five major domains are identified: leadership, technology, process, education, quality and safety. Leadership was found to be the most important factor oppositely of technology was the least important.

KEYWORDS

Analytic Hierarchy Process, Barcode System, Education, Leadership, Medication Errors, Process, Quality and Safety, Technology

1. INTRODUCTION

Medication errors in healthcare are one of the main causes of patient harm (Radley et al., 2013). The Institute of Medicine (IOM) estimates that medication errors happen at least daily in hospitals (Aspden et al., 2007). The cost of medication errors is high and leads to inefficient utilization of healthcare organization resources (Chan et al., 2008). Typical medication administration process involves physicians to write medication orders and nurses to carry out these orders by administering medications (Leape et al., 1991). This process carries the risk of many errors (Elixhauser and Owens, 2007). Medication administration has moved gradually to be electronic in line with the movement to digitalize healthcare processes. Digitizing medication administration involves introducing the Barcode Medication Administration (BCMA) System, which is considered to be a powerful tool to prevent errors and ensure more manageable support of patient safety (Radley et al., 2013). BCMA systems

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bring many technologies into the workflow of the medication administration process (Hook et al., 2008). However, this system may be difficult to implement due to various reasons (Klingner and Prasad, 2013). This difficulty comes from its direct effect on the patient safety (Poon et al., 2010).

A wide range of studies address the concept of patient safety in literature and there are factors that found to contribute to patient safety mentioned in literature reviewed in this study. Schein (2010) identified leadership as the first factor that affects patient safety in healthcare organizations directly. This finding was supported by another study done by Squires and his colleagues in 2010 that identified those leaders acknowledgement is essential to deal with high-risk healthcare environments, and seeks to align vision/mission, staff competency, and fiscal and human resources from the boardroom to the frontline (Squires et al., 2010).

Alahmadi (2010) identified teamwork, a spirit of collegiality, collaboration, and cooperation among healthcare professionals as key to patient safety and Greenfield et al (2011) added evidence base practice to this finding. Communication was identified as a key patient safety factor by large number of studies (Cima et al., 2011; Groves et al., 2011 & Russ et al., 2013). Joint Commission International accreditation (JCIA) has identified six main approaches to patient safety and structured them to be the international patient safety goals (Almidani et al., 2014). Medication safety is one of these safety goals (JCI, 2013). Research on medication errors, effects, and solutions, has been ongoing for three decades, and one of these solutions is using the BCMA system (Leape et al., 1991). BCMA is typically utilized in conjunction with an electronic medication administration record (eMAR) system (AHA, 2002). This system offers several levels of functionality by helping to enforce the rights of patient medication administration rights (i.e. right patient, right drug, etc.) that are likely to be more accurate than a manual medication administration (Hook et al., 2008).

This system has helped greatly to reduce medical errors (Kimmel and Sensmeier, 2002). Furthermore, competition among the wide range of available eMAR software and systems (Henneman et al., 2010) can help drive positive improvement effects in hospital performance through low implementation costs. The administrative efficiencies realized through the use of BCMA can result in improved inventory control, billing accuracy, and reduction of rework (Chan et al., 2008). This system can also support nurses by providing drug reference information and various alerts (e.g. look-alike/sound-alike) and reminders (e.g., important clinical actions that need to be taken when administering certain medications) (Hook et al., 2008). BCMA implementation can be complex and multiple factors may affect its successful implementation (Boonstra et al., 2014). To control these factors to support implementation, they must be prioritized. There are several prioritization techniques and methods found in literature.

The purpose of this study is to prioritize factors affecting implementation of BCMA in medical units in a tertiary hospital of Abu Dhabi city in United Arab Emirates. BCMA implementation involves multiple factors and sub factors and indeed is a multi-criteria decision making complex issue. Five important factors (leadership, technology, process, education and quality and safety) affecting BCMA implementation in health sector of UAE has been identified and these factors have been further broken down in many sub factors. To deal with this complexity, issue has been arranged in hierarchical form and AHP has been chosen as the best possible option. The study will use Analytical Hierarchical Process (AHP) model to examine set of factors mentioned in literature to affect the BCMA implementation. The medical city where the BCMA is implemented is the largest healthcare provider in the UAE with more than 625 beds and multi-speciality services. Results of this study will be presented to the facility and system's leadership to be used as a new strategy to improve safe implementation of this technology. The structure of this study involves a literature review to explore factors that might affect the implementation BCMA. These factors will be tested using the analytical hierarchical process (AHP) model. Discussion of all factors and their subcategories will follow, and conclusions and recommendations from this study will be described accordingly.

2. LITERATURE REVIEW

The Institute of Medicine (IOM) has reported that medical errors cause death to 44,000 - 98,000 people in U.S. hospitals each year (Donaldson, Corrigan & Kohn, 2000). This report was used to begin the process of improving deficits in patient safety, including a focus on organizational safety culture (Leape, Berwick, & Bates, 2002). Organizations use various strategies to control, if not eliminate, these errors and use of technology is one of these strategies. Technology is an integral part of every healthcare setting nowadays. BCMA is one of these technologies to eliminate medication errors. The literature identified several factors affecting implementation the BCMA in healthcare organizations. Factors identified were: organization leadership, type of technology, processes, proper education, and quality and safety.

2.1. Organization Leadership

The literature demonstrated that leadership is one of the crucial factors affecting successful implementation of BCMA, and that there are underlying factors leading to this effect of leadership. Leaders are required to have the ability to critically appraise team processes and outcomes on the path toward achieving a shared goal (Fowler et al., 2009). Investment of resources needed to support system evaluation, and a balance between safety and production costs and engagement with front-line staff is also needed (Klingner and Prasad, 2013). Additionally, the importance of leadership support and commitment from the top level was often emphasized (Ash et al., 2012), as was bottom-up physician leadership and input (Lake et al., 2011).

The stability of the organization and its ability to manage change will ultimately determine the success of a change implementation. Recognition of organizational characteristics and past experiences with implementing new technology should be considered early in the planning stages (McAlearney et al., 2012). This will require healthcare leaders to find a system for identifying, reporting, analysing, and reducing the risk of medication errors (Klingner and Prasad, 2013). This action is referred to as system assessment for implementation readiness. Part of this assessment is implementing a non-punitive culture of safety, and it must be cultivated to encourage disclosure of errors and near misses, stimulate productive discussions, and identify effective system-based solutions. Speaking about the human part of the management Karsh et al (2006) studied the human factors engineering paradigm for patient safety, and found that healthcare leaders must appreciate the complexity surrounding the electronic medical record (EMR) system and understand the safety issues in order to mandate sound design, development, implementation, and use. They have reported that all new systems under study, including the BCMA, generate unintended adverse consequences to patient safety that may relate to design or implementation problems (Karsh et al., 2006). Staffing pattern deficiencies, excessive workloads, and complex work processes are also factors underlying a broad range of errors (Fowler et al., 2009).

Change management is another issue that leadership should consider when looking implementing a new technological system. Sutherland (2013) studied the use of Lewin's Change Management theory to guide the implementation of a barcode medication administration system at a psychiatric facility. She concluded that this theory could help promote acceptance by front-line nurses by involving them in all aspects of planning and implementation (Sutherland, 2013). Moreover, Garrett in 2009 with others concluded that addressing restraining forces can help ease adoption and help ensure smooth implementation of the BCMA system, which can result in reduced medication errors (Garrett et al., 2009). Environmental factors such as poor lighting, cluttered work spaces, noise, interruptions, high patient acuity, and non-stop activity contribute to medication errors when health care providers cannot remain focused on appropriate medication use (Garrett et al., 2009). Staffing pattern deficiencies, excessive workloads, and complex work processes were also identified factors underlying a broad range of errors (Fowler et al., 2009).

2.2. Technology

Most of the literature related to the barcoding systems linked to medication administration practices refers to different studies carried out in Western countries, but not in the developing world. No literature was found in reference to implementing BCMA systems in the UAE, it is a new technology for the health care sector and is still in the initial stages of implementation. Health information technology (HIT) has the potential to improve the health outcomes of individuals and the performance of providers by yielding improved quality, cost savings, and greater engagement by patients in their own health care (Buntin & et al., 2011). Bates and Bitton (2010) reviewed the benefits accrued more frequently in large organizations that were early adopters of HIT. They reported that benefits might be more widely attainable than previously thought (Bates & Bitton, 2010). This finding is supported by a study done by Middleton et al; who found t that the use of technology effects care delivery and on provider and patient satisfaction (Middleton et al., 2013).

On the other hand, Fineberg's (2012) research was on the implementation of technology in health care reported that implementation was associated with an increase in patient care errors, including medication errors, procedure errors, and patient falls (Fineberg, 2012). Another study conducted in the Netherlands focused on the outcomes of implementing computerized provider order entry in six internal medicine wards of an academic medical centre (Øvretveit, 2011), and found that nurse-physician medication collaboration was impaired by the implementation of computerized provider order entry (Øvretveit, 2011). The use of technology in the healthcare setting has increased dramatically over the last decade. Technologies such as electronic billing, EMR, computerized Physician order entry (CPOE), and BCMA technology have been implemented in varying degrees at many major hospital institutions. Many of these innovative technologies were created for the sole purpose of promoting safety by preventing the potential for human error (McGrath et al., 2010).

Sakowski and colleagues (2013) studied the effect of technology on medication errors in a network of 27 hospitals in Northern California, and found that errors were prevented in 1.1% of all attempted medication administrations (Sakowski et al., 2013). More over Yates in 2007 proved that the implementation of a bar-coded bedside medication administration system, by a hospital in Missouri, led to reduced medication administration errors, increased patient safety, and accurate reporting (Yates, 2007). Ideally, a hospital would integrate multiple technologies (Hunter, 2011) for other clinical systems to achieve maximum safety benefits for patients and efficiency for the organization (Radley et al., 2013). This might include order entry, pharmacy systems, a laboratory system, and technology-supported medication administration processes (Ash et al., 2012). These systems are usually embedded incrementally by organizations and require certain specifications to interact among each other (Poon et al., 2010).

Ease of use is one of the factors identified to affect successful BCMA implementation as per the research study conducted in 2003 by Mustonen and his colleagues; they focussed on the Information System process innovation adoption using a longitudinal data set of process innovation adoptions. The study recognized several important factors influencing adoption: user need recognition, technological infrastructure, past technological experience, own trials, autonomous work, ease of use, learning by doing, and standards (Mustonen, Ollila and Lyytinen, 2003). Ease of use is also one of the Technology Acceptance Theory (TAM) which was developed by Davis in 1986 (Davis, 2010). The ability of IT to support a task is expressed by the formal construct known as 'Task Technology Fit' (TTF), which implies matching of the capabilities of the technology to the demands of the task (Goodhue & Thompson, 1995). TTF posits that IT will be used if, and only if, the functions available to the user support (fit) the activities of the user. Rational and experienced users will choose tools and methods that enable them to complete the task with the greatest net benefit. Staffs' perceptions in the literature were studied, and factors leading to satisfied staff are highlighted. & one of the staff satisfaction factors in implementing BCMA identified is the usefulness of the system for the daily activities of staff (Wideman et al. 2005).

2.3. Processes

In order to have a successful implementation of new technology we should have a process on place which is an ultimate need to have safe practices especially when this technology deal with human health. The process is a set of actions or steps, each of which must be accomplished properly in the proper sequence at the proper time to create value for a customer or patient (Hook et al., 2008). Primary processes serve the external customers in healthcare, patients, and their families. Primary processes are easier to see, but internal processes are also necessary to create value in the primary process (Alharthi et al., 2015). Nurses prepare and administer medications for one patient at a time. Many errors are preventable simply by minimizing floor stocks, restricting access to high-alert drugs and hazardous chemicals, and by distributing unit-dose packages of drugs from the pharmacy in a timely fashion (Radley et al., 2013). To facilitate proper identification of drugs, healthcare organizations should provide all medications in clearly labelled, unit-dose packages, and should take steps to prevent errors with look-alike and sound-alike drug names, ambiguous drug packaging, and confusing or absent drug labels. The *ISMP Medication Safety Alert* and/or other current literature is reviewed regularly to identify drug labelling, packaging, and nomenclature problems, and alerts are built into the pharmacy computer software to remind practitioners. Point-of-care technology can be interfaced with the barcode system to provide nurses with relevant alerts (Klingner and Prasad, 2013).

Staff compliance with BCMA has been studied extensively in the literature. Implementation workarounds are defined by many researchers (Koppel et al., 2008). These workarounds can result from many causes, e.g., administering medications without scanning, omission of process steps and more (Mariani et al., 2010). Novak and his colleagues, in 2013, studied omission of process steps and its effect on the BCMA implementation. They found that this workaround can occur in many different manners. To avoid scanning the patient's actual identification (ID) wristband, users were found to affix extra copies of patient ID barcodes on desks, scanner carts, doorjambs, supply closets, or clipboards, or to wear extra copies themselves on belt loops or their own arms (Novak et al., 2013). In 2009 McNulty with his colleagues studied the post-implementation workflow of BCMA, they set a goal of 95 percent compliance, which was achieved. Key success factors identified were; demonstrating executive dedication, creating a culture of ownership by engaging frontline nurses in the solution design, and providing a strong support system (McNutly et al., 2009). In contrary, Alper wit other researchers reported violations during the implementation of BCMA, the staff were skipping steps in the BCMA system which was the main reason in compliance with this technology (Alper et al., 2012).

2.4. Proper Education

With accelerating advances in health information and technology, physicians, nurses, and other healthcare professionals must maintain and improve their knowledge and skills throughout their careers to provide safe, effective, and high-quality healthcare for their patients (Agrawal and Glasser, 2008). Healthcare providers frequently talk to patients about their diseases instead of training them in the daily management of their condition. To address this need, therapeutic patient education is designed to train patients in coping, processes and skills, as well as self-management or adaptations in treatment to address characteristics of their particular chronic disease. Therapeutic education should also contribute to reducing the cost of long-term care to patients and to society (Hook et al., 2008). Doyle's in 2005 research used the diffusion of innovation theory, and the findings show that implications for education include careful review and revision of training material. This is to avoid conflicting statements about the capability of BCMA, and to emphasize critical thinking about the five "Rights" of medication administration. In addition, procedures for BCMA that cannot be accommodated due to unit environment or workflow should be studied further and addressed (Doyle, 2005).

Paterson et al (2002) reviewed lessons learned in the post-implementation evaluation of a barcode medication administration technology implemented at a major tertiary-care hospital in 2001, and they reported that healthcare professional education leads to systematic sustainability of gains achieved by implementing BCMA (Patterson, 2002). Patients can play a vital role in preventing medication errors when they have been educated about their medications and are encouraged to ask questions and seek satisfactory answers. Because they are the final link in the process, healthcare providers should seek patient input in related quality improvement and safety initiatives, and should teach patients how to protect themselves from medication errors (VanderKooi, 2014). Although education in itself is a weak error-reduction strategy, it can play an important role when combined with system-based error-reduction strategies (Agrawal & Glasser, 2008). Activities with the highest leverage include ongoing assessment of healthcare providers' baseline competencies and education about new and non-formulary medications, new technologies related to medication use, high-alert drugs, and medication error prevention strategies (Fowler et al., 2009).

2.5. Quality and Safety

Many people view quality healthcare as the principal umbrella under which patient safety resides. For example, the Institute of Medicine (IOM) considers patient safety "indistinguishable" from the delivery of quality health care. Work groups, such as those in the IOM, have attempted to define quality of healthcare in terms of standards. Initially, the IOM defined quality as the degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge (IOM, 2001). To guide appropriate drug therapy, healthcare providers require readily available demographic information (e.g. patient identity and location), clinical information (e.g. age, weight, allergies, diagnoses, and pregnancy status), and patient monitoring information (e.g., laboratory values, vital signs, of medication effect) (Hook et al., 2008). To minimize the risk of error, the drug formularies must be tightly controlled, and up-to-date drug information must be readily accessible to healthcare providers through references, protocols, order sets, computerized drug information systems, medication administration records, and regular clinical activities by pharmacists in patient care areas (VanderKooi, 2014).

3. METHODOLOGY

A meta-analysis of literature was conducted to establish a base line picture of the variables affecting the successful implementation of BCMA. The identified variables are leadership, technology, process, education, and quality and safety. This literature review began by reviewing studies mentioned the general concept of patient safety, to justify the rationale, and was followed by clarifying the concept of medication error. This step is another way of highlighting the importance of this study. The review then shifted into bringing the concept of technology to the healthcare and how important it is. Part of the technology practices in healthcare is the BCMA which is studied through several articles and studies. SINHAL, Cochrane, and Google scholar search engines are used to identify research articles and studies. Studies are shortlisted and divided into themes: medication errors, technology in healthcare, barcode medication administration, leadership, technology, process, education, quality and safety, and AHP model, and these were used as keywords in conducting the search. Studies that fit the search framework were included in this study. Articles that studied implementation of technology in general or have no connection to patient safety were excluded from this study.

The five major domains were confirmed after conducting interviews with five different experts in healthcare from more than one organization. The main aim of these interviews was to explore the factors affecting implementation of the BCMA in the medical units, in addition to affirm the literature review findings. The interviewees highlighted the most important factor that may affect BMCA implementation is choosing the right equipment and technology. Other experts emphasize was that quality and safety was the main concern for this technology implementation on administering medication to the patients. They accentuate that BCMA process management is one of the important factors that should be clearly stated for the employee to understand the correct flow, and they stressed on having leadership engagement and support to be successful during the implementation stage of

BCMA. While discussing the main factors that were raised and shared by different expert during the second interview, the outcomes were almost similar as they focused on having quality measures in place during and after implementation. Setting the correct medication administration process is essential with proper implementation plan of BCMA, and this plan should have leaders on-board with correct and clear process.

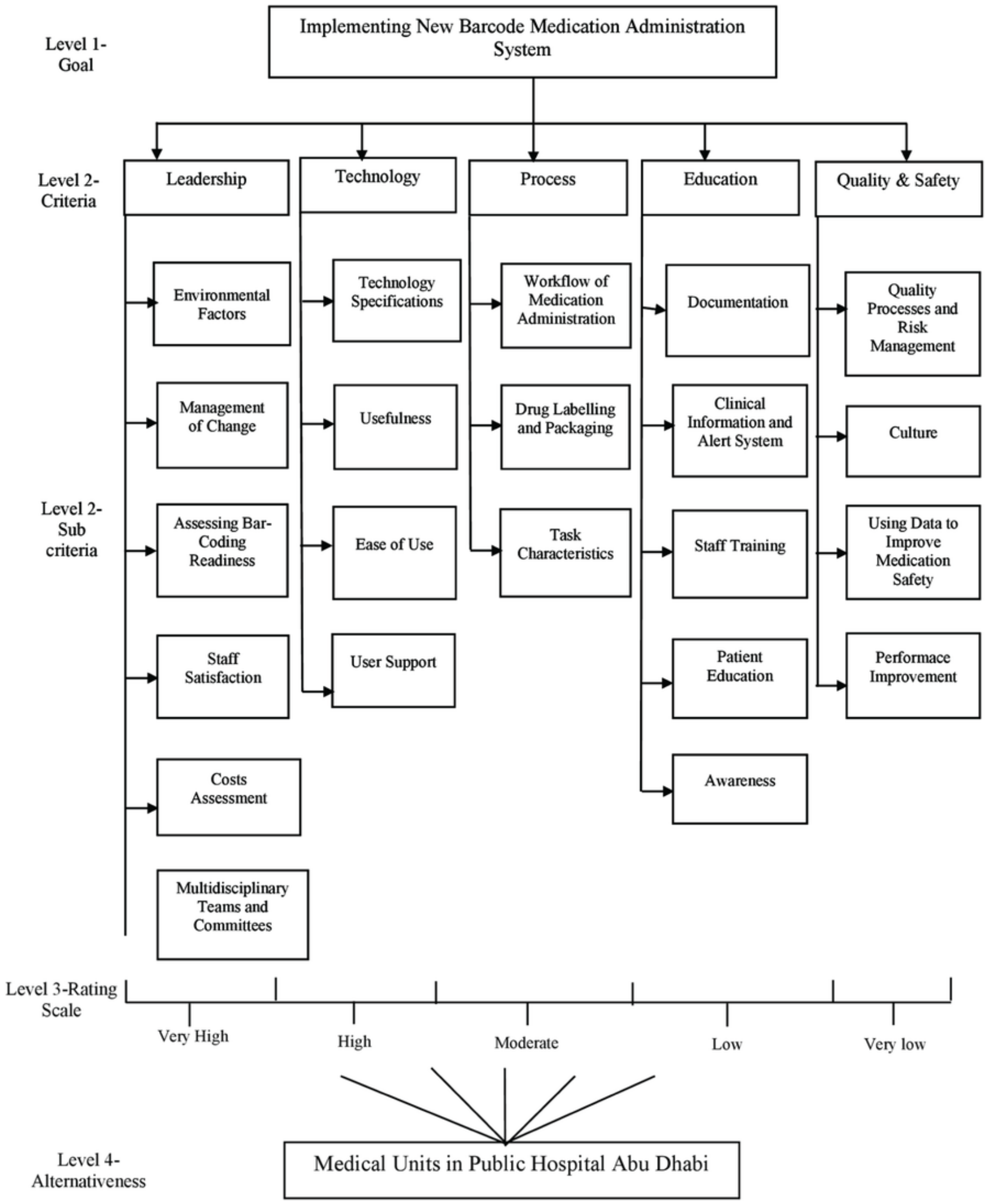
The five factors: leadership, technology, process, education, and quality and safety, were then examined using the Analytic Hierarchy Process (AHP). AHP is one of the most famous methods used to determine which elements that leads to better prioritization and decision making. It was developed to optimize outcomes when one is faced with a mix of qualitative, quantitative, and sometimes conflicting factors that have to be considered. AHP has been very effective in enabling complicated and irreversible decisions (Saaty, 2012). Thomas Saaty developed AHP in the 1970s as a way of dealing with weapons trade-offs, resource and asset allocation, and decision making when he was a professor at the Wharton School of Business and a consultant with the Arms Control Disarmament Agency. There he was faced with the problem of dealing with high costs and a host of considerations with many conflicting factors that were not easily specified (Saaty, 2012). AHP uses the judgments of decision makers to decompose problems into hierarchies; problem complexity is represented by the number of levels in the hierarchy which combine with the decision-maker's model of the problem to be solved. The hierarchy is used to derive ratio-scaled measures for decision alternatives and the relative values that alternatives have against organizational goals (customer satisfaction, product/service, financial, human resource, and organizational effectiveness) and project risks. AHP uses matrix algebra to sort out factors to arrive at a mathematically optimal solution. AHP is a time-tested method that has been used in multi-billion-dollar decisions (Saaty, 2012).

Typical applications where AHP have been used include: 1) Prioritizing factors and requirements that impact software development and productivity; 2) Choosing among several strategies for improving safety features in motor vehicles; 3) Estimating cost and scheduling options for material requirements planning (MRP); 4) Selecting desired software components from several software vendors; and 5) Evaluating the quality of research or investment proposals. The prioritizing approach is important to filter the most affecting factors on the implementation of the BCMA. Multiple prioritizing techniques were examined (Quality Function Deployment, Opportunity Scoring, Story Mapping "MoSCoW" and AHP model). The implication of AHP is making the road map easy for prioritizing the main factors that been identified through the literature review and raised by the experts' during the interviews which highlighted five main factors to be under focus. However, this study is the first of its kind in a United Arab Emirates (UAE) hospitals setting. All literature reviewed indicated BCMA implementation in other care setting. Using the AHP model will provide a scientific way of choosing these factors. AHP is reported to be easy and direct method to choose among multiple options, which is the case in this study. The AHP model showed acceptable results after implementation in this study as factors prioritized are in line with literature and experts' opinions.

4. RESULTS

The AHP method comprises four sequential phases: 1) structuring the decision problem; 2) data collection and measurement; 3) determination of normalized weights; and 4) synthesis and solutions to the problem (Tummala and Wan, 1994). Using this four-phase approach, an AHP model for a BCMA system was formulated. This classifies the goal and all decision criteria and variables into three major levels. The highest level of the hierarchy is the overall goal, that is, implementation of the barcode medication administration system in a particular unit. Level 2 represents the criteria and sub-criteria used in implementing the system. In this research, five criteria are considered: leadership, technology, process, education, and quality and safety. Level 3 contains the decision points that affect the successful implementation of the system. Figure 1 show the hierarchy of the AHP model for evaluating the implementation of barcode medication administration system.

Figure 1. AHP model for evaluating the implementation of barcode medication administration system



After building the AHP hierarchy, the next phase is measurement and data collection. The data were collected from five multi-disciplinary staff teams. As suggested by Saaty (2012), a questionnaire was designed on nine-point scale based on five aspects related to the implementation of new technology (Barcode system), such as leadership, technology, process, education, quality and safety. The questions were discussed and explained to the five selected staff teams working in medical units. They were involved during the implementation of the medication administration system.

The next step in the AHP process was to determine pair-wise comparison among the applied criteria. To determine comparison criteria, Saaty (2012) suggested a nine-point scale, as shown in Table 1. For example, if a participant identifies leadership as moderately more important than technology, the former is rated "3" and the latter "1/3" in this comparison and so on. To check for consistency, the consistency index (CI) is applied. Saaty (2012) defined consistency as follows: CI = $(\lambda_{max} - n)/(n-1)$ where, (λ_{max}) is the maximum Eigen value of the matrix of importance and 'n' is the number of factors. Then, the consistency ratio (CR) is used to assess whether a matrix is sufficiently consistent or not. This is the ratio of the CI to the Random Index (RI), which is the CI of a matrix of comparisons generated randomly: CR= CI/RI.

Random pair-wise comparisons have been simulated to produce average random indices for different sized matrices. The values of RI are given in Table 2. The inconsistency is acceptable if CR is smaller or equal to 0.10 (Saaty, 2012). As suggested by Saaty (2012), the geometric mean approach instead of the arithmetic approach is used to combine the individual pair-wise comparison judgment matrices to obtain the consensus pair-wise comparison judgment matrices for all evaluators.

The competitive priorities of the geometric means of pair-wise comparisons of the main criteria in Table 3 show that leadership is the highest ranked main criterion with a priority weight of

Table 1. 1 to 9 scale for AHP preferences

Intensity of importance	Definition	Explanation
1	Equal importance	Two criteria contribute equally to the objective
3	Moderate importance	Judgment slightly favour one over another
5	Strong importance	Judgment strongly favour one over another
7	Very strong importance	A criterion is strongly favoured and its dominance is demonstrated in practice
9	Absolute importance	Importance of one over another affirmed on the highest possible order
2,4,6,8	Intermediate values	Used to represent compromise between the priorities listed above

Table 2. Random index

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.48

Note: n is number of factors

Table 3. The geometric means of pair-wise comparisons of the main criteria

	Leadership	Technology	Process	Education	Quality & Safety	Priority weight
Leadership	1.00	7.60	2.87	2.67	3.07	0.43
Technology	0.13	1.00	0.13	0.13	0.14	0.03
Process	0.35	7.69	1.00	0.11	1.12	0.14
Education	0.37	7.69	0.89	1.00	5.43	0.26
Quality & Safety	0.33	7.14	0.89	0.18	1.00	0.13

CR= 0.00 <0.10 (acceptable)

0.43. Similarly, technology is the lowest ranked criterion (0.03), and education the second highest priority at 0.26. Overall, the consistency ratio (CR) is below 0.10, which indicates that the matrix is sufficiently consistent.

Under the first main criteria of *Leadership* in Table 4, six sub-criteria were identified. Environmental factors had the highest priority ranking (0.30), whereas assessing readiness was lowest (0.09). The consistency ratio (CR) is below 0.10, which indicates that the matrix is sufficiently consistent.

The four criteria of *Technology* as presented in Table 5, where usefulness carries the highest priority weight (0.44), and user support is the lowest (0.07) The consistency ratio (CR) is below 0.10, which indicates that the matrix is sufficiently consistent.

The three sub-criteria under *Process* which shows in Table 6 that workflow carries the highest priority weight (0.70), and task characteristics carries the lowest (0.07). The consistency ratio (CR) is below 0.10 which indicates that the matrix is sufficiently consistent.

Table 4. The geometric means of pair-wise comparisons of the leadership criteria

	Environmental Factors	Management of Change	Assessing Readiness	Staff Satisfactions	Costs Assessment	Multi-disciplinary Teams	Priority weight
Environmental Factors	1.00	4.06	5.23	2.28	2.28	2.29	0.30
Management of Change	0.25	1.00	6.20	2.27	1.30	1.10	0.17
Assessing Readiness	0.19	0.16	1.00	1.31	2.28	0.13	0.09
Staff Satisfactions	0.44	0.44	0.76	1.00	4.83	6.80	0.21
Costs Assessment	0.44	0.77	0.44	0.21	1.00	3.25	0.10
Multidisciplinary Teams	0.44	0.91	7.69	0.15	0.31	1.00	0.13
							CR= 0.00 <0.10 (acceptable)

Table 5. The geometric means of pair-wise comparisons of the technology criteria

	Technology Specifications	Usefulness	Ease of Use	User Support	Priority weight
Technology Specifications	0.33	0.39	0.22	0.18	0.28
Usefulness	0.36	0.43	0.64	0.34	0.44
Ease of Use	0.19	0.09	0.13	0.41	0.20
User Support	0.12	0.09	0.02	0.07	0.07
					CR= 0.00 <0.10 (acceptable)

Table 6. The geometric means of pair-wise comparisons of the process criteria

	Workflow	Drug Labelling	Task Characteristics	Priority weight
Workflow	1.00	5.23	7.40	0.70
Drug Labelling	0.19	1.00	5.63	0.23
Task Characteristics	0.14	0.18	1.00	0.07
				CR= 0.00 <0.10 (acceptable)

In Table 7, documentation ranked highest (0.31), and awareness ranked lowest (0.06). The consistency ratio (CR) is below 0.10 which indicates that the matrix is sufficiently consistent.

Among Quality and Safety criteria Table 8, quality processes ranked highest (0.52) and performance improvement ranked lowest (0.06). The consistency ratio (CR) is below 0.10, which indicates that the matrix is sufficiently consistent.

5. DISCUSSION

Bedside barcode medication verification is usually implemented in combination with an eMAR system. This system allows nurses to automatically document drug administration and simultaneous patient identification in a real-time manner. This has been identified as the safest method of medication administration. The system imports medication orders electronically from physician order entries or the pharmacy system. Its implementation may reduce transcription errors (American Hospital Association, 2002). This paper is designed to study implementation of a barcode medication administration system in one of the largest hospitals in Abu Dhabi. AHP has been used to select, compare and prioritize the domains of this implementation in terms of highest impact on successful implementation.

The dimensions of leadership, technology, process, education, and quality and safety were identified from a literature review. Sub-criteria were developed for each of these five domains, and a questionnaire was designed with a nine-point scale to rate the five domains and sub-criteria. Leadership ranked as the highest priority criterion (0.43) for successful system implementation. This finding is consistent with previously published literature, which states that leadership buy-in and involvement is the most important factor to consider when implementing change. Leadership is connected to decision making and ultimate accountability of the organization. Among the six leadership sub-criteria, environmental factors rank as the highest priority item (0.30), followed by staff satisfaction (0.21). This reflects the belief that setting the stage is an important part of the implementation process, while looking at the project from the point of view of frontline staff. Environmental factors include not only the overall implementation atmosphere but also the physical hardware used and placement of the technology.

Table 7. The geometric means of pair-wise comparisons of the education criteria

	Documentation	Clinical Information	Staff training	Patient Education	Awareness	Priority weight
Documentation	1.00	3.9	1.5	1.7	2.5	0.31
Clinical Information	0.26	1.00	3.84	4.82	3.25	0.29
Staff training	0.66	0.26	1.00	4.26	4.86	0.22
Patient Education	0.59	0.21	0.21	1.00	2.65	0.11
Awareness	0.40	0.31	0.21	0.38	1.00	0.06
					CR= 0.00 <0.10 (acceptable)	

Table 8. The geometric means of pair-wise comparisons of the quality and safety criteria

	Quality Processes	Culture	Using Data	Performance improvement	Priority weight
Quality Processes	1.00	4.45	5.63	4.06	0.52
Culture	0.22	1.00	5.03	6.40	0.28
Using Data	0.18	0.20	1.00	5.23	0.13
Performance improvement	0.25	0.16	0.19	1.00	0.06
				CR= 0.00 <0.10 (acceptable)	

In contrast, the type of technology itself was ranked as the least important priority (0.03). This indicates that if leadership set the standards and the correct environment, the technological advancement would follow automatically. The newness of BCMA technology suggests that the technology used will also be the most current. Education is the next important domain for successful system implementation, with a weight of 0.26. Providing clinical information and staff education are of high importance for successful implementation. Without proper staff education and provision of correct clinical information, this system will not be implemented in a safe or sustainable manner. The other two primary criteria both had priority weights of 0.14. Quality and safety was ranked at 0.13, but deeper examination revealed that workflow (under process) carried the highest weight in comparison with other sub-criteria (0.70), followed by quality processes (which ranked 0.52). These provide evidence that both workflow and process sub-criteria must play an important role in successful implementation of the new BCMA system.

6. RESEARCH IMPLICATIONS

This research will support senior leadership in reliable healthcare organizations to identify factors that lead to best approaches in implementing this system. Highly reliable organizations are built upon validated and solid bases that lead to sound decision making. Using scientific and clinically proven approaches for decision making will enable organizational leadership to drive the organization to deliver safe care. The driving factors identified by this research will enable healthcare leaders to focus on areas that best help in delivering best results. The approach of prioritizing factors will at the same enable leadership in healthcare organizations to spend less resources and efforts on less affecting factors. Therefore, this study should be used as an example when implementing the barcode medication administration system. It represents several different internal and external components that leaders should consider. Once an organization has determined it is ready to move forward with a BCMA system, there are many implications that must be considered before actually proceeding. The first consideration is the presence of a strong leadership team to guide the organization through an effective implementation process, followed by obtaining the right resources, and providing education to support successful implementation.

The implication of introducing BCMA to patient care is strongly connected to patient safety. There are several sources for medical errors in hospitals and medication administration errors are part of that. Improving medication administration will have a positive impact on decreasing medical errors in general. BCMA system is intended to eliminate errors attributed to medication administered to a wrong patient as they system will detect such kind of errors. In addition, the system will be able to detect if wrong medication will be administered to a patient as well as timing, dosage, route and frequency of medication. These areas are the most common sources of errors in medication administration. The BCMA system will be able to eliminate all these errors if it the implementation stage went smoothly and correctly. So by eliminating these errors will improve patient safety; increase the reliability of the organization, decrease the potential compensable events and patients' claims. The BCMA is an innovative technology tool that can be used in any healthcare organization that has the suitable infrastructure. It is the future technology that will add value on the quality of patient care with safe practice of to use in preventing medication errors in the UAE and the gulf region.

7. CONCLUSION

The benefits of Barcode Medication Administration are many, human factors, along with basic system functionality and architecture, which is necessary for organizational leadership to promote and endorse a culture of support during the system implementation and troubleshooting period. Once implemented in the medical units, the barcode medication administration system will have a great effect on patient safety. The same influence can be used throughout the healthcare system of the Emirate of Abu Dhabi and the UAE in general. There are factors that affect implementation of this system, and these factors vary on the importance of their effect. The most important effects will be higher levels of safety and quality in patient care through fewer medication administration errors and adverse events.

Healthcare organization leadership may use results of this research as an improved approach to implement new technologies. Leadership, technology, process, education, and quality and safety are found as factors affecting successful implementation of a BCMA system. Leadership was found to be the highest impact, while quality and safety was found to be the least. Each of these factors has sub-criteria that led to it. This study, within the context of the UAE healthcare industry, may set the groundwork for future studies of BCMA system implementation. It may also effect change in various other sections of the healthcare system, particularly among rapidly developing countries. Using the Analytic Hierarchy Process (AHP) for identification of priorities to work on is found beneficial in this type of study. Future research can be conducted to find the interrelationships between the sub-criteria across the main headings.

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