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CHARGING MEDICAL SUPPLIES: THE BEST PRACTICE AN IMPLICATION FOR NURSE ADMINISTRATORS TO IMPROVE QUALITY CARE AND CONTAIN COST

by
CHRISTINE KHALIL HELOU

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CHRISTINE KHALIL HELOU

Approved by:

Dr. Lina Younan, Clinical Associate Professor — Adviser
Rafic Hariri School of Nursing

Dr. Nuhad Yazbik Dumit, Associate Professor — Reader
Rafic Hariri School of Nursing

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AN ABSTRACT OF THE PROJECT OF

Christine Khalil Helou for Master of Science in Nursing
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Title: Charging Medical Supplies: The Best Practice An Implication for Nurse Administrators to Improve Quality Care and Contain Cost

Providing quality care is the utmost goal of health care organizations. For nurses, who are the largest body of health care professionals, to perform at high level, it is essential to provide them the sufficient resources mainly medical supplies necessary to perform their service. The lack of these resources would compromise the quality of care, patient safety, and cost containment. At AUBMC, although the organization has shifted to electronic documentation, nurses are instructed to write down on a paper all the items used on each patient and give to the floor clerk who will do the financial charging. This inefficient practice is leading to delays in care, staff dissatisfaction, and increased cost. The main objectives of this project are to identify evidence-based automated methods for charging medical supplies on a hospital unit then use a decision-making tool to choose the best-fit method for AUBMC.

The result of the search yielded three automated charging methods: Automated dispensing cabinets (ADC), Barcode and Radiofrequency identification. The advantages and disadvantages of each technology were assessed using a decision-making matrix; the final recommendation was to use ADC in closed units and Barcode in open units. The implementation of this new charging process will help improving patient care and satisfaction, staff productivity and satisfaction, in addition to reducing financial and supplies waste.

The decision methodology followed in this project showed that reaching an optimum decision lies in properly assessing the problem, specifying the expected outcomes, and accounting for the context barriers and facilitators where it occurs.
The findings of this paper can add up to the currently available literature concerning the importance of managing and controlling not only medication management but also medical supplies management. Future studies are necessary to assess the effectiveness of combining ADC and barcode technologies in charging medical supplies on patient safety, staff satisfaction, and cost containment.

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CHAPTER 1
INTRODUCTION

Providing excellent and quality care is the utmost goal of healthcare organizations. Nurses are considered the largest body of professionals providing direct patient care (Monteiro, Avelar, & Pedreira, 2015). Thus, they are the most important entity responsible for providing efficient and quality care. For nurses to be able to perform at a high level, it is essential to provide them with all the required resources mainly medical supplies necessary to provide their service. Rastogi (2012) specified that nurses are the main users of medical supplies and that the care provided by these is highly affected by the availability of such resources sufficiently. In their qualitative study, Rivaz, Momennasab, Yektatalab and Ebadi, (2017) have found a positive relationship between the performance of nurses and the availability of resources where the adequate allocation of physical assets such as modern medical equipments that facilitate medical processes resulted in improved outcome. The lack of these resources would risk and compromise the quality of care and patient safety.

1.1. Background and Problem Description

Since the first day of work at the American University of Beirut- Medical Center (AUBMC), nurses are oriented on the importance of charging the medical supplies that they use. Stewardship, a core value at the institution, is required from each staff. Nurses are expected to provide quality and excellent care; still, they have to show stewardship towards the institution. On the medical/surgical units at AUBMC, nurses are instructed to write down on a paper all the items used on each patient and give to the floor clerk who will do the financial charging. Recently, the organization has shifted to electronic documentation; however, the charging process of medical supplies is still the same. Nurses are still required to write down all the charges, and they are still missing to record all the used supplies. This method of charging medical supplies is making nurses prone to either undercharge or overcharge the medical supplies items.

With all the other functions that they have to do within the limited eight hours shift, the majority of nurses are busy running around and trying to meet the patients' needs on time. They could barely have the time to remember all the items that they have used for their assigned patients. Consequently, undercharging occurs. Therefore, the unit had to suffer a shortage of several medical supplies especially during the evening and night shift where the material management department is closed. The results of this are frustrated nurses, delayed care, and compromised patients' safety. When items are not charged, unit supplies start to decrease. Consequently, nurses will have a hard time to find the needed items and they have to run around and go to the main store to get them. Nurses know that this will affect the care so an additional reason for tension and stress will arise since nurses have to provide high quality and excellent care.

Undercharging will not only induce additional stress on nurses, but it also leads to patients' dissatisfaction. Patients admitted to the hospital expect excellent and high-quality care. They expect that their needs will be responded to in a fast and efficient manner. They don't want to see a nurse coming in and out of their room to bring the needed items. Therefore, nurses must always be ready and reflect a high sense of confidence in what they do. A patient would trust more a nurse who shows knowledge and confidence in her work. Moreover, uncharged medical supplies are losses for the institution. Patient medical supplies are expensive especially high-quality products.

Every time a product is used and not charged; the institution has to bear the losses. If happened in a repeated manner, it will lead to financial losses and waste that will negatively affect the organization's goals as well as its mission and vision.

Another crucial consequence of the current charging process is the overcharging that sometimes is occurring on isolated patients. Nurses caring for a patient in an isolation room finds it very hard to go in and out of the room to have everything ready. Therefore, the nurse would take additional items to the room and has to charge them even if not used on the patient. Nothing that goes into the isolation room can go out. Therefore, the nurse has to put extra charges on the patient that might result in an inflated bill at the end of hospitalization.

All these factors have triggered the initiation of this project that aims at improving the process of charging medical supplies and control all its consequences that lead to decreased quality of care, unsatisfied nurses and increased financial waste.

1.2. Significance

The inefficient process of charging medical supplies is highly significant since it can impact the quality of care provided, the nurses' performance and the hospital expenses. This issue of providing adequate resources have been of high importance for the healthcare sector, specifically, the health care supply chain management that has been the focus of several studies for the last decade (Bélanger, Beaulieu, Landry & Morales, 2018). Heydari, Najar, and Bakhshi (2015) stated that to control resources at an institution, improvement plans should target the supply management at units that are mainly controlled by nurses. According to Landry and Beaulieu (2013), the services related to supply chain management include several actions of purchasing, inventory management, and dispensing of supplies to the end users. They added that an improvement in the efficiency of these functions allows healthcare organizations to provide a high quality of patient care and decrease related costs. In their quantitative study, Al-Saa'da, Taleb, Al Abdallat, Al-Mahasneh, Nimer and Al-Weshah (2013) have found that the management of supply chain elements (relation with supplier, specifications, delivery, after sales services) had significantly impacted the quality of care provided at hospitals. This means the better control for the supply chain elements, the better will be the quality of the health care services provided. To achieve this, Al Saa'da et al (2013), had emphasized the importance of recognizing the patients' needs and expectations from healthcare services. Besides, the authors stressed the importance of hiring qualified and competent staff to run these processes for a better outcome.

Bélanger, Beaulieu, Landry and Pablo Morales (2018) have further reinforced the importance of inventory management of medical supplies in the reduction of cost associated with processes of delivering patient care without compromising the service or quality of care. Having sufficient supplies is essential for staff to perform their functions to the max and achieve the best patient care outcomes (Bijvank &Vis, 2012). This fact has been recently reinforced by Moons, Waeyenbergh and Pintelon (2019) who have noted that effective management of medical supplies had been a challenge to healthcare providers, and controlling the budget is highly beneficial for achieving high-quality care.

According to Esmaili, Norman and Rajgopal (2018) 30% to 40% of hospital expenses accumulate from operations and logistic related to supply chain management; whereas, revenues generated from inventory management is estimated to be between 10% and 18% of the total revenues. Bijvank and Vis (2012) stated that supplies cost is ranked as the second after labor. Similarly, Rastogi (2012) stated that 42% of all hospital budget is allocated for supplies, where two-third of this is used for the medical supplies. Thus, cost-containment in hospitals is highly dependent on controlling the use of medical supplies and limiting waste from this area (Heydari, Najar, & Bakhshi, 2015).

With respect to the context of AUBMC, improving the charging process of medical supplies will improve the quality of care provided, increase staff productivity and reduce costs. Excellent quality care is considered one of the main objectives of the hospital and this is clearly mentioned in the organization mission statement. Therefore, it is essential to have projects that serve the purpose and goal of the institution and improving the process of charging supplies will improve the quality of care provided. In order to achieve its goals, AUBMC puts strategic plans that will improve staff performance for best productive outcomes. Through providing the staff with essential supplies in an organized manner, staff productivity will increase and this will impact the quality of care they provide. At the same time, these projects will be planned appropriately to control costs and eliminate any waste produced from inefficient processes.

1.3. Objectives of the project:

The main objectives of this project are to identify evidence-based methods for charging medical supplies on a hospital unit, and then use a decision-making tool to choose the best-fit method for the medical/surgical units at AUBMC.

CHAPTER 2
LITERATURE REVIEW

Since the hospital has recently shifted to electronic health records and integrated automation of processes into its system, the focus of this literature review is limited to identifying evidence-based automated charging methods that improve the quality of care and contain cost. Three automation methods were explored: The Automated Dispensing Cabinets (ADC), Bar-coding, and Radio Frequency Identification (RFID). The objective was to identify the impact of those technologies on patient's safety, nurses' satisfaction, and hospital's cost. Search terms used include Charge capture, patient medical supplies, barcoding, quality care, automated charging, automated dispensing machine, financial revenues, RFID, supply chain management, material management**.** The AUB Libraries and Google search engine were used and the Databases searched included Science Direct, Pubmed, Medline, ProQuest Central, Scopus, Web of Science, and Research Gate. Studies selected included one quasi experimental, one systematic review of literature, four pre-post interventional studies, three cross-sectional studies, two observational descriptive studies, two literature review, one comparative (technical) report and three post implementation of project reports; a total of 17 studies. The John Hopkins Evidence level and Quality Guide was used to evaluate the level of evidence of selected articles (Appendix A). According to this grading system, ten of the selected articles are level V, six are level III and one level II (Appendix B). The level V articles were mainly quality improvement projects and financial implications and literature reviews. The lack of research and empirical studies related to inventory and medical supplies at hospitals was previously noted by Shim and Kumar (2013) and Coustasse et al (2013).

2.1. Automated Dispensing Cabinet

Automated Dispensing Cabinets (ADC) (Figure 1) are decentralized medication and supplies dispensing units that use computerized technology to store, dispense, and control inventory by using a barcoding system to charge and document the medication administration process (Douglas, Desai, Aroh, Quadri, Williams, Aroh, & Nyirenda, 2017; Zaidan, Rustom, Kassem, Al Yafei, Peters & Ibrahim, 2016).

Figure 1. An Automated Dispensing Cabinet

Note: An automated dispensing cabinet. From "Barcoding and other scanning technologies to improve medication safety in hospital", by M. Bainbridge and D. Askew, 2017, Australian Commission on Safety and Quality in Health Care, p 14. Copyright 2017 by Micheal Bainbridge.

The automated dispensing cabinet (ADC) usage at hospitals started in the 1980s. These cabinets serve as dispensing machines at the point of use for medical supplies and medications. ADCs used in dispensing and controlling medications has been utilized by around 89% of hospitals as of 2011 and it has been proven to be effective in tracking inventory count, medication safety and waste reduction (Esmaili, Norman & Rajgopal, 2018; Bourcier, Madelaine, Archer, Kramp, Paul & Astier, 2016). On the other hand, Esmaili, Norman and Rajgopal (2018) stated that a poorly designed system can negatively affect the nursing productive time; thus, the quality of patient care might be compromised. Add to this, ADCs are quite expensive and they consume a large space on units (Esmaili, Norman & Rajgopal, 2018). Furthermore, the number of ADCs on patient care units is often limited, therefore, it is necessary for the management to wisely select the items that have to be purchased as well as the quantity (Esmaili, Norman & Rajgopal, 2018).

Usually, ADCs used for medications are controlled by the pharmacy department (Zaidan, et al., 2016); to be effective, the ADC has to have an inter-phase with an Electronic Health Record (EHR) (Bourcier, et al., 2016). The scanned medication will be checked as correct for the correct patient and it will be financially charged and linked to the patient's bill. What is worth mentioning is that although ADC suppliers such as Omnicell and Pyxis indicated that these cabinets are designed for dispensing medication and medical supplies, still, the literature on the use of ADC as a medical supplies dispenser is shy and very few articles discussed widely the effectiveness of these cabinets for this purpose. Bourcier, et al. (2016) have implemented the use of ADC at a 26- bed intensive care unit at a teaching hospital for dispensing sterile medical devices. The results showed a 34% reduction in staff time spent on logistics after introducing the system, as well as a reduction in financial waste with a positive return of investment. In another study conducted by Clou, et al. (2018) the benefits of ADC use for expensive cardiac medical devices were assessed. The results revealed a rapid return on investment, improvement in stock availability and dispensing processes on the unit. Moreover, the investment was highly appreciated by users and it did not result in any negative economic impact (Clou, et al., 2018). There were no major barriers identified in these two studies; however, Bourcier, et al. (2016) have recommended the need for future studies on securing the medical supplies circuit and to assess the overall cost-benefit of the system.

2.2. Barcoding

Barcode technology has been used in retail since the 1970s. It is a simple technology composed of a picture with black and white lines, the barcode (Figure 2), that once scanned by a scanner (Figure 3) provides unique information about the product, price, and even expiry dates (Investopedia, 2020).

Figure 2. Barcode Sample

Note: Picture was taken by Christine Helou

Figure 3. Barcode Scanner

Note: Picture was taken by Christine Helou

Barcoding has been used by many institutions including healthcare. The barcode doesn’t contain any descriptive data, instead, the numbers on the barcode are used to link with certain information fed into a computer. The Healthcare Information and Management Systems Society (HIMSS) (HIMSS, 2003) has promoted the use of barcoding in the various domains of healthcare institutions. Barcoding is effective in patients’ registration and admissions processes, patients’ clinical care and safety maintenance, supplies management and traceability, and accurate patients’ bills issuing. Barcoding activities can thus be used in three main ways: tracking, inventory management and validation. According to HIMSS (2013), using the barcode for any of the above-mentioned ways will positively reduce cost, improve staff productivity and assure quality care.

Barcoding had been proven effective in increasing patient safety especially when used as an accurate identifier for the patient against proper medication, blood sample, and blood transfusion (Hachesu, Zyaei & Hassankhani, 2016). The barcode has been used in the retail market for a long time and was proven successful in controlling stocks and inventories (O’Hanlon, 2018). In addition, O’Hanlon (2018) indicated that using the barcoding method to track supplies at healthcare institutes had massively helped in controlling health care costs by preventing the over-ordering of supplies, loss of items due to expiration, and securing the availability of needed items at the right time. Moreover, the automation of supply chain management has helped in reducing the time spent in manually ordering supplies, hence, nursing staff can use the freed-up time for better patient care (O’Hanlon, 2018).

Sakowski and Ketchel (2013) found that cost reduction is successful with this technology since it can reduce medication errors and harm resulting from them. In a report prepared by Bainbridge and Askew (2017) on behalf of the Australian Commission on Safety and Quality in Health Care, it was noted that barcoding technology is considered of low cost, easy and universal. A position paper that was published in the World Hospitals and Health Services (2018-2019), included three articles addressing the implementation of barcoding and its effect on improved patient safety, reduced cost, improved staff productivity, controlled inventory and improved efficiency (Sabogal, Rincon, & Rodriguez, 2018; Rocchio, & Mantel, 2018; Kasamatsu, Sato, Ishimoto, 2018). Each article was mainly a descriptive report that disseminates the improvements that implementing barcode had brought to their institutions.

Results from Sabogal, Rincon, and Rodriguez (2018) revealed 98% enhancement in inventory control and waste reduction, as well as 15% decrease in inventory levels at satellite pharmacies. Another benefit was the reduced time to issue a patient invoice from around one hour to only 18 minutes. The study by Rocchio and Mantel (2018) showed that post deploying the barcode system into the operation theater, Mercy hospital has reported a 99% reduction in expired products and recalls in the operating rooms for its fiscal year 2017- 2018, a 12% decreased turnover times in OR, increased revenues (909$ gain per case), decrease supplies cost (123$ per case), and decrease in labor cost (29$ per case). Kasamatsu, Sato, and Ishimoto (2018) discussed how Fukui hospital surgical center has implemented the barcode technology to improve patients’ safety and efficiency. The end result was impressive with reduced errors in surgical equipment and devices count from 3054 to 175, improved time management with 4000 hours saved, and improved operational performance by saving 4971 hours (Kasamatsu, Sato, & Ishimoto, 2018).

Several studies were conducted to assess the barcoding's acceptability level among nurses and to identify the barriers, challenges, and recommendations for proper implementation. A study conducted by Ehteshami (2017) showed that 76.9% of end-users considered barcode technology as acceptable. Six areas were identified to mostly influence the acceptance of this technology including ease of learning, the capability of the barcode, perception of its usefulness and its ease of use, users' attitudes towards the use of barcode, and intention to use it. All these elements work in a chain-like where one element influences the other. The author recommended taking into consideration these elements when planning to implement barcoding technology (Ehteshami, 2017).

In a previous study, Hachesu, Zyaei and Hassankhani (2016) indicated that managers have to plan appropriately by starting to adjust policies to integrate the new process, then to set priorities and implement an audit system to monitor the process functioning. The same authors stated that notifying end-users and educating them is an essential step in the success of the process. Through training and explaining the benefits, people tend to accept and adapt more positively to the changes. Also, they mentioned that allocating an adequate budget or finding the necessary fund is another essential element and without it the infrastructure as basic items needed cannot be performed. Culture was identified as another barrier that should be taken into consideration. In addition, the barcode type and ease of use were also considered as important barriers if not well assessed (Hachesu, Zyaei & Hassankhani, 2016).

Recently, Darawad, Othman, and Alosta (2019) studied the impact of barcoding medication administration process on nurses' satisfaction level. The results revealed a moderate satisfaction level with the process. In addition, a negative correlation was found with age, clinical experience, and experience of using barcode. On the contrary, training and computer and barcoding competence and perception of being productive had a positive relationship with the barcode introduction. The authors reinforce the necessity of implementing training and educational programs before implementing barcoding (Darawad, Othman & Alosta, 2019).

Introducing barcoding technology is considered beneficial for safe practice, efficient patient care, and cost-effective practice. Still, it needs the availability of infrastructure and additional assistive software for its appropriate functioning. Even though the use of barcodes is widespread among hospitals, still many limitations are identified. After scanning the barcode, there is a remaining need for manual work to verify inventory and usage. Also, scanning should be done at a close distance and necessitates accurate human interference. Add to this, the limited amount of data that can be stored on the bar code (an estimate of 10-12 digits) (Coustasse, Tomblin & Slack, 2013).

2.3. Radio Frequency Identification (RIFD)

Radio Frequency Identification (RFID) is a wireless automated technology that uses radio waves to identify tagged objects with minimal human intervention. The process includes an RFID tag that is encoded with data, a reader that communicates with the tag using radio waves signals, a middleware system necessary to transcribe the information, and a host system that receives the data and manage it to be ready for use by end-users (Figure 4). This technology had been approved since the 1970s; however, its use became more prevalent few years ago with pets microchipping (Bendavid, Boek & Philips2010; Kenton, 2018).

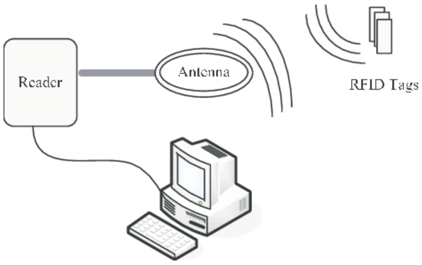

Figure 4. Structure of an RFID System

Note: From "Supply Chain Information Transmission based on RFID and Internet of Things - Scientific Figure on ResearchGate. From: https://www.researchgate.net/figure/Structure-of-RFID-system_fig1_224596140. Copyright 2009, B. Yan.

RFID is the third fast-evolving identified technology that has been proven to be effective in managing supplies and capturing charges. RFID allows the scanning of several items at the same time within a certain area. It allows efficient tracking and inventory of items in real-time in an automatic manner. It also minimizes waste related to items misplacement and loss or expiration, without human intervention. Moreover, it enhances the productivity and efficiency of operations and decreases wasted personnel time (Yao, Chu & Li, 2012; Coustasse, Tomblin & Slack, 2013). This technology does not need a clear distance of the barcode to read the tag; instead, it can locate multiple tags from a further distance. The attached electronic tags can be further managed by a centralized database using computerized services. It carries positive expectations for controlling operational activities and improve patient safety.

There are two types of RFID tags: passive and active (Coustasse, Tomblin & Slack, 2013; Roper, Sedehi, & Ashuri, 2015). Passive tags do not have an integrated power source; thus, they can store and transfer data by using a nearby RFID scanner and within a distance of 18 inches to 30 feet. These tags are cheaper and can be used under restraining or strict environments. This type of tags is beneficial when only tagged items have to be located or identified in limited areas (Coustasse, Tomblin & Slack, 2013; Roper, Sedehi, & Ashuri, 2015). The active tag has its integrated power source; hence, signals can be sent and received continuously within a farther distance. Larger amounts of data can be stored, and useful for real-time tracking. In addition to the tags, an RFID system includes RFID scanner, antenna, software, and hardware to read the data (Coustasse, Tomblin & Slack, 2013; Roper, Sedehi, & Ashuri, 2015).

The benefits identified with the use of RFID technology include: improved patient safety and reduced errors, access to real-time data, time-saving, cost-saving, enhanced medical processes, and others such as improved medication supply, resource utilization and patient satisfaction (Yao, Chu & Li, 2012; Coustasse, Tomblin & Slack, 2013; Roper, Sedehi, & Ashuri, 2015). In addition, Coustasse, Tomblin and Slack (2013) in their literature review have shared various studies that proved RFID cost-effectiveness for managing supplies. On top of this, manual hand-on inventory count was eliminated with this system, therefore, better charge capture, reduced out of stock items, and improved cash retrieval (Coustasse, Tomblin & Slack, 2013). Moreover, privacy by using RFID is increased through the adoption of universal re-encryption of tags. In 2012, Yao et.al found that patient privacy was being exposed to threats of breach by this technology; however, Coustasse et al (2013) had explained that the RFID technology allows tracing of assets and not persons, thus the privacy of patients was not exposed to a threat.

Despite the many barriers are identified. The barriers include interference with other medical devices work, the ineffectiveness of the tag (due to several reasons such as distance, angle of rotation and others), lack of standardized protocols to apply RFID, the high cost of the technology, and legal issues. Other barriers include lack of organizational support, unclear return on investment, and trust issues (Yao, Chu & Li, 2012). Coustasse, Tomblin and Slack (2013) added that healthcare institutions were hesitant to deploy the system due to reasons such as lack of capital money, unclear return on investment, insufficient IT staff, and time constraints.

On the other hand, Yao, Chu and Li (2012) recommended a list of factors necessary for the success of implementing RFID technology at hospitals. The factors are divided into strategies that include leaders' support, excellent choice of the vendor, clear RFID vision and mission, a clear timed plan, and dealing with privacy issues. The other factors are tactical and include taking steps such as integrating the routine testing of the system into existing IT services proper training and education, effective communication processes to disseminate the new process and auditing the system to act upon issues in an immediate manner (Bendavid, Boeck & Philippe, 2010; Yao, Chu & Li, 2012). In addition, Bendavid, Boeck and Philippe (2010) showed that implementing a process of medical supplies replenishment using the RFID helped in increasing patient care time by reducing the hand-on inventory of supplies, and business and operational improvements. The authors recommended additional research on RFID impact and linked the failure of IT projects to sociological, cultural, and financial issues. Therefore, top management should highly consider these elements when implementing new IT technologies into healthcare. In another study conducted by Del Carmen León-Araujio, Gómez-Inhiesto and Acaiturri-Ayesta (2019), data on the inventory management of expensive cardio-thoracic items needed for surgery using smart cabinets with RFID system was collected in terms of supervisory staff time, waste and resource utilization and management. The study results revealed decreased supervisory staff time needed, 0% out of stock items, 0% stock mismatch using, no patient-item mismatches or wrong assignments per patient, and a range of 0- 13% of urgent restocking of items. This study has confirmed the positive ability of the system in monitoring the usage and tracking of expensive items per patient as well as an impressive time-saving method.

CHAPTER 3

SELECTION AND IMPLEMENTATION PLAN

3.1. Selection plan

Deciding which technological method fits best the context of AUBMC depends on several factors mainly the implementation constraints imposed by the context and the criteria against which those technological methods will be compared. For that reason, a decision matrix was used, which is a tool that evaluates and prioritizes a list of options when one improvement opportunity must be selected based on several criteria. The process starts by choosing the evaluation criteria, prioritizing those criteria based on how important that criterion is to the situation; then accordingly assign a weight for each criterion. The second step includes listing the options and rating each option using a rating scale based on how well each option meets each criterion. The third step includes multiplying each option rating by the weight of related criterion; then adding the points for each option. The option with the highest score will be the one to be chosen.

According to the International Journal of Technology Assessment in Health Care (2002), criteria for evaluating any health technology application (CHTA) should target Safety; Efficacy/effectiveness; Psychological, social, and ethical considerations; Organizational and professional implications; and Economic issues. The sixteen studies retrieved from the literature were revisited to identify the types of meaningful outcomes measured and classify those outcomes under CHTA evaluation categories. The findings were displayed in Appendix C.

Those criteria were given the following weights according to priority (3 being the highest priority, 1 being the lowest priority) (Table 1). Accordingly, the weight per criteria was assigned to be 3 for safety since decreased patient safety will lead to complications that will in turn negatively impact all other criteria. The weight assigned to Economic issues was also 3 since the implementation context has financial constraints considering the poor economic situation all over the world and specifically in Lebanon who is suffering a severe financial crisis even before the Coronavirus outbreak. Efficacy/effectiveness weight was also 3 because the main problem at the unit was that used items were missed to be charged, a lot of time is wasted to locate misplaced items or to order and receive items when urgently needed. Thus, quickly accessing items, and accurate capturing and charging are key issues for solving the problem. As for the Psychological, social and ethical considerations criterion, it was assigned a weight of 1 knowing from the literature that proper implementation steps can mitigate the psychological and ethical barriers. Organizational implications were assigned a weight of 2 because some of the identified negative implications (for example the electromagnetic interference with other devices) might not be easily addressed.

Table 1. 1st Step Assigning Weight to Criteria

Criteria	Safety	Economic issues	Efficacy/ Effectiveness	Organizational and professional implications	Psychological, social and ethical considerations
Weight	3	3	3	2	1

The second step included rating each option against the chosen criteria with 1 being the option that has the least desirable outcome and 3 the option that has the most desirable outcome related to each criterion (Table 2). Using the findings listed in Appendix C and the scores in table 2, the results came as follow:

The highest rate for safety was given to barcoding and RFID because the literature reviewed has proven that both technologies are very safe to use since they generate accurate patient data and help massively in reducing medication errors at institutions and improving the quality of care. As for ADC, although this technology was found to help in reducing errors especially by requiring an authorization to access it, still, the fact that one study has found that 15% of medication errors have ADC as the source of error because of the availability of the override option in ADC and the absence of pharmacy control. This is why this technology scored lower than the other two with regard to safety (Appendix C & Table 2).

Concerning Efficacy/effectiveness criteria, the highest rate was given to ADC. The ADC was found efficient in reducing waiting time for medications to arrive from the pharmacy, enhancing the traceability of supplies, improving medication information capture with the security measures available, securing the storage and dispensing of medical supplies, and reducing the need for emergency orders. The literature on ADC didn’t reflect any negative connotations concerning this criterion. The barcode technology allows accurate data collection, prevents errors in data entry and improves effectiveness by saving time and reducing work hours; however, to achieve correct capture, the scanning of the item should be done at a closer distance. Besides, the barcode is known to have a limited data capacity and is prone to human error. Moreover, for the barcode technology to work best, organizations should train staff, review workflow, and change policies. As for the RFID, the reviewed literature has indicated that this technology saves time, reduces emergency orders of supplies, has a high data capacity, allows accurate capture of data, and not prone to human error. Yet, RFID might have readability issues and ineffectiveness related to distances (Appendix C & Table 2).

The barcode technology scored the highest for the psychological implications criterion and the other two scored equally. The barcode is user friendly with an 80% satisfaction rate and it reduces patient admission/discharge time. No negative implication was found for the barcode in this aspect. On the other hand, although the ADC has gained the nursing staff satisfaction for preventing stock out and reduced emergency reordering; still, one study reported that waiting in queue to access it was a drawback. Similarly, the RFID has its positive features such as ease of use, improved staff satisfaction, effectiveness for supply chain management and patient flow and satisfaction. Yet, the literature has reflected some uncertainties regarding the protection of patient privacy with RFID. This concern is of high importance especially in health care and it is considered one of the most important patients' rights (Appendix C & Table 2).

Knowing that some of the organizational and professional implications are hard to be managed or changed, the evaluated technologies showed that the ADC scored the highest with a score of '2', followed by both barcode and RFID that scored '1' each. The negative connotations of ADC were the large space consumption and the need for interphase with an electronic health record. However, with an appropriate environmental design and a well-established information technology, this issue can be resolved. On the opposite side, the RFID might interfere with medical devices and several hospitals are not designed to accommodate this technology. As for barcode, additional staff is needed and it still needs manual inventory count. Therefore, the disadvantages of ADC can be resolved easier than those of barcode and RFID; thus, making it a better option (Appendix C & Table 2).

The highest rating for Economic issues was for barcode technology because it is effective in charge capture; therefore, stock-outs and emergency orders will be reduced as well. Moreover, the cost of implementing barcode technology is very low when compared to both RFID and ADC. The ADC received the second score. The ADC is expensive and more than one cabinet might be needed per unit to accommodate all supplies. However, the return of investment and equal cost-benefit ratio makes it a better option than RFID. The RFID has an unclear return on investment and it is an expensive technology. Therefore, investing such a high cost with an unclear return on investment is not a good choice for managers and administrators (Appendix C & Table 2).

Table 2. 2nd Step Rate Each Technology

	Criteria	Safety	Efficacy/effectiveness	Psychological, social, and ethical considerations	Organizational and professional implications	Economic issues
Technology options	Automated dispensing cabinets	2	3	2	2	2
	Barcoding	3	1	3	1	3
	Radio-frequency identification	3	2	2	1	1

The third step includes multiplying each option rating by the weight of related criterion as shown in table 3.

Table 3. 3rd Step Multiply Rate Provided by Weight of Related Criterion

	Criteria	Safety	Efficacy/effectiveness	Psychological, social, and ethical considerations	Organizational and professional implications	Economic issues	Total
Technology options	Weights	3	3	1	2	3	
	Automated dispensing cabinets	6	9	2	4	6	27
	Barcoding	9	3	3	2	9	26
	Radio-frequency identification	9	6	2	2	3	22

Looking at the sum of ratings presented in table 3, it was noted that ADC got the highest rate followed by barcoding and least RFID. ADC has been proven to ensure safe practice for medication administration and supplies storage and dispensing, reduce time waste of staff, improve nursing satisfaction, and had a positive return on investment. With appropriate planning and design, ADC has been proven to have high-efficiency rate and an acceptable economic impact.

3.2. Implementation Barriers and Facilitators

Before implementing the new charging process, it is very important to consider the possible barriers identified in the literature as well as the current facilitators at AUBMC. The Anticipated barriers include inappropriate design selection for the ADC and barcode related technological issues such as poor label qualities, recurrent system downtimes, or human-related such as low staff compliance and resistance to change. Managing these barriers can be doable through appropriate planning and prior anticipation. Therefore, choosing the correct design of the ADC is highly important during the initial planning phase and appropriate testing of the labels and barcode system should be done before production. In addition, scheduling fixed times for routine maintenance and performance checkup will help greatly in resolving this issue. Moreover, the availability of a hotline for staff to report any technological issue is essential for the success of the implementation. As for the staff resistance and low compliance rate, the managers can use change theory such as Kurt Lewin's theory of change as a framework to successfully manage the resistance of staff and improve the compliance rate.

Among the facilitators identified, the hospital has already implemented a health information system. A Pyxis machine which is an ADC is already in use for medication storage and dispensing, and the staff is very well acquainted with it. Besides, the barcode technology is already being used for medication administration and labeling specimens. Therefore, both technologies are not new to the staff and this can facilitate the process. Darawad, Othman and Alosta (2019) have found a positive association between staff satisfaction and the experience of using the barcode. Furthermore, the availability of the infrastructure will reduce the cost of implementation since the bulk of the cost is related to the availability of the software and all the supportive equipment such as computers, scanners, labels printers, and network availability. Moreover, the hospital had previously purchased ADC for medications, hence, this will facilitate the purchasing process of additional ADCs. Add to this, by combining both ADCs and barcoding, the number of ADCs needed will be less, so the cost will be less.

3.3. Implementation and Evaluation Plan

To implement this project, the PDCA model will be used. PDCA stands for Plan - Do - Check - Act. The planning phase starts with organizing a multidisciplinary team including experts from the nursing department, material management department (MMD), information technology (IT), Clinical and Professional Development Center (CPDC), and financial management unit. This team will jointly work to set the objectives of the project which is applying the use of ADC and barcode to charge medical supplies at the hospital. In addition, the team will put an action plan with the interventions needed to be achieved during a determined timeline to reach the objective. The interventions needed will include studying the market for determining the best brands available. This step should be performed jointly by the team members since each discipline can provide input into the selection process. In addition, since two technologies will be deployed, it is necessary to conduct a needs assessment to identify how many ADCs and additional barcode scanners/ printers are needed. Besides, the team has to assign the right technology to the appropriate unit.

For this project, two units are selected: the pediatric Intensive Care Unit (PICU) and the Children Cancer Center of Lebanon Outpatient Unit (CCCL- Out). An ADC will be implemented at the PICU and the Barcode will be used at CCCL out. Once the ADC brand is selected, the financial management department will process in ordering any additional necessary supplies and managing financial issues and budget control. As for the IT team, their job is to prepare the system for the new process and eliminate any possible technological problems. The IT team responsibilities include preparing the setup for the ADC and activating the scanning process to be used for charge capture in the system, feeding data into the system to produce labels that will serve as identifiers, setting printers to generate scan-able labels, securing the interconnectedness and interoperability among various departments such as MMD, Nursing units, and billing. The MMD, and based on the history of units’ needs, will study the designs needed for the ADC that will best fit the necessary supplies to each unit. It is necessary to choose the right design of ADC for the best outcome (Esmaili et al, 2018). The nursing team will review the available policy on charging medical supplies, as well as the workflow of the current process to integrate the use of ADC and the barcode into the process. The CPDC will prepare an educational plan that will include policy and workflow dissemination and staff training on the use of the new technology. The Nursing department can assign super users to help in the training process across the selected units.

Following the training and full dissemination, evaluation of the educational process has to be done to make sure staff are ready for production. Training and involving nursing in the process is necessary to gain their buy-in which is highly related to the success of the implementation of the new technology (Darawad, Othman & Alosta, 2019). The team should also develop a plan to continuously monitor the system is working effectively, control downtimes, and come up with back-up plans for real downtime and unexpected system failure. Following this, the institution will be ready to implement this process. The timeline expected for the planning phase is five months (Table 4). These interventions were recommended by Hachesu, Zyaei and Hassankhani (2016), and Darawad, Othman and Alosta (2019), who have found that lack of these might act as hindering factors for the success of the barcoding process.

Table 4. Responsibilities during the Plan Phase

	1st month	2nd month	3rd month	4th month	5th month
Team effort	Select the brand. Decide on which units you will implement barcoding and/or ADC				

Financial department		Secure financial approval for purchasing supplies needed for the charging process.	Order the supplies	
IT		Prepare and test the system for errors		
Nursing		Review policies Review workflow		Select super users and train them extensively to help during Go Live
CPDC			Develop an educational plan to disseminate, train, and evaluate.	Start educational and training sessions

The next step of the model is the Do phase. During this phase, the process is pushed into production, and end-users will start using the new workflow. Close monitoring and support are needed by the implementing team to help the smooth transition from manual to automated charging. When going live new problems might be encountered which were not detected during the planning phase. Therefore, by close monitoring and allowing immediate reporting of issues, such problems can be immediately solved with the least amount of error. This period will extend over three months (Table 5).

Table 5. Responsibilities during the Do Phase

	6th month	7th month	8th month
End-users	• Implement the process • Report problems to super-users • Identify drawbacks		
IT staff	• Monitor closely the process • Fix emerging issues immediately • Control unplanned system downtimes		
Super-users	• Support and help colleagues to get better acquainted with the process • Fill tickets of the reported problems		
Nursing department	• Oversee the whole process closely		
MMD	• Provide the units with correctly labeled supplies • Fill the ADC with the needed supplies • Replenish the units on a routine basis		

The third step is the check phase. Random audits will be performed to check the effectiveness of the system and staff compliance with the new process. This period will extend over another three months (Table 6) where data will be collected by the involved departments. The MMD will collect data regarding the traceability of supplies, reordering rates, reduced number of expired supplies, and inventory control. The nursing department will collect data regarding the compliance of the staff in charging patients' medical supplies and interfere in case of breaches. The financial unit will collect financial data to assess the cost-effectiveness of the new process.

Table 6. Responsibilities during the Check and Act Phase

	9th month	10th month	11th month	12th month
	Check phase			**Act phase**
MMD	• Collect data • Inventory control			• Identify gaps • Review policies and workflows
Nursing department	• Collect data on staff compliance • Identify breaches			
Financial unit	• Collect financial data • Control waste and losses			

Finally, the Act phase where any identified gap in the system will lead to the revision of the process and introducing changes necessary to maintain performance and reach objectives. The check and act phases are continuous actions that are necessary for the sustainability of the project and the appropriate functioning of the process (Table 6).

3.4. Budget Plan

Financial planning was found a necessary source for the success of implementing the barcode technology (Hachesu, Zyaei & Hassankhani, 2016). The cost of introducing bar-coding technology on one medical/surgical unit (CCCL –out) was calculated as shown in table 7. A complete barcode system must include barcode hardware and software.

The budget needed for the implementation of such a system involves the cost of manpower, IT infrastructure, tools, and training (DevTeam.Space). The manpower includes staff from the various disciplines mentioned such as Nursing, MMD, IT, CPDC, and financial management unit. The number of needed staff for the team project is relevant to the hospital size. These team members are already hospital employees; hence, no additional expenses will be needed on manpower. The barcode hardware includes scanners to read the labels and printers to generate the labels. As for the barcode software, it is the system through which barcodes are generated and all data are saved on for tracking. However, since the hospital has already an available health information system the expected cost will be for additional scanners, printers, and labels.

The estimated price of a handheld scanner is 200$ per piece and 300$ for a printer. Knowing that both the CCCL out and the MMD have the needed software and hardware, the only expense will be on the labels price that is calculated based on the number of items needed per the selected unit. At CCCL out, an approximate of 300 items are needed per day of patient care or 9000 item per month. This means that the MMD will need 9000 labels per month to code the supplies issued to the selected unit. The price of the label pack is 1.5$. Each pack contains 1000 labels, therefore, the MMD will need nine packs per month that is equal to 13.5$ a month and 162$ per year as an ongoing cost.

The training cost on the barcode use will be around 55$. The CCCL out has a total of 14 registered nurses and one nurse manager. The unit has one shift schedule; therefore, the CPDC has to provide five sessions in order to deliver the content to all staff including the super-users who have to attend the session twice. This will result in providing the session to 17 nurses. Each session will be of one-hour duration that will be divided into a PowerPoint presentation and simulation part to allow the staff to have hands-on training. For best results, attendance per session will be limited to three to four staff only. Each one educational hour costs around 11$.

Table 7. Cost of Barcode Implementation

Cost of Barcode Implementation			
Item	Cost Per Item	Number of units per month	Total
Ongoing Cost:			
Labels: 1000 label per pack	1.5$ per pack	9 packs: 9000 labels	13.5$ per month= 162$ per year
Installation Cost			
Software	0	0	0
Hardware: Printers Scanners	0	0	0
Training	Cost per hour: 11$	# of educational hours: CCCL out: 5 sessions- one-hour duration sessions for 14 RNS, 1 NM	CCCL out: 55$
Total Cost per first year of implementation			217$

Regarding the ADC implementation costs, the market searched revealed variation in the prices based on the model and design of the ADC. For this reason, an exact budget could not be calculated. Instead a cost-benefit analysis was done based on the data from two articles where ADCs were implemented for the use of medical supplies and devices at an ICU and cardiac unit (Table 8). These two projects have proven that implementing ADC for medical supplies can help in reducing costs and improving revenues.

Table 8. Cost- Benefit Ration for ADC

Automated Dispensing Cabinet: Cost-Benefit Ratio			
Article author	ADC #	Implementation cost	ROI during one year
Bourcier, Madelaine, Archer, Kramp, Paul & Astier, 2016	3	ADC & wireless devices & interface: €79000 = 86000$	During first 12-month post implementation benefits generated were equal to 70% of the implementation cost: 1- €15000 (16,346.98$) first cost saving by reduction in stock amount 2- €40000 (43,598.00$) saved on orders of Sterile medical devices (16% of annual expenses on supplies)
Clou, Dompnier, Kably, Leplay, Poupon, Archer& Paul (2018)	3	ADC & Maintenance & Interface: €45710= 49,812.47$ €390 per year = 425$	Benefit: Gross profit: €90823= 98,974.36 $ Net profit: €44723 = 48,745.83$

CHAPTER 4

DISCUSSION AND CONCLUSION

4.1. Discussion

Inefficient charging of medical supplies had several negative implications on the quality of patient care, patient satisfaction, staff satisfaction, and cost control at healthcare organizations. The proposed methodology for identifying the best-automated charging process was a literature review, followed by using a decision matrix to help in choosing the most appropriate method. The aims were to select a safe, efficient, and cost-effective technology; also, to choose a technology that is easily adopted by nurses, and has the least negative organizational implications. Two things drove the decision process: (1) the desired outcomes expected from the technology, and those were categorized under five evaluation criteria (safety, Efficacy/effectiveness; and (2) the context's barriers to implementation, and they included the financial crisis, the users' challenges, and the additional organizational implications. Those barriers were used to guide the weight assignment for each criterion.

What is worth mentioning is that any change in the weights assigned to each criterion might affect the final decision. For example, considering the financial crisis in Lebanon, the cost was assigned a weight of 3; however, if there is no financial crisis, it will be assigned a weight of two. Efficiency/effectiveness should be rated as 3 because it targets the key aspects of the problem on the unit. If the main problem was different, the weight of this criterion would have been less. Moreover, considering the implementation context is a key when choosing the solution; in our case, ADC alone might solve the problem on medical/surgical units, however, it will not be the optimal choice in intensive care units. Thus, when using a decision-matrix the key to reaching the optimum decision lies in lies in properly assessing the problem, specifying the expected outcomes, and accounting for the context barriers and facilitators where it occurs.

Before multiplying the scores by the weight of each criterion, the total scores showed that Barcode and ADC scored the same. When individual scores were multiplied by the weight of each criterion, the highest total score was for ADC, followed by barcoding, then RFID. However, when dissecting the evaluation criteria, one can notice that ADC is safer than barcoding or RFID when used in open units; yet, it was the safest when used in closed units (Bourcier et al, 2016). Therefore, combining the two technologies (ADC and barcoding) for charging medical supplies would be an optimal solution. ADC has been proven effective in the ICU and cardiac surgery department (Bourcier et al, 2016; Clou et al, 2017); these two units are closed areas and having available ready to use supplies is highly essential. Moreover, knowing that intensive care units are at the highest risk for having infections, having supplies stored in a secured cabinet can help reduce the waste generated by discarding all the items that enter the room once a patient is discharged (Morrow, Hunt, Rogan, Cowie, Kopacz, Keeler, . . . Kroh, 2013). ADCs have secured access and it is kept locked and only opened when an order is given to it. Therefore, staff can have all the needed supplies available by them and they can open the cabinet while maintaining a sterile and clean environment. The ADC allows access only for the requested item; therefore, the staff will not contaminate any unneeded item. Similarly, ADCs can be put in isolation rooms; thus, controlling infection control and charging issues. By placing ADCs in intensive care units and isolation rooms, patients' safety and satisfaction can be improved, staff will be able to use their time more productively, and no over or undercharging will occur. And the most important thing is that the quality of care at these units or rooms will be improved.

As for the open units, the barcode technology can be implemented safely on these units without compromising the environmental space issue. All open units have a decentralized storage area that is accessible by staff. By using the barcode, staff can immediately charge the used supplies that they used on the patient instead of writing things down on a paper and handover to the unit clerk to charge. Therefore, an accurate charge of supplies is done and at the same time staff time will be used for direct patient care. This has been proven by Sabogal, Rincon, & Rodriguez (2018) and Kasamatsu, Sato, Ishimoto (2018). In addition, by using any of the selected automated charging methods, information regarding the expiry date of supplies can be better controlled. The result will be a reduction in the number of supplies that are discarded due to the expiry date being left unchecked. The financial benefits of these two technologies have been proven effective throughout the literature (Table 2). By combining these two technologies, a synergistic effect can be developed and the advantages of these two will overcome the disadvantages generated by each technology separated.

4.2. Conclusion

The main objectives of this project were to identify evidence-based technology for charging medical supplies on a hospital unit and then use a decision-making tool to choose the best-fit method for the medical/surgical units at AUBMC. The results of this search yielded seventeen studies that have identified the advantages and disadvantages of three main automated charging systems: ADC, Barcode, and RFID. The findings were integrated into a decision matrix where the ADC technology scored highest among the three when used in closed areas, whereas the barcoding scored highest when used in open areas. Accordingly, to have a combination of both the ADC in closed units and the barcode technology in open units would improve the charging of medical supplies in a cost-effective manner. The implementation of this new process will help improving patient care and satisfaction, staff productivity and satisfaction, in addition to reducing financial and supplies waste.

It is worth noting that the majority of the studies addressing the charging of medical supplies focused on describing the use of technology in medication management and few related their use in medical supplies management. The findings of this paper can add up to the currently available literature concerning the importance of managing and controlling medical supplies and not only focusing on medication management. Future studies are necessary to assess the effectiveness of combining ADC and barcode technologies in charging medical supplies on patient safety, staff satisfaction, and cost containment.

APPENDIX A

The John Hopkins Nursing Evidence- Based Practice	
Level I	• Evidence form experimental well controlled studies • Randomized control trials (RCT) • Systematic reviews of RCT with or without meta-analysis
Level II	• Quasi-experimental study • Systematic review of a combination of RCTs and quasi-experimental • Quasi-experimental studies only, with or without meta-analysis;
Level III	• Non-experimental study • Systematic review of a combination of RCTs • Quasi-experimental and non-experimental studies, or non-experimental studies only, with or without meta-analysis • Qualitative study or systematic review with or without a metasynthesis
Level IV	• Opinion of respected authorities and/or nationally recognized expert • Committees/consensus panels based on scientific evidence that includes: 1. Clinical practice guidelines 2. Consensus panels
Level V	• Articles that are based on experiential and non- research evidence such as: 1. Literature review 2. Quality improvement program or financial evaluation 3. Case reports 4. Opinion of nationally recognized experts
Dearholt, S., Dang, Deborah, & Sigma Theta Tau International. (2012)	

APPENDIX B

The selected articles' level of evidence			
Date & author	Title	Design	Level of evidence
Esmaili, Norman & Rajgopal, 2018	Shelf-space optimization models in decentralized automated dispensing cabinets.	Comparative study: comparison of two ADC models and interpreting results using analysis and computational methods	Level II: Quasi experimental study
Bourcier, Madelaine, Archer, Kramp, Paul & Astier, 2016	Implementation of automated dispensing cabinets for management of medical devices in an intensive care unit: Organisational and financial impact.	Pre- post study design	Level V: Quality improvement, program and financial evaluation
Zaidan, Rustom, Kassem, Al Yafei, Peters & Ibrahim, 2016	Nurses' perceptions of and satisfaction with the use of automated dispensing cabinets at the heart and cancer centers in Qatar: A cross-sectional study	Cross sectional study	Level III: non-scientific research
Clou, Dompnier, Kably, Leplay, Poupon, Archer& Paul (2018)	Impact of an automated dispensing system for medical devices in cardiac surgery department	Pre- post study design	Level V: quality improvement for program implementation with financial and organizational impact evaluation
Hachesu, Zyaei & Hassankhani, 2016	Recommendations for using barcode in hospital process	Observational descriptive	Level III : non-scientific research
Ehteshami, A. (2017).	Barcode technology acceptance and utilization in health information management department at academic hospitals according to technology acceptance model	Descriptive cross-sectional study	Level III: non-scientific research

Darawad, Othman and Alosta, 2019	Nurses' satisfaction with barcode medication-administration technology: Results of a cross-sectional study.	Descriptive Cross-sectional study	Level III: non-scientific research
Sakowski & Ketchel (2013)	The cost of implementing inpatient bar code medication administration	Retrospective, observational study	Level III: non experimental study
Bainbridge and Askew (2017)	Barcoding and other scanning technologies to improve medication safety in hospitals	Comparative (Technical) Report	Level V.
Sabogal, J. L., Rincon, J. C., & Rodriguez, A. (2018).	From the simple scan of a barcode to a complete patient safety strategy	Descriptive report after project implementation	Level V: Quality improvement
Rocchio, B. J., & Mantel, M. (2018).	Mercy shows how collaboration and the introduction of global identification standards can lead to increased patient safety in the operating room	Descriptive report after project implementation	Level V: Quality improvement
Kasamatsu, S., Sato, K., Ishimoto, Y., (2018)	University of Fukui Hospital Surgical Center creates an integrated sterilization management system for traceability and patient safety	Descriptive report after project implementation	Level V: Quality improvement
Coustasse, Tomblin & Slack, 2013).	Impact of radio-frequency identification (RFID) technologies on the hospital supply chain: A literature review	Literature review	Level V: Literature review
Yao, Chu & Li, 2012	The adoption and implementation of RFID technologies in healthcare: A literature review	Literature review	Level V: Literature review
Roper, Sedehi, & Ashuri, 2015	A cost-benefit case for RFID implementation in hospitals: Adapting to industry reform	Systematic review: Cost Benefit analysis framework	Level III: Systematic review of literature

Bendavid, Boeck & Philippe (2010)	Redesigning the replenishment process of medical supplies in hospitals with RFID	Pre-post design	Level V: Quality improvement; case study
Del Carmen León-Araujio, Gómez-Inhiesto & Acaiturri-Ayesta (2019)	Implementation and evaluation of a RFID smart cabinet to improve traceability and the efficient consumption of high cost medical supplies in a large hospital	Pre-post design	Level V: Quality improvement

APPENDIX C

Advantages & Disadvantages of Technologies under CHTA			
	Barcode	RFID	ADC
Safety	• Reduce medication errors[5,6,7,8,9,13] • Reduce operational errors[10,11,12]	• Improves medication administration safety • Improves patient safety[14,15] • Increase safety since no incorrect assignments to patients of surgery products or prostheses were detected[18] • Reduced delays in patient care especially during emergency[16] • Higher quality of care[16]	• Reduce medication errors[3,6,7,8,13] • Safe practice due to the controlled access[2] • Reduced oversight of pharmacy, therefore, increased risk of medication error[1,3] • Nurses believe it is a source of error[1]
Efficacy/effectiveness	• Improves effectiveness (80%)[6] • Saves time (80%)[6,9,10,11] • Increasing work speed[6] • Reliable (93.3 %) with an increase in data accuracy[6] • Decreased presence of expired medications[9] • Improved staff productivity[9,12] • Accurate charge capture[9,16] • Scanning should be done at a close distance • Limited data capacity[14] • Prone to human error[16] • Necessitates, staff education, policy dissemination, and health information	• Save time[15,17,18] • Reduced emergency orders of supplies[2,18] • High data capacity[14,16] • Accurate data capture[16] • Enables tracking from a distance up to 100 meters, in real time[14] • Not prone to human error[16] • Ineffectiveness due to readability issues that might be affected by distances[15,18]	• Reduce waiting time for the medication to arrive from pharmacy[2,3,13] • Improved traceability of medical supplies[4] • Improves medication information capture and support security measures[13] • Secure storage and dispensing of medical devices[4] • Reduced emergency orders of supplies[2]

	system implementation [5]		
Psychological, social, and ethical considerations	• User satisfaction (80%); workload and pressure reduction (82.2%)[6,10] • Easy to use system (43%) and useful (54%)[7,13] • Easy to check the "five rights"[7] • Reduced patient admission/discharge time[9]	• Ease of use • Improved staff satisfaction[16] • Effective for supply chain management and asset tracking[13] • Improved patients' privacy[14,16] • Improved patient flow and patient satisfaction[15,16] • Privacy issues related to data saved on discarded tags[15]	• Ease of use[1,3,13] • Available as tower module to be used for supplies and large bulk medications[1] • Nurses were satisfied and felt safe using it[3,4] • 1/3 of nurses reported they had to wait in line to use the ADC[3] • Reduced time use by unit and pharmacy staff on supply chain management by 34%[2]
Organizational and professional implications	• Requires an increase in the number of pharmacy's personnel[8] • Manual inventory count[16] • Improved quality of care[12] • No electromagnetic interference[16]	• Improve assets' control & traceability[15,16] • Automatic inventory count[14,15,16,17] • Interferes with other medical devices[15] Electromagnetic interference[16,18] • The lack of standardization of the protocols for RFID at the hardware and software levels causes a lack of interoperability across providers. The design might not meet the needs of hospitals[15]	• Consume large space[1] • Has to have an inter-phase with an Electronic Health Record[2]
Economic issues	• Affordable cost[8,13] • Cost saving[6,10,11,12] • Positive return on investment[13]	• High cost[13,15,16] • Unclear return on investment[14,15] • Increased charge captures, reductions in stock-outs, and	• Quite expensive[1,] • You need more than one cabinet per unit to accommodate all supplies[1] • Rapid return on investment[4]

		increased cash collection[14] • Cost effective[16]	• Reduced over-storage and waste of supplies[2] • Equal cost-benefit ratio[2]

[1] Esmaili, Norman & Rajgopal (2018), [2] Bourcier, Madelaine, Archer, Kramp, Paul & Astier (2016), [3] Zaidan, Rustom, Kassem, Al Yafei, Peters & Ibrahim (2016), [4] Clou, Dompnier, Kably, Leplay, Poupon, Archer& Paul (2018), [5] Hachesu, Zyaei & Hassankhani (2016), [6] Ehteshami, A. (2017), [7] Darawad, Othman and Alosta (2019), [8] Sakowski & Ketchel (2013), [9] Sabogal, J. L., Rincon, J. C., & Rodriguez, A. (2018), [10] Rocchio, B. J., & Mantel, M. (2018), [11] Kasamatsu, S., Sato, K., Ishimoto, Y., (2018), [12] HIMSS (2003), [13] Bainbridge and Askew (2017), [14] Coustasse, Tomblin & Slack (2013), [15] Yao, Chu & Li (2012), [16] Roper, Sedehi, & Ashuri (2015), [17] Bendavid, Boeck & Philippe (2010), [18] Del Carmen León-Araujio, Gómez-Inhiesto & Acaiturri-Ayesta (2019).

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