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BARCODE MEDICATION ADMINISTRATION AND PATIENT SAFETY

A narrative literature review

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THESIS
Abstract

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Abstract

Patient safety is a global challenge to health care systems. Medication errors are the main cause for patient harm. Smart technology in health care is developed to enhance patient safety through preventing and reducing medication errors. This thesis explored academic literature on the smart technology "Barcode Medication Administration", BCMA used in hospitals by conducting a narrative literature review. Factors that impact the successful use of BCMA and therefore compromise patient safety were analysed. Methods to recognise and reduce these potential risks were examined, and suggestions on the reduction of these safety risks were discussed. The research tried to find answers to the questions on how the factors that impact the safe use of BCMA in hospitals can be described, on what the effect of BCMA on patient safety is like, and on how safety problems can be addressed and solved to improve patient safety.

The concepts "Smart Health", "Patient Safety", and "Smart Technology and Barcode Medication Administration, BCMA" were described and provided a supportive conceptual framework. The method used in this thesis was the narrative literature review. The academic articles were selected or dismissed for this thesis based on selected standards. The data was analysed by performing the inductive content analysis and categorised into main themes and sub-themes which were then described in more detail. The results of the narrative literature review discussed factors that impact the successful use of BCMA and patient safety, and methods that aim to reduce or eliminate these risk factors through improving the BCMA system. The influencing factors were categorised into technological, social, and organisational factors. Technological factors included technical problems, compatibility, interconnectivity, integration, design, and ease of use. Social factors included user-related issues, attitude, social influence, awareness and expectations, user engagement, and workflow-related issues. Organisational factors included organisational culture and context, policy and regulations, economic factors, evidence- based research, and workflow related issues. Methods to address and overcome problems included improvement of communication and cooperation, the use of the closed loop system, training and education, and the use of models such as the Technology Acceptance Model, TAM, the Electronic Medical Record Adoption Model, EMRAM or the Adaption Model for Analytics Maturity, AMRAM that facilitate change and development.

The findings help stakeholders in their decision – making associated with the safe implementation of BCMA and are hopefully also used as supportive teaching material in health organisations and schools.

Keywords

Barcode Medication Administration, Patient Safety, Smart Technology, Impact, Improvements, Hospital Setting

In smart technology many abbreviations are used which are summarised in the glossary below. The aim is to provide a clear definition of the terminology and a structured overview to help with reading and comprehension. The abbreviations are ordered alphabetically.

Glossary: Abbreviations of terminology that occurred in the narrative literature review

ADM: Automatic Dispensing Machine

(Computerised medication cabinet for authorized staff only)

AIDC: Automatic Identification and Data Capture System

(Automatically identifies individuals or objects and stores the data in system)

ATC: Automatic Tablet Counter

AMAM: Adoption Model for Analytics Maturity

BCMA: Barcode Medication Administration

(The system is used during the order, transcription, dispensing, and administration of medication)

CDW: Clinical Data Warehouse

(Provides instantaneously data about a patient from various clinical sources)

CLMA: Closed-Loop Medication Administration system:

(Uses barcode scanning in manufacturing, dispensing, administration of medication)

CPOE: Computerised Physician Order Entry

(Physician enters electronically instructions for patient´s treatment)

DASH: Data Analytics for Safe Healthcare

DR: Disaster Recovery

(Plan and guidelines to restore fast health data in case of data loss)

EC: European Commission

ECAMET: Alliance of European Collaborative Action on Medication Errors and Traceability

EEG: Electroencephalography

(Test to record electric activity of the brain)

eHealth: electronic Health

EHR: Electronic Health Record

(Patient's data is stored electronically instantaneously)

EKG: Electrocardiography

(Test to measure electrical signals of the heart)

eMAR: Electronic Medication Record

(Electronically tracks and stores process of medication administration and treatments)

EMRAM: Electronic Medical Record Adoption Model

EMS: European Medicines Agency

EXPH: Expert Panel on Effective Ways of Investing in Health

GOe: Global Observatory for eHealth

GPRS: General Packet Radio Service

GPS: Global Positioning System

GS1: Global System of Supply Chain Standards

GVP: Good Pharmacovigilance Practices

HIE: Health Information Exchange

(Health information is securely shared between various healthcare providers)

HIMSS: Healthcare and Information Management Systems Society

HIS: Hospital Information System

HIT: Health Information Technology

ICT: Information and Communication technology

IMRAD: Introduction, Methods, Results, Discussion

IoT: Internet of Things

MAK: Medication Administration Check

mHealth: mobile Health

PBMA: Paper-Based Medication Administration

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

RFID: Radio Frequency Identification

TAM: Technology Acceptance Model

WHO: World Health Organisation

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1 INTRODUCTION

Patient safety is a fundamental concept in health and has a high priority globally. The seriousness of patient safety has been recognised by all stakeholders. The leading cause for compromising patient safety is medication errors. The European Medicines Agency defines medication error as an unplanned mistake in any of the medication treatment levels. Medication errors may happen during various phases from ordering to administering medication and may potentially harm or does harm the patient. (European Medicines Agency 2021). According to the European Collaborative Action on Medication Errors and Traceability and to cite but one national example, ECAMET (2022), the Spanish Patient Safety Strategy in the National Health System calculates the cost of medication errors between 2015-2020 to be approximately €2 billion euros which is 3% of the total national healthcare spending. The reduction of medication errors is essential in minimising costs, and in enhancing patient safety. Patient safety organisations, research centers, many healthcare professionals and other stakeholders are cooperating to achieve a successful implementation of smart technology as a means of addressing this problem.

There are efforts at European and national levels to achieve common practices to minimise and prevent mistakes and to support the implementation of smart technology such as "Barcode Medication Administration", BCMA. The Alliance of European Collaborative Action on Medication Errors and Traceability (ECAMET) sees problems caused by lack of European data conformity, and the high variability among the European countries of medication error risks. The Alliance aims to facilitate the use of smart technology by conducting a Pan-European survey. The results help to develop best practices, enhance collaborative development, and achieve innovation by evidence-based processes and altering substandard behaviour. The Alliance recognises the importance of the medication traceability through smart technology in preventing and minimising medication errors. European institutions and EU member countries are encouraged to adopt common regulations and guidelines. (ECAMET patient safety project 2022.)

This narrative review is intended to analyse literature on the smart technology "Barcode Medication Administration", BCMA applied in hospitals. Factors which impact the safe use of BCMA, and solutions associated with BCMA to enhance patient safety are discussed. It is essential to identify, analyse, and evaluate the different factors that influence the safe and successful implementation of smart tools such as the "Barcode Medication Administration System" to promote positive changes in behaviour, processes, procedures, or policies to finally overcome factors that negatively influence BCMA and patient safety. Understanding these interrelating factors promotes the development of new solutions to enhance safe use of BCMA and to improve patient safety.

Health care professionals, patients and advocacy groups face new obstacles and must adapt to a new technology-driven and fast changing environment. More theoretical information and practical knowledge on the impact of smart technology on patient safety is needed, as well as better training and skill in their use. The idea for this thesis stems from the author´s experiences in the implementation of smart tools in nursing. The author also believes there is a need to provide health care students at Savonia University of Applied Science an updated overview on this topic.

The result of this research is important to all stakeholders who apply smart tools such as BCMA, and who deliver or receive smart health care services. Based on the results of this thesis, healthcare professionals and healthcare policy makers can make better decisions on the implementation of BCMA to improve patient safety. Ongoing research should investigate newly arising challenges further and support the use of novel BCMA solutions associated with BCMA to improve patient safety. It is hoped this thesis can be used as a resource to teach healthcare students more effectively about smart health and its relation to patient safety.

2 CONCEPTUAL FRAMEWORK

The concepts "Smart Health", "Patient Safety", and "Smart Technology and Barcode Medication Administration, BCMA" will be explained to achieve a clear picture of the topic. Factors that impact the safe use of BCMA and patient safety will be discussed based on previous research. Examples of improvements to overcome problems and enhance the successful use of the BCMA system and patient safety will be addressed.

The traditional health system has developed rapidly and shifted towards the Internet of Things, or "IoT" based healthcare system. Usage of the term health has changed, and new terminology has appeared. There is often confusion about the terminology of digital health, electronic health, mobile health, or smart health. Some terms are used interchangeably.

Digital health is an umbrella term which includes information and communication technologies, ICTs. The goal is to implement the ICTs to deliver healthcare to a wide range of citizens with the help of various tools and services. The aim of these digital tools is to improve prevention, diagnosis, treatment, monitoring, and management of the clients´ health, and to supervise and manage the clients` habits which effect their health condition, and to enhance the effectiveness of health services (European Commission 2018).

Electronic health (e health) is supported by the information and communication technology, "ICT". E health tools are services, products, and systems. Their goal is to improve the access and the quality of healthcare. Mobile health, "m health" is a part of e health. A standardised definition for m-health is not yet available. M health is described as public health services which uses wireless technologies such as wireless devices, tools which keep track of the user´s health data, and local tracking systems. (WHO 2011, 6.) These technologies have a broad reach, evolve rapidly, can be integrated with other e health services, and are user-friendly.

2.1 Smart Health

Smart health is often described as a system which incorporates different technologies to collect health data, to connect people and things and to manage and respond to needs. The smart health system includes for example wearable devices, robotics, and mobile internet. Smart health care has the potential to improve the monitoring of patients, diagnosing, treatment, the decision- making, the prevention of diseases, and medical research. Smart healthcare can be applied by clinicians, researchers, individual patients, or family users. (Tian et al. 2019, 62-65.)

Smart health developed from digital health and the Internet of Things, IoT. IoT is complex, has grown rapidly during the last several years and has revolutionised healthcare. IoT is a term for wireless digital tools connected to each other and to the internet. These "things" or devices collect, transmit, and store information. The network is expansive, and it helps to improve healthcare by monitoring the patient´s health condition in real-time. With the IoT, some health conditions may be predicted, heart rate, respiration rate, and blood pressure measured, and diagnoses made. IoT has a huge potential, but there have also been challenges in the implementation of IoT in healthcare. These issues concern the storage and management of information, the exchange of information

between different devices, security and privacy, and accessibility. According to research, there is no universal definition for the Internet of Things. The IoT is an arrangement of things equipped with functions to identify, perceive, network, and process information. These objects are connected to each other and other objects or services via the Internet. (Whitmore, Andrew, Agarwal, Anurag & Xu, Li Da 2014, 261-274.)

Smart health care provides services that are based on the newest technology and smart tools. The Internet of Things has developed rapidly, and new personalised eHealth services have emerged. Devices connect with IoT sensors to gain real-time data and to monitor the patients remotely. Costs can be reduced, and medical resources can be more efficiently used, because smart health facilitates access to various health services in different regions improving the distribution of resources. (Meola, 2022.) Smart tools support health care professionals and patients to collect, to share, and to interpret big health data. More information is gathered, and the stakeholders have an ever-growing need for tools to process this data. The impact of smart technology on health care is growing, and it effects the delivery of health care services all over the world. New technology is developed to focus more on the patients 'individual needs and safety, to allow easy access to services and efficiency in care. Although smart technology brings with it many potential benefits, it also creates a renewed need to focus on patient safety.

The implementation of smart technology in healthcare enables efficient and safe care. Continuous development of electronic systems reduces deficiencies in smart tools, drug mistakes, and patient harm. Despite the support of innovative technology, mistakes associated with drugs are still harming the patient. Healthcare professionals experience challenges in implementing smart tools successfully due to the complexity of the systems, or due to dysfunctional applications or processes. Instead of blaming the users for making mistakes, the organisations´ policies should support healthcare professionals by creating a blame-free culture. The "Expert Panel on Effective Ways of Investing in Health", EXPH emphasizes the importance of implementing blame-free technology systems in organisations. EXPH is an independent Expert Panel founded by the European Commission, EC. The aim of the EXPH is to support the EC by providing non-binding, evidence-based and independent opinions and recommendations on issues related to health, innovation, alertness, and cost-effectiveness. (Barros, Brand, Barry & Brouwer 2014, 1, 9.)

2.2 Patient Safety

The World Health Organization, WHO recognises patient safety as a global health priority. According to the WHO patient harm due to safety problems is ranked as number 14 in the causes for morbidity and mortality globally, and in countries with high living standards one out of ten inpatients is harmed. Half of the incidents may have been preventable. The World Patient Safety Day promotes patient safety to make the public aware of the issue and to facilitate more engagement, cooperation, solidarity, and action. Efficient, safe, people-centered, and high-quality health services are fundamental for patient safety. The aim is to support patient well-being and not do harm. Patient safety improves continuously through learning from adverse events. The WHO focuses on universal health coverage (UHC), and an ongoing need to enhance public health and ensure safe provision of quality services (World Health Organization 2019)

The concept of "safety" is an important concept in health care, health safety, and patient safety. It is fundamental to the health care system and in the relations between patients and health providers. Factors that may harm a person physically, mentally, or financially must be reduced or eliminated to safeguard the individual´s and the society´s wellbeing. (Institut national de santé publique du Québec 2018). According to Bell (2019), medical errors can affect the patients in many ways. The patients` emotions, psychological state, relationships, physical, and financial condition may be impacted. Psychological problems include post-traumatic distress, guilt, fear, frustration, or loss of trust occur. These psychological conditions may require professional treatment and remain a long-term problem for the patients and their families. Financial strains may remain a life-time problem due to prolonged treatment, or due to additional medication needed to overcome adverse drug events.

In 2012 the pharmacovigilance law was introduced to enhance efforts in improving patient safety by minimising medication errors. A guide of good pharmacovigilance practices, GVP was created. In Europe, the European Medicines Agency (EMA) oversees the operation and coordination of the European Union pharmacovigilance system. Pharmacovigilance are activities and systems to identify, evaluate, comprehend, and avert medication errors to enhance patient safety. The EU government and regulatory bodies provide common guidelines for the correct documentation of medication errors, which includes the reporting, evaluation, and prevention of medication errors. Guidelines on risk management planning are also provided. (European Medicines Agency 2021.)

In 2017 the Institute for Healthcare Improvement (IHI) conducted a survey in the United States to collect citizens´ experiences and perceptions of patient safety. The survey showed that 41 percent of adults were personally affected, or a family member or friend was affected by a medical error. These experienced medical errors had effects that lasted not only for a brief time, but also for a prolonged time. According to IHI the enhancement of patient safety is the responsibility of numerous different stakeholders which include healthcare leadership, organisation administration, healthcare providers and patients. (IHI/NPSF 2017,1-2.)

The protection of the patient means that errors and negative events are avoided, which means doing no harm and trying to eliminate or minimise risks that compromise the patient´s safety. Patient harm is an unintended and preventable incident that happens after care was provided and is not linked to the patient´s disease. The goal of patient safety is to achieve a condition free of harm by applying processes and structures to promote safer healthcare. The care processes must be evaluated regularly to recognise elements that compromise patient safety. How care is provided, smart technology, and smart services affect the patient´s safety. In research three different types of qualities in healthcare have been identified. How the patient encounters care, how his health is protected, and how choices in the hospital setting are made. (Lillrank 2015, 362).

Lillrank (2015, 361-364) emphasizes that several tools or procedures can be applied to enhance quality of care. In clinical decision making, such tools are appropriate education and accurate diagnostic, ethics, collecting of all relevant data, and comprehensive consultations with other healthcare professionals. Patient safety can be improved through reports and assessments of errors, near misses, and learning from adverse events. Patients´ activities which compromise safety are

more challenging to monitor and address. It is difficult to measure quality of care in the context of patient satisfaction. Patient experience of quality of care can be very diverse because it depends on the patients´ preferences, cognitive condition, expectations, and perceptions. Patient satisfaction and thus quality of care are influenced and can be enhanced by the healthcare provider´s attitude, social competence, and awareness.

The Joint Commission is a U.S. based, non-profit organisation which performs regular inspections and evaluations of healthcare organisations. Its aim is to improve performance and quality of care by providing data transparency, expertise, knowledge, and standards. The Joint Commission developed "DASH" (Data Analytics for Safe Healthcare) to help organisations achieve these goals. DASH is an assembly of intelligent tools which include the application SAFER Dashboard. This application can be used by healthcare organisations as a tool to process health data and get an overall view of the hospital´s performance. Findings of surveys, or the staff´s and organisation's efficiency can be viewed, for example. Charts and graphs are used for a better visualisation, and data can be shared with other stakeholders and healthcare providers for comparison. By applying this tool, the organisation can identify aspects which need to be improved, set goals to achieve the improvements, and survey the progress of change. (The Joint Commission 2021.)

2.3 Smart Technology and Barcode Medication Administration, BCMA

Smart technology refers to services or tools which work autonomously. The purpose is to empower patients to self-management, promote and improve personalised care, and to minimise patient harm. Smart tools enhance the utilisation of resources to a high level. Health services can be provided without geographical restrictions. Smart tools may reduce costs and help in remote patient monitoring. According to researchers, the classification of smart health is broad. Smart health includes aspects such as users, services, medical tools, and applications. Three categories that classify smart health technology have been identified: Application-oriented (data transfer between detectors and mobile apps), things-oriented (intelligent processing, tracking in real-time), and semantics-oriented (develop behavioural patterns based on data acquired) (Sundaravadivel, Kougianos, Mohanty & Ganapathiraju 2018, 1-10.)

Smart technology can support cooperation and interaction and help health care professionals and patients in their decision-making. Smart technology can improve quality of care and promote personalised care. Many innovations have been developed to reduce patient harm. The electronic health record, e-prescriptions, the pharmacy information systems, the automated dispensing machines, point of administration systems, intelligent infusion pumps, smart sheets to prevent pressure sores, smart beds, barcode scanning, and adverse drug event surveillance systems, just to mention a few. This thesis focuses on barcode scanning in connection with medication administration in the hospital setting. This smart health tool is defined as "Barcode Medication Administration" (BCMA) which is applied by nurses, doctors, and pharmacists to provide safe medication administration to the patient.

Smart tools in healthcare such as BCMA have the potential to improve efficiency, health care professional`s performance, reduce costs on the administrative and operational level, and enhance

patient safety if the application is designed and implemented appropriately. Because smart tools are often technically advanced, care processes may become more complex and new challenges for health care professionals arise. It is important to identify reliable procedures and guidelines to prevent wrong diagnoses or wrong treatment when smart tools are introduced to improve patient safety. Unfortunately, many implementation shortcomings from individual human, organisational, and technology aspects have been identified through research studies. (Ossebaard, De Bruijn, Van Gemert-Pijnen & Geertsma 2012, 1-69.)

Beuzekom, Boer, Akerboom & Hudson (2010) state that patient safety is not improved effectively by analysing only human contributing factors. Analysis of the smart systems and the organisational factors are needed, too, to improve patient safety more significantly. Smart technology must be designed to prevent users from making mistakes. Underlying problems in the systems must be addressed, and an appropriate work environment and equipment must be provided to promote users´ performance. (Beuzekom et al. 2010.) According to the WHO, the minimisation and avoidance of medication errors is possible by improving smart systems and processes and by providing safeguarding processes. The WHO supports actions which aim to improve dedication and responsibility among stakeholders, and to reduce patient harm by 50% between 2017 and 2022. (World Health Organization 2017.)

Smart technology may not only enhance but also threaten the patient´s well- being. Cyber- attacks are a risk to health records which store identifying information such as social security numbers, health information and banking details. Planned or unplanned breakdowns of systems such as electronic health records were identified as another issue that affects patient safety. Patient safety can be endangered because of too much information, miscommunication, or misinterpretation of test results. Software applications or products that diagnose, treat, or prevent an illness, must be carefully monitored to minimise harm. Experts in cyber security recommend taking five actions to prevent cyber-attacks. These include making risk assessments of new devices, adhering to general security procedures and guidelines, grant access to devices only to authorised users, disable the device´s connection to the internet or allow only certain internet sites to connect to devices, and use effective tools that support internet security. (Gloss 2020.)

Barcode Medication Administration requires a high level of security and privacy. Like other smart devices, BCMA relies on identification through scanning and tracking using intelligent sensors. Only authorised users should be able to access smart devices by scanning their personal identification card. Network firewalls, verified passwords, and assuring access only by authorised users for confidentiality and integrity for sensitive health data are essential to facilitate security. Furthermore, the identity of users and their location should remain private to reduce breaches of sensitive information.

Software platforms support organisations to improve data security. For example, Varonis is a software company which is based in New York. Via Varonis software platform effective tools are provided to protect sensitive information from malware and other security threats. The tools recognise for example suspicious account activities and user behaviour. Varonis provides a five-step operational plan that helps organisations to minimise security risks. (Varonis 2022.) Other

competing companies offer similar data security protection, including the American company Verve, and Europe based companies Andersen, and Thalesgroup.

One aim of the European Commission (EC) is to enhance the digitalisation in the health sector between 2019 and 2024. (European Commission s.a.). The EC has developed the "eHealth Digital Service Infrastructure". E- prescriptions and patients´ medical records have been shared between various healthcare providers across EU member state borders since 2019. The goal is to establish a European electronic health record exchange format for all EU citizens. In Europe, efforts are made in increasing the implementation of barcoding medications. In the U.S. single unit medications have been required to be labelled with a barcode since 2006. In Europe, the European Association of Hospital Pharmacists (EAHP) helps organisations and other stakeholders to implement barcoding of medications. The Netherlands is one of the first countries within the EU that aims to enhance implementation of barcoding at the single unit level of medications. According to Tjalling van der Schors (2017), pharmacist at the West Friesland Hospital and chairman of the Dutch Association of Hospital Pharmacists NVZA, uniform barcoding should become mandatory within the European countries. 80% of the medication administered in Dutch hospitals is already labelled with a uniform barcode at the single unit level. The Minister of Health, Edith Schippers states that a general uniform barcode implementation would save costs of up to 21.4 million Euros yearly, reduce mortality, enhance quality of life, and minimise costs of compensation in case of medication errors. (gs1 interview 2017, 1-3.)

3 OBJECTIVES

The topic barcode medication administration (BCMA) and patient safety in the hospital setting is explored through conducting a narrative literature review. This thesis examines the concepts of "Smart Health", "Patient Safety", and "Smart Technology and Barcode Medication Administration, BCMA". Barcode Medication Administration technology (BCMA) is chosen to be investigated in more detail, because it is an important tool to make drugs administrations safer. The focus is put on the use of BCMA in the hospital setting. The results of the literature search are analysed to select relevant academic literature on BCMA smart tools used in hospitals. The purpose of the thesis is to understand factors that have an impact on the successful use of the BCMA system and thus affect patient safety. Methods to better address these potential failures will be examined, and suggestions on how these safety problems can be overcome will be discussed. Common themes and sub-themes will be identified to achieve a clearer structure and picture of the topic. The findings of the narrative literature review help explain factors that impact the safe implementation of BCMA, their impact on patient safety, and how these factors can be addressed and modified to enhance patient safety. This information is useful for clinicians, educators, and healthcare students to improve their knowledge of patient safety issues. The findings of the thesis will also be useful for clinical work or educational work. The results of the thesis can also be implemented in the study plans of healthcare students at universities of applied sciences or other educational institutions. In future research these issues can be further addressed, investigated, and more solutions can be developed and implemented to reduce patient harm in smart health care.

The research questions are:

How can the factors that impact the safe use of BCMA in the hospital setting be described?

How does BCMA affect patient safety?

How can safety issues be addressed and overcome to enhance patient safety?

4 METHODS

The method for the implementation of the thesis is the narrative literature review. This procedure is used to critically discuss appropriate and reliable literature on the chosen topic. The reviewer aims to identify common themes and certain connections among the numerous academic articles to find answers to questions which could not be answered by a single study. Literature reviews are essential to make interpretations, and draw conclusions based on the findings of numerous of academic studies. Broad conclusions cannot not be made by conducting a single investigation, but by a thorough literature review. (Baumeister & Leary 1997, 313) A narrative literature review is described as a useful tool to develop and test theories. (Baumeister & Leary 1997, 311-320).

Researchers use various types of literature reviews, for example the systematic and the non-systematic or narrative literature review. The systematic literature review uses evidence -based instructions according to the "preferred reporting items for systematic reviews and meta-analyses". (PRISMA 2021). This set of guidelines stems from Cynthia Mulrow (1987, 485-488) who analysed the quality of 50 literature review articles published between 1985 and 1986. The reviews were assessed based on eight criteria which were published in earlier academic articles and included the aim of the review, the recognition and the choice of the information, the evaluation of reasonableness, qualitative and quantitative methodology, recapitulation, and prospective recommendations. Mulrow (1987) recognised that many researchers did not follow the eight scientific principles and suggested the use of the systematic methods of exploration, evaluation, and synthesis to promote quality review articles. (Mulrow 1987, 485-488.) PRISMA 2020 are updated guidelines for writing systematic literature reviews and include a checklist and a flow diagram. The guide discusses improvements in methods to recognise, analyse, choose, and produce studies. PRISMA is mainly used when describing reviews which evaluate the impact of interferences. The PRISMA checklist 2020 provides a structure for the review article, which consists of the title, abstract, introduction, methods, results, discussion, and other information such as registration and protocol, support, other material. (Prisma 2021.)

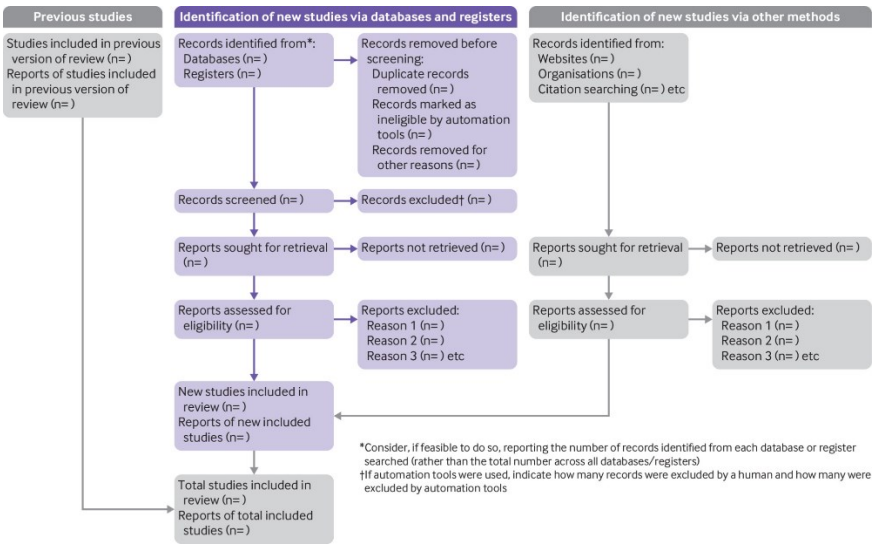

FIGURE 1. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews (Page et al. 2021)

The PRISMA 2020 guide describes the identification of previous studies which were included in earlier reviews, and the recognition of novel research from various repositories and catalogues, and from other websites or organisations. (Figure 1).

Unlike the systematic literature review, the narrative literature review is not based on any pre-conceived guidelines. The most common used model is called IMRAD (introduction, methods, results, discussion). It provides a common organisational structure for the study and is not a complete checklist for writing a narrative literature review. In narrative literature reviews, the methods section is not compulsory, but it is advisable to use a structured approach to search for the literature. The non- systematic review investigates previous academic research studies, general discussions, and gaps in knowledge. The literature reviewer provides recommendations for future research and addresses potential interpretations. The assumptions, the planning, the selection, and evaluation biases are not often known. (Ferrari 2015, 230-235).

The researcher uses tools which help to organise and structure the academic work. One example is the IMRAD model. IMRAD is an acronym for introduction, methods, results, and discussion. With the help of the IMRAD model, the academic work is organised into these four main sections. Table 1 describes the four main sections and their content. The introduction of the narrative literature review states for example the relevance of the thesis, presents existing research, identifies problems and the purpose of the thesis. The Methods section discusses how the research was conducted. It is explained how the information was gathered and evaluated. Under the Results chapter, the results of the literature search are presented. In the discussion part, the results are analysed and interpreted, limitations are addressed, and recommendations for further research are made. (Adevusi 2021.)

TABLE 1. IMRAD model (Adevusi 2021)

Introduction section	Define the problem
Methods section	Describe the methods used to explore the problem
Results section	Present the findings
Discussion section	Explain the importance of the findings Draw comparisons, make recommendations for future research

In literature reviews five common goals can be determined, such as developing a theory, writing an overview of a certain area, identifying a problem, or providing historical information on the development of a theory. (Baumeister et al. 1997, 312). In this narrative literature review the concepts of "Smart Health", "Patient Safety" and "Smart Technology and Barcode Medication Administration, BCMA" are introduced and explained. The method of narrative literature review is applied to identify and to connect academic findings and studies on the chosen topic. The research objective is to find relevant literature on BCMA as used by doctors, pharmacists, and nurses who work in a hospital directly with patients. The policies, processes, and procedures associated with BCMA will be explained, and factors that impact the safe use of the BCMA system and patient safety are discussed. Methods for improvements associated with BCMA to enhance patient safety will be addressed. The review is written in a structured and transparent way.

4.1 Data collection

The purpose of this narrative literature review is to search for academic research literature that addresses the smart technology Barcode Medication Administration (BCMA) as used in hospitals to improve patient safety. The aim is to gain more information and insight on the topic, to collect relevant data, and to dismiss data not relevant to the topic. Figure 2 describes the process of the literature search which are divided into four steps.

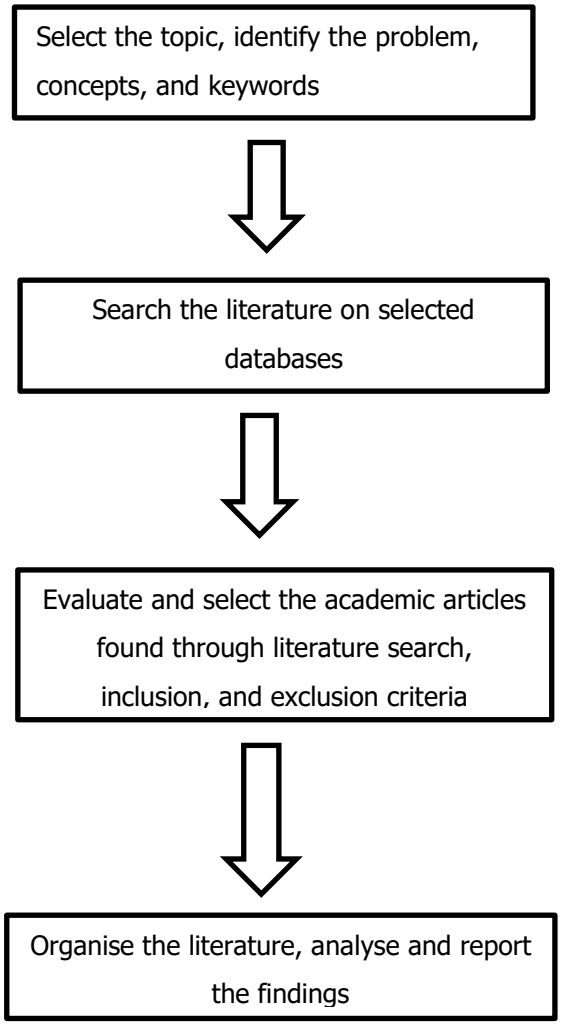

FIGURE 2. Literature Search Cycle (Charles Sturt University 2022)

The Literature Search Cycle explains the steps involved in a literature search and the connection between the various steps. The researcher selects the topic, identifies the main concepts and keywords, selects the databases, and performs the literature search. Literature resources are included or excluded based on the selected criteria. The researcher reviews the academic articles gained through the literature search, analyses the search results, and creates new keywords or uses other additional databases if necessary. (Figure 2.)

For this thesis the literature search was conducted by applying several search engines including Research Gate, Science Direct, Semantic Scholar, Google Scholar, Savonia thesis platform, and pubmed. Search engines are a research tool. They are web-based services which allow users to search for content via the worldwide web. By using algorithms, a catalogue of web sites with the most applicable sources shown at the beginning of the results is created. The importance of the source is evaluated based on full text, place of publishment, authors, or the amount and timing of citations. Sources are diverse and stem from various disciplines, they can include articles, theses, books, or abstracts. Also, information on related works, authors and citations can be found.

Research engines such as Research Gate which started its operation in 2008, facilitate cooperation, interconnection, and easy access in research. Research engines are free to use, but by subscribing users gain better access to academic literature. There is also the possibility to buy individual documents. The search engines` names and their respective URLs are listed in the table below.

TABLE 2. Search Engines and their respective URLs

Name of data base	Internet Site
Research Gate	https://www.researchgate.net/
Science Direct	https://www.sciencedirect.com/
Semantic Scholar	https://www.semanticscholar.org/
Google Scholar	https://scholar.google.com/
Savonia Theseus	https://www.theseus.fi/
Savonia Finna	https://savonia.finna.fi/
Pubmed	https://pubmed.ncbi.nlm.nih.gov/

Data was gathered by using search words which included "smart technology", "barcode medication administration", "patient safety", "impact", and "hospital setting." The aim was to find qualified academic literature on the topic. The search words were used in combination to increase the spectrum of the search results. The Boolean operators AND, NOT and OR were applied to structure search terms. Reference lists of literature reviews were studied to find valuable research on the topic. Selection standards served as a tool to collect relevant data by filtering the search results.

TABLE 3. Data analysis. Selection Standards

Articles selected	Articles dismissed
Articles about the use of barcode medication administration in the hospital setting	Articles not related to barcode medication administration
Articles about benefits and challenges of BCMA associated with patient protection	Articles that did not discuss the benefits and challenges of barcode medication administration
Articles about improvements concerning the use of BCMA	Articles that did not discuss improvements concerning the use of BCMA
Articles about barcode medication administration and patient safety	Articles that did not discuss patient safety and barcode medication administration
Articles accessible without subscription and fees	Articles not accessible without subscription or fees
Full text articles	Articles without full text
Evidence based, peer reviewed articles	Articles that were not evidence based or peer reviewed
Articles in English, Finnish, and German	Articles in other languages
Most research studies not older than 2012	Articles older than 2012

The results of the literature search were selected and analysed according to the selection standards. Most of the material selected has been published within the last 10 years. Some material older than ten years has been used because the author felt it was still relevant. The selected articles are freely available, peer-reviewed, and written in full text. The source of the material was critically evaluated for academic validity, and unreliable resources were dismissed. Articles written in English, German, or Finnish were selected. The material corresponded with the research questions and the search words. The goal was to find academic material about BCMA when used in hospitals, and to find material on how patient safety can be enhanced by addressing factors that impact the safe and successful implementation of BCMA, including how to address and overcome potential risk factors to improve patient safety. The abstracts and results of all articles were read to filter the material and to reduce the number of articles. A few studies on BCMA in connection with other applications were included which discussed also the electronic medical record (eMAR), the electronic health record (EHR), and the computerised physicians order entry (CPOED). The purpose was to describe the potential of interconnectivity and integration of BCAM into other smart systems to improve these systems, and to enhance patient safety. These applications are also described briefly in the results and reflection chapter.

4.2 Data analysis

The data was narrowed down by selecting one smart technology to gain more in-depth data. The aim was to explore aspects that affect the successful use of this smart technology, and to analyse methods on how to minimise or eliminate these factors to improve the safe use of this smart tool to enhance patient safety in more detail. Barcode Medication Administration (BCMA) was selected as the topic for this thesis because it is an essential part in the journey of digitalisation of hospitals globally. The Healthcare and Information Management Systems Society (HIMSS), the American Food and Drugs Administration (FDA) and the European Medicines Agency (EMS) are working on how to improve patient safety when smart systems are used, including the barcode system.

Narrative research is a continuing process. For this thesis the researcher analysed the data using the inductive content analysis method. Thomas (2006) describes inductive analysis as the thorough reading of text, the consideration of various meanings within the text, and the forming of themes, concepts, or models. Themes can be analysed further and be organised into sub-themes. Sub-themes are then explained in more detail. The inductive data analysis includes several steps such as preparation, organisation, and reporting of results. It is a methodology used to systematically investigate qualitative data to produce connections between the research objectives and reliable and valid findings from the data. The researcher reads and interprets the texts, and by doing so gains understanding of the topic. (Thomas 2006, 237-246.)

The main concepts of this thesis are "Smart Health, "Patient Safety", and "Smart Technology and "Barcode Medication Administration (BCMA)". Certain recurring themes were identified in the selected articles. These main themes addressed the factors that impact BCMA implementation and patient safety, and suggested methods to improve the use of BCMA to minimise errors and enhance patient safety in the hospital setting. The main themes were categorised as "technological factors", "social factors", and "organisational factors".

These main themes were analysed further to identify sub-themes. Sub-themes were put under their respective main themes. For example, "technical factors", "usefulness", "ease of use", and "compatibility" were identified as sub-themes. These sub-themes were organised under the main theme "technological factors". Sub-themes such as "user related", "perceptions", and "expectations" were added under the main theme "social factors". Sub-themes "policy and regulations", "economic factors", or "organisational factors" were categorised under the main theme "organisational factors". The sub-theme "workflow" was identified as a very prominent factor and was discussed in numerous studies. "Workflow" is organised under both main themes "organisational factors" and "social factors" because factors influencing workflow show organisational and social attributes. Sub-themes were then described in more detail. For example, the sub-theme "technical factors" is associated with wi-fi connectivity, or reliability of the system. The sub-theme "usefulness" describes aspects such as benefit, performance, and users´expectations. The sub-theme "design" includes layout, culturally appropriate design, or patient centered. The sub-theme "policy and regulations" is associated with privacy, security, legal issues, guidelines, protocols, policies. The sub-theme "economic factors" include funding, reimbursement, fees, or tools´ cost. The categorisation of

themes, sub-themes, and more detailed explanations of the sub-themes are illustrated in a table to achieve a clearer picture of the data analysis process. (Table 4.)

TABLE 4. Data analysis process of smart technology on patient safety

Main themses	Sub-themes	Explanations
Technological factors	technical factors, usefulness, ease of use, compatibility, design, convenience	Wi-fi connectivity, reliability, technical support, usability, benefit, efficiency, performance, expectancy, interoperability, integration of computerised physician´s order entry, EMR, EHR, layout, the system´s mobility, flexibility, convenience, culturally appropriate design, patient- centeredness
Organisational factors	organisational culture and context, policy and regulations, economic factors, evidence base, workflow related	hospital, ward, communication, supportive environment, privacy, security, legal issues, guidelines, protocols, policies, funding, fees, costs, quality of clinical research, training, workload, workflow, time and cost efficiency, infrastructure, standardisation of processes, planning, changes to clinical practice, decision-making
Social factors	User related, workflow, perceptions, expectations, social influence, user engagement	support, nurse-patient ratio, workload, manufacturer, pharmacist, physician, nurse, patient, acceptance, perceptions, expectations, distress, tiredness

In the selected research articles recommendations, solutions, and methods to improve BCMA and to reduce patient harm were discussed. Methods to enhance successful and safe implementation of BCMA and patient safety included for example the reduction of workarounds, creation and adoption of standard guidelines, the enhancement of cooperation, and communication, proper staff training, and the implementation of various smart systems connected with each other. Tools that help managers to enhance the use of BCMA may be the "Technology Acceptance Model" (TAM), the "Adoption Model for Analytics Maturity" (AMAM), the "Electronic Medical Record Maturity" (AMRAM) model, and the conduction of research. The various methods and tools identified in the research articles are presented in the table below. (Table 5.)

TABLE 5. Methods to improve safe implementation of BCMA to enhance patient safety

Reduction of workaround by addressing influencing factors such as workload, time pressure, nurse -patient ratio	Efforts of regulatory bodies, the development of standard guidelines, regulations, surveillance
Development of barcode medication administration, implementation of various interconnected systems such as the closed loop medication system (CLMS)	Mobile nursing stations, mobile phones, tablets, wireless scanners
Improvement of communication and cooperation of pharmacists, physicians, and nurses through better integrated applications	Use of models to facilitate change and to improve the successful use of the barcode medication administration system
Cooperation between hospital organisations and other stakeholders such as pharmacies and manufacturers to facilitate change and research	Ongoing research to evaluate and improve the system
Training and education of users, staff education modules	

The concepts are described in the Conceptual Framework chapter. The Results chapter presents the results of the literature search and data analysis. The themes, sub-themes and more detailed explanations of the sub-themes, and methods to improve the use of BCMA to enhance patient safety are discussed. In the Reflection chapter the results are put into context and associated with references. Conclusions are drawn and recommendations for further research are made. Further, ethical issues and the validity and the academic integrity of this thesis are addressed.

5 RESULTS

The results of the narrative literature review are discussed in the following sections. The information was gained through searching the literature, and through gathering and analysing relevant data. The literature search on barcode medication administration and patient safety in the hospital setting produced for example 23 100 results on google scholar and 554 results on science direct. The author used Savonia Theseus only to read a few theses to get a better idea in how to proceed with this thesis. The articles of the literature search were reduced by selecting more keywords such as smart technology, impact, patient safety and improvements. The author recognised themes and adapted the search words. For example, nursing workarounds with 17 300 search results and nurses 'perceptions on barcode medication administration and patient safety with 16 100 were prominent themes which were reduced by applying selection standards and by reading the abstracts of the academic articles. Articles which systematically reviewed the literature related to the topic of interest were excluded unless the author needed these literature reviews to better explain the topic. Instead, experimental, and observational studies, such as cross-sectional studies on the topic were included. Articles published before 2012 were excluded with a few exceptions. In the end 92 articles were selected and analysed further for this thesis to answer the research questions. The keywords were translated into German and the search produced 105 results. A few German articles were read, but only one article was included in the thesis. Two Finnish articles out of 35 were included in the thesis.

This research focuses on the smart technology Barcode Medication Administration (BCMA). In the following chapter the components of this system and the process of barcode medication administration will be explained. The results discuss factors that impact the safe use of BCMA, with an emphasis on procedures and situations that compromise patient safety. Moreover, possibilities and suggested methods to successfully address and overcome these safety issues to improve patient safety are discussed. The table below presents the most relevant research articles discussed in this study. The articles´ authors, the research topics, and main findings are listed in the table below. (Table 6.)

TABLE 6. Most relevant research articles selected

Authors	Title	Findings
Barakat, Sara & Franklin, Bryony Dean 2020	An Evaluation of the Impact of Barcode Patients and Medication Scanning on Nursing Workflow at a UK Teaching Hospital	Nursing activity and workflow was investigated on a ward where BCMA was not used and on a ward where BCMA was implemented. Findings showed that the length of the drug round stayed the same, but the administration time needed per dose decreased. Patient Id identification and scanning increased. There was less deviations from standard procedures and nursing workflows were more fluent.
Bjornstad, Camilla & Ellingsen, Gunnar 2022	Medication quality and work practice	The impact of closed loop medication management (CLMM) introduced in a Norwegian hospital was investigated. According to the findings, BCMA required more time in the scanning and dispensing process. Workarounds occurred. Some medications lacked barcodes. The system could not distinguish between automatic and manual barcoding. Improvements are needed regarding technology, policies, and evaluation of BCMA processes and workarounds.
Burkoski, Vanessa, Yoon, Jennifer, Solomon, Shirley, Hall, Trevor, Karas, Albert, Jarrett, Scott & Collins, Barbara E 2019	Closed-Loop Medication System: Leveraging Technology to Elevate Safety.	The study investigated the impact of BCMA/CLMS regarding the number of medication mistakes and adverse events. The results showed that BCMA led to a gradual reduction and CLMS led to an instant decrease in the numbers of medication errors and adverse events.

Connelly, Tim P & Korvek, Scott J 2021	Computer Provider Order Entry	CPOE design, workflows and functions are analysed. According to the findings, the system has the potential to support the clinician in decision making. Safety functions alert the user in case of drug-drug interactions, drug-disease interactions, or expired drugs. Testing, evaluation, and development of CPOE is essential to improve the system and patient safety.
Cummings, Joseph, Ratko, Thomas & Matuszewski, Karl 2005	Overview of Components involved in BCMA	The study described the steps of BCMA, and hardware and software elements needed for the processes which are presented in figure 4.
Dwibedi, Nilanjana, Sansgiry, Sujit, Frost, Craig P & Johnson, Michael L 2012	Bedside Barcode Technology: Impact on Medication Administration Tasks in an Intensive Care Unit.	The results showed that BCMA was more time efficient regarding medication administration, documentation and double-checks. There was more time needed for dispensing medications, assisting the doctor, and patient interaction.
Giraldo, Liliana, Schachner, Bibiana, Luna, Daniel & Benitez, Sonia 2018	Exploring Nurses´ Perceptions and Expectations Toward a BCMA Implementation Using a Mobile App and Workstations as a Change Management Strategy. Studies in Health	Nurses´ perceptions and expectations on BCMA were investigated. Several factors that impact the acceptance of BCMA were identified: the moving of the mobile station, the usefulness of the tool and the software, and the users ` great expectancy.
Hachesu, Peyman R, Zyaei, Leila & Hassankhani, Hadi 2016	Recommendations for Using Barcode in Hospital Process.	According to the results, 90% of the hospitals studied did not evaluate the changes that had to be made in the workflow processes due the introduction of BCMA. Staff was not educated about the international standards for

		barcoding (GS1). 80% of the hospitals did not consider coaching or finances, nor the demands for BCMA implementation. The researchers recommended to educate stakeholders and staff, to consider financing aspects, and the evaluation of work processes, and to establish policies.
Ho, Jackie & Burger, David 2020.	Improving medication safety practice at a community hospital: a focus on bar code medication administration scanning and pain reassessment	The study applied John Kotter`s model for change at a community hospital. Dashboards to support data transparency, and weekly meetings between stakeholders were introduced. Findings showed that BCMA scanning rates and pain reassessments improved and the rate of adverse drug events declined.
Holden, Richard J, Brown, Roger L, Scanlon, Matthew C & Karsh, Ben-Tzion 2012	Pharmacy workers' perceptions and acceptance of bar-coded medication technology in a pediatric hospital	According to the results, pharmacy workers perceived BCMA as not useful and the ease of use as low. Social influence to use BCMA was seen as important. Pharmacy workers had the intention to use BCMA, but they were not satisfied with the system.
Holden, Richard J, Brown, Roger L, Scanlon, Matthew C & Karsh, Ben-Tzion 2012	Modeling nurses' acceptance of bar-coded medication administration technology at a pediatric hospital	Based on the TAM model (by Davis 1989) nurses` perceptions and acceptance of BCMA were discussed. Nurses regarded the usefulness of BCMA as low and the ease of use as average. Nurses had a more positive attitude towards training and social influence to use BCMA.
Holden, Richard J, Rivera-Rodriguez, Joy A, Faye, Helene, Scanlon,	Automation and adaptation: Nurses' problem-solving	The impact of BCMA on nurses´ problem-solving behaviour was investigated. Three themes were

Matthew C & Karsh, Ben-Tzion 2012	behaviour following the implementation of bar-coded medication administration technology.	identified: nurses developed new methods to solve challenges; they created deviations to overcome an obstacle; new challenges occurred, and nurses could solve them with acquainted or new methods, or they could not solve the challenges at all.
Juste, Francoise 2018	Staff Education Module for Bar Code Medication Administration.	In the study an education program for staff using BCMA was developed to increase compliance with BCMA procedures and to reduce mistakes in the BCMA process.
Mulac, Alma, Mathiesen, Liv, Taxis Katja & Granas, Anne Gerd 2021	Barcode medication administration technology use in hospital practice: a mixed-methods observational study of policy deviations	The study identified bypasses from standard protocol which are related to nurses, tasks, technology, organisational factors, and policies. Environmental aspects such as the remote location of the drug room were also identified to lead to bypasses.
Ozturk, Eceberil, Kose, Ilker & Ozge, Beytiye 2020	Effect of Closed Loop Medication Administration on Drug Returns in Inpatient Facilities	The impact of CLMS regarding medication return rate was investigated. Findings showed that the number of drugs that were sent back grew and that documentation on the grounds for returns had improved.

Pandey, Pranjal, Pandey, Subhash Chandra & Kumar Upendra 2019.	Security Issues of Internet of Things in Health-Care Sector: An Analytical Approach	The authors discussed various security concerns such as spoofing, eavesdropping, replay attacks, and security architectures. Cryptography was presented as a solution to protect sensitive data.
Poon, Eric G, Keohane, Carol A, Yoon, Catherine S, Ditmore, Matthew, Bane, Anne, Levtzion-Korach, Osnat, Moniz, Thomas, Rothschild, Jeffrey M, Kachalia, Allen B, Hayes, Judy, Churchill, William W, Lipsitz, Stuart, Whittemore, Anthony D, Bates, David W & Ghandi, Tejal K. 2010	Effect of Bar-code technology on the safety of medication administration.	The findings showed that the BCMA/eMAR system reduced mistakes in the medication administration process and eliminated mistakes in the transcription process. The researchers concluded that the system is an effective tool to reduce patient harm.
Sakushima, Ken, Umeki, Reona, Endoh, Akira, Ito, Yoichi M & Nasuhara, Yasuyuki 2015	Time trend of injection drug errors before and after implementation of bar-code verification system	According to the results, BCMA has the potential to reduce medication errors. The system must be improved in reducing mistakes that occur during the preparation of drugs.
Staggers, Nancy, Iribarren, Sarah, Guo, Jia-Wen & Weir Charlene 2015	Evaluation of a BCMA's Electronic Medication Administration Record	The study investigated the BCMA/eMAR system of the Department of Veterans Affairs and recognised 99 usability issues, of which 15 were very serious. Issues included for example technical problems, interoperability, design, and interface issues.
Thompson, Kristine, Swanson, Kirsti M, Cox, Debra L, Kirchner, Robert B, Russell, Jennifer J, Wermers, Robert A, Storlie, Curtis	Implementation of Bar-Code Medication Administration to Reduce Patient Harm	Findings showed that BCMA minimises the rate of medication administration errors by 43,5%. BCMA helps to enhance patient safety.

B, Johnson, Matthew G & Naessens, James M 2018		
Truitt, Erin, Thompson, Ross, Blazey-Martin, Deborah, NiSai, Danna & Salem, Deeb 2016	Effect of the Implementation of Barcode Technology and an Electronic Medication Administration Record on Adverse Drug Events	The before-and-after study showed that the number of adverse drug events and transcription errors decreased after the introduction of BCMA/ eMAR. Patient safety could be improved.
Van der Veen, Willem, Taxis, Katja, Wouters, Hans, Vermeulen, Hester, Bates, David & van den Bemt, Patricia M.L.A. 2020	Factors associated with workarounds in barcode-assisted medication administration in hospitals	In the study bypasses from standard procedures were observed the most. These included omission of scanning, wrong scanning, or scanning of several medications and ID wristbands at once. Bypasses regarding administration of drugs included not giving the drug at all, giving a drug that was not prescribed, or giving the wrong dose.
Venkatesh, Viswanath & Davis, Fred D 2000	A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies	The TAM 2 model considered social influence and cognitive processes when investigating users´ attitudes towards new technology, and their intention to use it. Findings showed that aspects such as the tool´s importance for the job, the ease of use, peers, and the image of the tool impact the individual`s decision to use new technology.
Vehko, Tuulikki, Hyppönen, Hannele, Puttonen, Sampsa, Kujala, Sari, Ketola, Eeva,Tuukkanen, Johanna, Aalto, Anna-Mari & Heponiemi, Tarja 2019	Experienced time pressure and stress: electronic health records usability and information technology competence play a role	Nurses who used electronic health records experienced discomfort and time pressure due to the unreliability of EHR, and due to the design, which was not user-friendly. Lack of support and little experience regarding e-health added to emotional distress.

Yoo, Sooyoung, Lee, Kee Hyuck, Lee, Hak Jong, Ha, Kyooseob, Lim, Cheong, Chin Ho Jun, Yun, Jonghoar, Cho, Eun-Young, Chung, Eunja, Baek, Rong-Min, Chung, Chin Youb, Wee, Won Ryang, Lee, Chul Hee, Lee, Hai-Seok, Byeon, Nam-Soo & Hwang, Hee 2012	Seoul National University Bundang Hospital's Electronic System for Total Care	The Seoul National University Bundang Hospital has reached HIMSS Stage 7, it is a fully digitised hospital. Information technology is used to enhance patient safety. One example of the various systems is the closed loop system. The findings showed that verification of patient ID and medication barcodes via radiofrequency identification (RFID) technology helps to reduce patient harm and nursing workload, and to enhance care processes.

5.1 Barcode Administration System (BCMA)

The barcode system is an automatic identification and data capture system (AIDC). It has many possibilities for applications such as barcode medication administration (BCMA), and it is regulated by global standards. A regular set of information and information carriers is achieved by these standards. (GS1 healthcare.) The barcode system can be used in hospital pharmacies for stocking and dispensing medication. It can also be applied in connection with the electronic medication record (eMAR) which documents the medication administration in real-time and stores it automatically in the electronic health record (EHR).

The barcode medication administration system (BCMA) was developed by a nurse who worked for the United States Department of Veterans Affairs in Topeka, Kansas. In 1992 Sue Kinnick got the idea from the scanner of a rental care agency at an airport. Based on her experience in data processing she developed a safe solution to administer medication to Veteran patients and created a successful prototype. The Colmery-O`Neil Veterans Affairs Medical Centre in Topeka and the Eastern Kansas Healthcare System further developed Sue Kinnick´s idea. The development resulted in an automatic and wireless system that supports safe medication administration and enhances patient safety. The system validates the physician`s order, records medication administration in real time, and documents the process. According to Rivera (2020), by 1999 all medical units of the Veteran Affairs in the United States used the BCMA system. By 2002, medication errors in the dispensing phase were reduced by 86% and medication errors are still low due to BCMA (Rivera 2020).

To perform barcoded medication administration, a printer is needed to print out the patients´ wristbands. A scanner must be available to scan the barcodes of the wristband and the medication. Furthermore, a computer or mobile phone and the necessary software applications are required. BCMA uses barcodes which consist of machine-readable bars and spaces. Smartphones, optical scanners, or other devices, transform optical into electrical impulses. (EU*US eHealth Workproject 2020.) The aim of this technology is to minimise mistakes made by staff in the medication distribution process and to reduce patient harm through electronic documentation and validation. In healthcare, a barcode does not directly include health information, it contains the patient`s ID number. The number is encoded and then the patient´s information is retrieved. With the help of barcode wristbands, the patient is identified correctly, and the healthcare professionals receive accurate information about the medication order for the patient. Barcode wristbands are used in connection with computerised physician order entry (CPOE), automatic dispensing machines (ADMs), administration of medication, and performing tests (for example EKG or EEG), and blood transfusions.

Each drug in the hospital is labelled with a unique barcode. After the physician has ordered the drug via the electronic system (CPOE), the prescription is transmitted to the computer system of the hospital's pharmacy. The medication order is reviewed and validated by a pharmacist, who then delivers containers containing the barcoded dose of the drug to the patient's ward or to a smart medication room from where nurses take the medication when needed. Before the medication is administered, nurses use a handheld scanner connected to a mobile computer to scan the barcodes

on their identity card, the patients` wristband, the medication packages, and the individual units of the drugs. Barcode medication administration (BCMA) support nurses in identifying the patient and in providing the right drug. The barcodes of the patients´ wristband and the medication package are linked to the EHR where information on the prescription for the drug and administration orders are stored. Nurses are notified in case of any incongruencies which facilitates reduction of medication errors. (Zebra ZIH Corp 2018.)

The barcode used in healthcare is the "2D Data Matrix" bar code symbol which is two-dimensional (2D) and includes black and white patterns. The patterns are displayed in a square or rectangular matrix. (GS1). There are various types of barcodes on the market including the 2D Data Matrix barcode. (Figure 3.)

Table 1. Types of barcodes

Criteria	1D Linear	2D Data Matrix	2D Quick Response (QR)	UPC Code
Visual Appearance				
Primary Purpose	Reduce medication errors	Identify and trace certain prescription drugs as they are distributed in the US	Provide information (website, nutrition information, etc.) about the product to which it is affixed	Keep track of sales and inventory of retail products sold within the US and Canada
Contains (Minimum Requirement)	NDC	NDC, serial number, lot number, and expiration date	Not applicable	12-digit number that identifies the specific product
Requirement	Linear barcode required on nearly all drug products in the US	2D data matrix required on the smallest saleable package	Not required by FDA on product labels and labeling	Required for OTC items

FIGURE 3. Types of barcodes (Institute for Safe Medication Practices, ISMP 2017)

The 2 D Data Matrix is used in medication packaging. Prescription drugs are identified and traced with this barcode; and the barcode must be attached to the smallest saleable package. The barcode contains the NDC, a universal product identifier (National Drug Code; a 10- or 11- digit, 3-segment number), a serial number, lot number (identification number for a certain quantity or lot of material from the same manufacturer), and expiration date. (ISMP 2017.)

The BCMA application interacts with electronic health care records, EHRs. EHRs are a secure system which contains confidential information on the client´s health history. EHRs rely heavily on manual input and only authorised users are granted access to the EHRs. In the hospital setting, the nurses use the EHR to monitor, coordinate, and provide care. They create qualitative data as written text or fill in quantitative data to document measurements, and they store, and manage information in the EHR. The health data can also be shared with other providers and organisations that are in a care relationship with the patient. Data on allergies, medication, laboratory results, medical imaging results, blood pressure, sugar levels, admission and discharge texts among others can be found on the EHRs. (HealthIT.gov 2019.)

In BCMA, documentation of the process is made at the patient´s bedside. If the medication cannot be connected to the medication order or to the patient because it is the wrong medication, the wrong patient, or the wrong time, the system alerts the nurse visually on the mobile computer at the patient´s bedside. All steps of the BCMA are electronically stored and errors in the procedure such as "missed medication warnings" alert nurses and pharmacists that a medicine has not been administered. The pharmacist investigates the request and dispenses the medication if the request was appropriate. Drug errors can take place at some point in the process of barcoded medication administration which include the prescription, transcription, dispensing, administering, and monitoring process.

The picture below describes the components required for a barcode medication administration system, which include hardware and software elements (Figure 4).

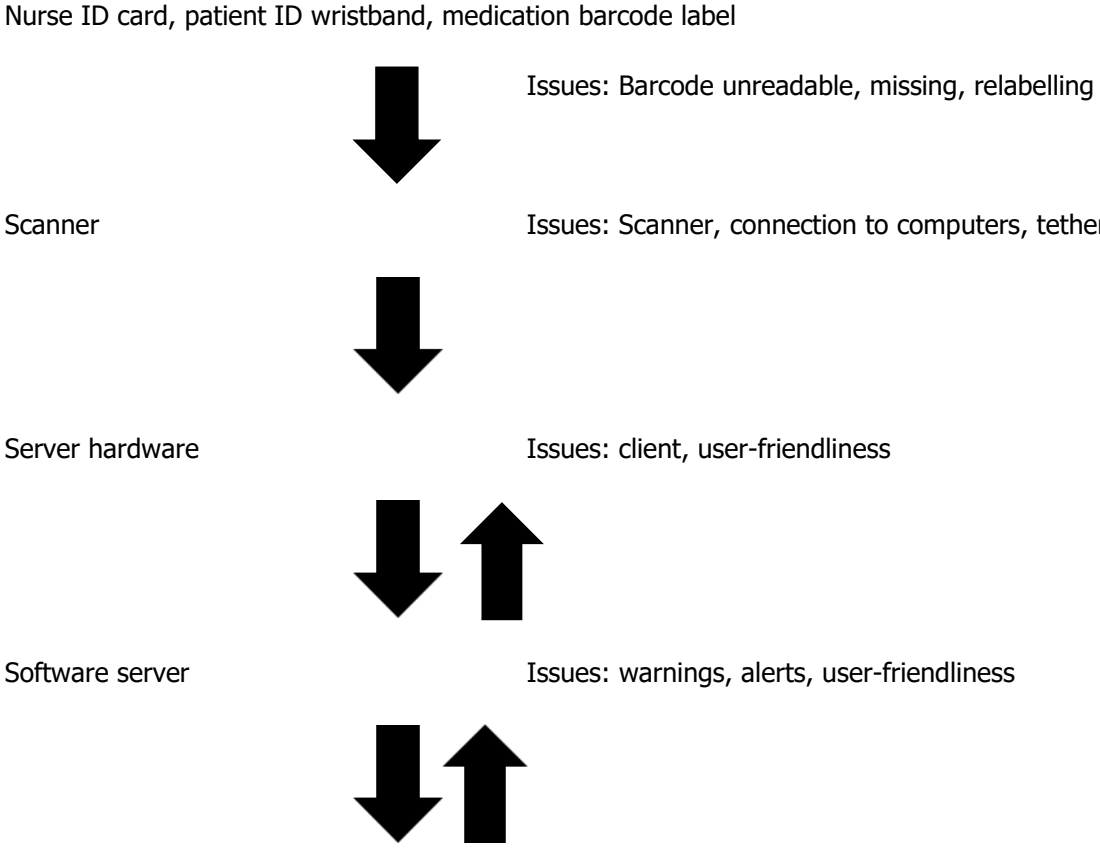

FIGURE 4. BCMA hardware and software elements (Cummings, Ratko & Matuszewski 2005)

The elements needed in BCMA are the nurse´s ID card and the patient wristband, the medication barcode label, the scanner, the hardware, and software server to store, manage and process the data, and various information systems. (Figure 4.) BCMA includes the nurses, patients, and the medication barcode printing system. The medication administration steps are performed by the nurse. They include scanning of his or her ID card, the patient´s ID bracelet, and the drug´s ID barcode by using wireless bar-code scanners. A wireless communication network connects the data scanned at the patient´s bedside to a centralized server. In the centralised server, the data is processed by software applications and displayed in the mobile computers at the patient´s bedside. Other related systems are also integrated, for example the information systems of the hospital, the hospital drugstore, and test centers. Problems may occur at any step in this process. Barcode

issues, scanner issues, client issues, and server/application issues have all been identified in research as potential problems. (Cummings, Ratko & Matuszewski 2005.)

Seoul National University Bundang Hospital opened in 2003. It is a fully digital organisation which is equipped with the Best Care System. This system includes various smart technologies, such as the drug administration system that is developed further to a closed-loop system, systems that manage, exchange, and restore data, and that support analytics. The Barcode medication administration system is used in this hospital, but radiofrequency identification (RFID) has replaced barcode scanning. The figure below describes the process of medication administration with radio frequency identification.

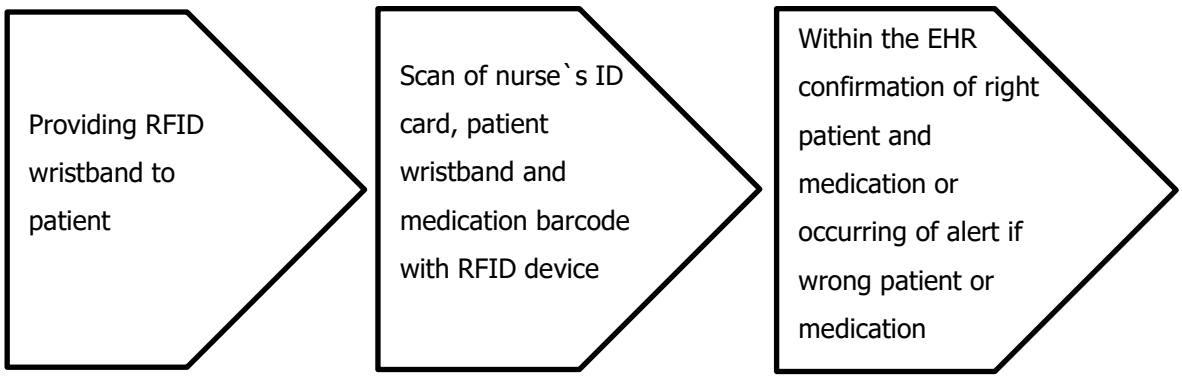

FIGURE 5. The process of BCMA using radio frequency (Yoo, Lee, Lee, Ha, Lim, Chin, Yun, Cho, Chung, Baek, Chung, Wee, Lee, Lee, Byeon, Hwang 2012, 150).

RFID systems (radio frequency identification systems) consist of devices which send radio waves at various frequencies to the RFID tag and then receive signals from the RFID tag. RFID wristbands are printed out and provided to the patients. The nurse scans his or her ID card and the patient´s wristband with the RFID device. The information is transmitted to the electronic health record (EHR) for further verification of the right patient and the right drug. If the patient´s ID and the scanned medication do not match, the system gives a visual and audible alert. (Figure 5.). For example, in the Seoul National University Bundang Hospital health information is transmitted via these radio waves using radiofrequency identification (RFID) technology. As the doctor prescribes the medication, the barcodes are attached automatically to the unit dose medications. The attachment is made by a machine which counts the medications automatically (ATC). A container with the relevant barcoded medication is automatically transported to the ward. No manual steps are required. At the point of admission to the hospital, bracelets with an RFID tag are attached to the patients` arms and scanned before medication is administrated. Additionally, the prescribed drug is scanned to validate the safe administration process. Through the system it is confirmed that the correct medication is given to the patient, at the scheduled time. The health data is transmitted to the electronic health record in real-time to check whether it is the right medication and the right

patient. In case of mismatch, a visual alert occurs on the nurses´ mobile computer. Through automatisation, the process of giving drugs is improved by reducing administration errors and by reducing nurse workload because there is no need for manual documentation anymore. (Yoo, Lee, Lee, Ha, Lim, Chin, Yun, Cho, Chung, Baek, Chung, Wee, Lee, Lee, Byeon, Hwang 2012, 150)

5.2 Factors that impact safe BCMA implementation

Sittig & Singh (2010) developed a design based on social and technological elements for exploring factors that impact tools and systems which process health data. This conceptual model has been developed further from existing models and describes eight dimensions that discuss problems associated with the outline, advancement, use, and analysation of smart technology such as the Barcode Medication Administration System. Sittig et al. (2010) suggested that to better study the health information technology in focus, researchers need to regard these eight aspects as a complex system, as interconnected, and they should not be addressed and discussed independently.

According to Sittig et al. (2010), the first dimension "Hardware and Software" includes software and tools. The second area describes the "Clinical Content", such as written text, numbers, images, unstructured text, or certain vocabularies to order medication or tests, description of patient`s condition, admission text, dismission text, laboratory results. The third aspect addresses the interface, which allows the interaction with the system. The fourth dimension discusses "People", users of the system which include nurses, doctors, pharmacist, patient, designers, developers, people who implement and evaluate the system. The fifth area describes "Work-flow and Communication", the collaboration of healthcare professionals with other professionals and the adoption of the system to integrate to the workflow, or the adoption of the workflow to the system. The sixth aspect includes "Internal Organisational Features", such as management decisions acquirement of new tools or applications, on IT regulations, procedures, surveillance, and evaluation. The seventh area is associated with "External Rules and Regulations", for example external forces that support or compromise health information technology. The last dimension addresses "Measurement and Monitoring" of health information technology (HIT). HIT must be monitored regarding the availability of features and functions (monitor how often healthcare professionals override alerts), the outcomes of HIT regarding services, the patient´s wellbeing, and unplanned events. (Sittig et al. 2010.)

Sittig`s et al. (2010) eight dimensions model can be adopted to investigate elements that impact the secure use of BCMA and patient safety. In academic literature, numerous studies applied various approaches to discuss smart technologies and patient safety. Numerous academic articles address technological factors including hardware and software problems, such as scanning problems which include medication packages without medication barcodes, fainted or partly destroyed barcodes problems with batteries, interoperability, and network.

Social factors were also identified as risks to BCMA systems` successful implementation. When problems did arise, nurses typically created new workflows to overcome the issue so they could continue the medication administration process. Sometimes difficulties in barcode systems forced

nurses to skip steps, to perform steps not following guidelines, or to create shortcuts in the procedure of giving drugs.

Social and organisational factors were discussed that contribute to the safe implementation of smart technologies such as BCMA. These elements include for example the pharmacy, the hospital setting, the ward, and the nursing unit. Security issues have also been identified as a risk to the successful introduction of smart technologies, including BCMA. Factors that impact the implementation of BCMA and patient safety are interconnected and overlapping. For example, workflow-related factors include technical and social aspects, but also organisational elements, such as guidelines, infrastructure, processes, and training.

To achieve a clearer picture of the influencing factors on BCMA the author applied the technical and social-organisational model with some modifications. The social-organisational aspect was again divided into "social factors" and "organisational factors". The author illustrates the main factors that impact safe BCMA implementation recognised in literature. (Table 6.)

TABLE 7. Factors that influence the safe implementation of BCMA

Technological factors	Technical factors, usefulness, ease of use, compatibility, interconnectivity, integration, design, convenience
Social factors	User-related, attitude, perceptions, peer influence, awareness and expectations, user engagement, workflow-related
Organisational factors	Culture and context, policy and regulations, economic factors, workflow related

The technological theme was divided into sub-themes that could be recognised in the data gained from the academic articles which were selected during the literature review. These sub-themes are described further in more detail. Under the main theme "Technological Factors" six sub-themes that impact the successful implementation of BCMA were identified, "Technology" (problems, support, reliability, connectivity), "Usefulness" (benefit, performance, expectancy), "Ease of Use" (effort, usability), "Compatibility" (interoperability, computerised physician`s order entry (CPOE), electronic health record (EHR), and electronic medication record (eMAR) integration), "Design" (layout, appropriate design for organisation, patient-centered), and "Convenience" (mobility and flexibility).

Within the main theme "Social Factors", five sub-themes were identified and classified as "Patient-Related" (quality and efficiency of care, providing patient communication, access to care, patient

consent, comfort and preference, applicability and appropriateness, empowerment and engagement, safety, education), "Perceptions and Peer Influence" (how users perceive technology, peer influence, endorsement), "Awareness and Expectations" (lack of awareness and promotion, high/low expectations), "User Participation" (participation of user in creation and implementation of technology) and "Workflow -Related" (skills and experience in technology, roles and responsibilities, leadership support, collaboration, and cooperation).

From the main theme "Organisational Factors" four sub-themes were extracted based on academic articles selected during the literature search. The sub-themes identified are classified as "Organisational Culture and Context" (hospital, ward related, support), "Protocols and Guidelines" (privacy, security, matters of law, clear guidelines, protocols, and policies), "Economic Factors" (funding, reimbursement, fees, tool´s cost), and "Workflow- Related" (training, workload, workflow, infrastructure, process standardization and planning, changes to clinical practice, decision-making).

The following chapters discuss the most relevant technical, social, and organisational factors and put them in relation to academic literature.

5.2.1 Technological factors

Technological factors include technology, usefulness, ease of use, compatibility, design, and convenience. Research studies have been performed to identify technological challenges related to barcode medication administration by investigating usability problems. A study on barcode medication administration (BCMA) and electronic medication record (eMAR) usability problems was conducted in a hospital managed by the US Department of Veteran Affairs in the Western U.S. (Staggers, Iribarren, Guo & Weir 2015, 899-921). The method used by the researchers was a "heuristic evaluation". Using this evaluation method, usability experts analysed the BCMA application by observing typical user tasks to find problems and then rank the problems according to heuristic categories. The study identified 99 usability problems of which 15 were categorised as major. Usability problems were categorised in chart medication, medication preparation, and screen design. An example of "chart medication issues" involved updating the system via the refresh button. If locked into the system, the refresh button had to be clicked constantly, or the nurse using the system had to exit out and re-enter to remain up-to- date and not miss new medication orders. Medication preparation issues included missed drug reports and organisational difficulties related to medication administration. Issues concerning the screen design included difficultly accessing key information and a poorly organised drug list. (Staggers et al. 2015, 899-921.)

Another technical factor which compromises the successful use of BCMA is the reliability of the system. In case of irregularities in medication administration, the system is blocked. If nurses forget to document that they have given the drug to the patient, nurses of the following shift cannot proceed with BCMA. The system is stopped and requires the documentation of the medication, which was due in the previous shift, before the current drug can be given. Pharmacists must be contacted for support, and this takes time, and the medication administration is delayed. (Holden, Brown, Scanlon & Karsh 2012, 509-522.)

In several academic articles connectivity was discussed to be an essential factor that hinders the safe implementation of BCMA. During a research interview, nurses express the problem of wi-fi connectivity. In some patient rooms, the wi-fi signal is lost or not good. The application cannot be accessed at all, or the process cannot be continued because the system is stuck. Problems in functionality of the BCMA impacts the nurses 'workflow. (Giraldo, Schachner, Luna & Benitez 2018, 134-138.)

New technology aims to be smoothly integrated with the nurses´ workflow, but there are some interruptions in workflow which may contribute to nurses` negative perception of the system. In the study by Giraldo et al. (2018) two main elements were identified by applying the "Technology Acceptance Model" developed by Fred D. Davis (1989), "perceived usefulness" and "perceived ease of use".

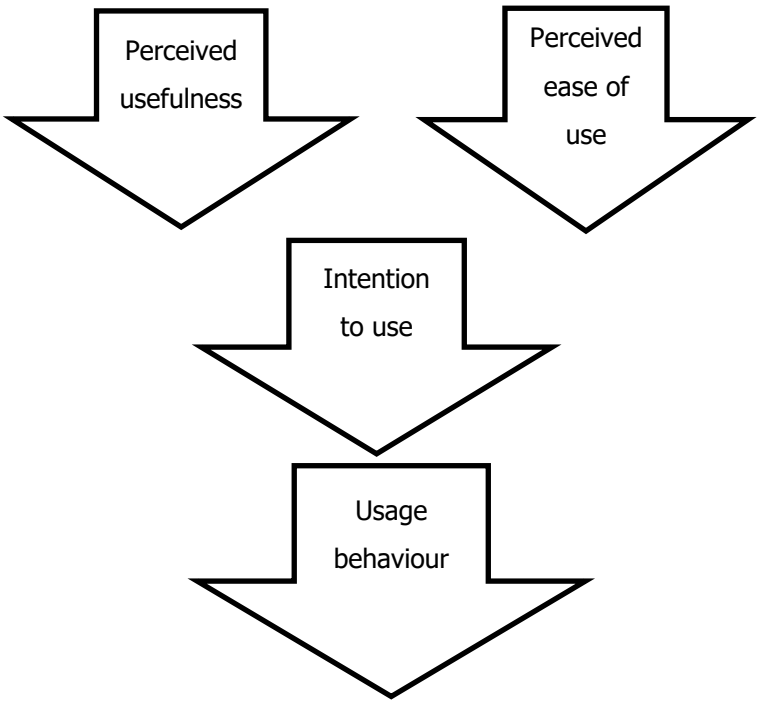

FIGURE 6. Technology Acceptance Model (Venkatesh and Davis 2000, 188)

The model presented in Figure 6 describes "perceived utility" and "perceived ease of use" as the two main factors that have an impact on how users accept and implement new technology. Davis` model (1989) suggests that users acquire an application mainly because it is useful for them to perform better at work and not so merely because it is easy to use. Perceived usefulness is an essential aspect whether the user understands, accepts, and uses the system or not and contributes to the successful implementation of the system. (Davis 1989, 333.) Social and cognitive factors impact user acceptance; healthcare professionals` expectations, benefits of BCMA and an improved

work performance affect the persons´ intention to use the system. If the system meets the users´ expectations, they are more likely to adhere to the correct implementation of BCMA. Venkatesh & Davis (2000) developed TAM further and proposed TAM 2. It is a theoretical extension of TAM by integrating social and cognitive aspects, such as whether the use of technology is voluntary, or whether it is useful in the job. (Venkatesh et al. 2000, 187).

Truitt, Thompson, Blazey-Martin, NiSai & Salem (2016) conducted research on the impact of a BCMA and eMAR combination associated with medication errors. The study was performed in an academic medical hospital in New England. The integration of the electronic medication record (eMAR) into BCMA took place in 2009 and 2010. The eMAR application was used by the pharmacy and nursing informatics from 2008 to 2010. Adverse drug events were analysed posteriorly using incident reports written five months before and five months after implementation of BCMA and eMAR. Nursing wards that introduced BCMA and eMAR after 2010 were not selected for the study. Results of the study suggested that the reported drug error rate was reduced by 20% after the combined BCMA and eMAR implementation. A significant reduction (60%) of transcription errors, especially "wrong time" errors was observed. Truitt et al. (2016) concluded that this decrease may be due to improved cooperation and communication when combining BCMA and eMAR. The number of administration errors stayed the same. Before the introduction of BCMA, mistakes were not identified or reported as frequently. After the implementation of BCMA, errors in medication administration were detected more effectively which led to a higher number of drug error reports, and therefore it seemed that the incidents of medication administration errors did not decrease after BCMA was used. Based on the findings of the study the researchers concluded that BCMA helped to reduce mistakes, especially in the transcription phase. The system also supported the detection and reporting of errors that occurred during the process of BCMA. (Truitt et al. 2016)

Holden, Brown, Scanlon & Karsh (2012) examined nurses´ acceptance of BCMA. The study was conducted in 2008 in a child`s hospital in the Midwestern United States. Data was gained via observation of the interaction between nurses and the BCMA system, and through interviews in 2008. The "Work System Analysis" was used as a method to collect information about the participating nurses, nursing tasks, technologies, the hospital, and the environment to assist the gathering of contextual data during observations. Information was collected in a child`s intensive care ward, a blood disease/cancer ward, and a medical-surgical ward of the pediatric hospital and written on paper. The handwritten notes were then transcribed and categorised into episodes of problems and solutions associated with BCMA and further analysed. The researchers identified 313 situations where nurses showed problem solving behaviour. 89 situations were associated with problem-solving behaviour during the process of barcoded medication administration. Holden et al. (2012) observed three themes: Nurses who used BCMA created new ways to overcome obstacles; BCMA hindered nurses and they used well-known actions to solve issues, and BCMA created new challenges.

Several episodes of "BCMA - associated new problem-solving behaviours" were identified by Holden et al. (2012). After the implementation of BCMA, nurses did not have to search for certain medications through a long paper medication record, but they could electronically sort medications

by name. With BCMA, nurses could determine when the medication was given based on the electronic medication administration documentation. BCMA allowed nurses to check whether a medication can be given by scanning the medication`s barcode. The system allowed medication administration only at the prescribed time. Before the use of BCMA nurses had to check for example the medication administration history, the administration schedule, and rules for adapting administration time.

Also, episodes of "BCMA blocked familiar problem-solving behaviour" were discussed by Holden et al. (2012) Before nurses started to use BCMA, they had created individual ways to solve certain problems. After the introduction of BCMA, these behaviours were no longer needed. To solve a certain problem, the staff had to develop new solutions in the situation, which did not comply with the BCMA standard procedures and may have impacted patient safety.

Episodes of "BCMA introduced new problems" included the occurrence of new challenges after the BCMA system had been implemented. The system was supposed to be fully electronic, but paper was still used by staff to complement BCMA and to document medication administration. Another issue concerned the scanners. Because it took a long time to load and sign in, nurses turned the scanners on early and stored them somewhere until they were needed, for example on a table or in their pockets. These actions did not comply with the organisation´s standard procedures. Furthermore, staff who experienced difficulties documenting missed drug doses, delayed drug administration, and medication not scanned, used a feature in the application to report these discrepancies. Nurses tried to overcome new problems that came with the use of BCMA by developing alternative nurse activities to avoid or to solve the challenges. This behaviour resulted in working around the common procedure, in workarounds.

The study by Holden et al. (2012) identified design problems by observing and analysing the users´ problem solving behaviours and workarounds to find solutions to the problems. The challenges included technical issues such as barcode scanning inability caused by the barcode label being un-readable, failure to log into the system, or a complete system breakdown. Holden et al. (2012) observed that nurses did not scan the barcode label of the patients´ wristbands but scanned the barcode label printed on a piece of paper which was against the standard procedures of BCMA. But to scan the barcode label printed on a sheet of paper was an effective strategy for solving the issue of the scanners´ too short tethers. Holden et al. (2012) suggested that the problem may also be solved by providing longer cords, adapting patient rooms to be compatible with the cord, or using wireless scanners. Furthermore, Holden et al. (2012) observed that the design of BCMA focuses on the medication aspect only. Other information concerning the patient´s nutrition and laboratory works such as blood samples which affect medication administration schedules was not included in the BCMA system. Holden et al. (2012) saw this as a weakness in the design of BCMA that has an impact on the successful use of BCMA.

Giraldo et al. (2018) investigated nurses` perceptions and expectations regarding the convenience in the use of BCMA and the challenges that occur. The study was conducted on five internal medicine and children´s wards at the Italian Hospital in Buenos Aires, Argentina. Data was gained by interviewing nurses who use BCMA. Mobile stations and accessories as part of the BCMA system

were assessed regarding interaction and functionalities. Staff found the mobile stations as easy to use, comfortable, adjustable to the user`s height, and practical. But nurses also experienced many negative factors, for example the bulkiness of the mobile station, and space problems in corridors and in patient rooms. The length of the scanner`s cable and the short life of the tablet´s battery were also problems in the implementation of BCMA. The mobile station had to be connected to the electric current often and could not be taken to the patient room. Nurses were asked about their perceptions of the mobile application of the barcode system. Negative factors were the impossibility of recording the administration of nebulisers, of correcting the insulin doses, and of documenting certain multidose medications such as eye drops, and oral suspensions. The process of giving drugs on the patient´s demand, or if clinically necessary was perceived as challenging. The medication was scanned and registered using the mobile application. But if scanning was not available, the desktop version was used to document the process. (Giraldo et al. 2018, 135 -137.)

The design of the BCMA system has been identified through a research study by Bjornstad & Ellingsen (2021, 673-683). The researchers investigated barcoded medication administration using the closed-loop system at Kalnes hospital in Norway. If for example one gram of a certain tablet was not available in the medication room, the nurses needed to dispense two 500-milligram tablets and document that they had prepared two tablets instead of one. Limitations in the system allow scanning for the same medication order only once, thus the nurse must manually document that she dispensed two tablets. A drug which combines two active agents can also be prepared as two separate tablets with each tablet including one active agent. They BCMA system does not allow scanning twice, so the nurse documents manually the change in medication dispensing. (Bjornstad et al. 2021, 678).

5.2.2 Social factors

Social factors include patient-related, attitude, awareness and expectations, user engagement, workflow, and workaround related factors.

Holden et al. (2012) who investigated the nurses´ problem-solving behaviour in the children`s intensive care unit, in the blood disease/cancer ward, and in the medical- surgical ward at a child`s hospital in the Midwestern of the United States, looked at changes observed in nurses´ problem - solving behaviour after the introduction of BCMA. As discussed in this thesis under the topic "technological factors", the researchers observed that BCMA led to new challenges to which nurses responded in three different ways: nurses responded to difficulties using their former methods, they responded to obstacles with workarounds, or they could not solve the problem. Holden et al. (2012) stated that the BCMA´s design did not include all health data needed for a safe medication administration. The researchers observed that nurses compensated by developing new steps in the BCMA process to retrieve and add the missing information. For example, they used paper sheets to add the missing data to enhance the incomplete BCMA system. The handwritten data had to be transcribed into the BCMA system afterwards.

In numerous research articles, nurses´ expectations, and acceptance of BCMA were investigated by using interviews or questionnaires. A study was conducted in several hospitals in Amhara in Ethiopia

by using a questionnaire to gather data on the healthcare professionals´ willingness to adopt new technology. (Kalayou, Endehabtu & Tilahun 2020, 1827-1837) The study used Davis´ "Technology Adaption Model" (TAM) which serves as a tool to investigate how users receive novel smart tools by examining the aspects of how much effort they must put into adopting the tool and as how useful they perceive the tool. Kalayou et al. (2020, 1827-1837) concluded that the TAM model can be applied to investigate a person´s intention to implement new smart technologies. Attitude towards smart technology was the most essential factor to predict whether a user intends to implement the technology or not.

The study by Giraldo et al. (2018) also determined that older nurses typically faced challenges in the implementation of the BCMA due to negative perceptions and resistance to change. Nurses were frustrated due to problems with the application, for example software bugs which hindered them from performing the BCMA process, due to difficulties in scanning the patient´s bracelet barcode, or the drug, and due to lack of time. They could not solve these issues instantly and had to request support, and this is time consuming. The nurses´ negative experience with and their perception of BCMA fundamentally impacted the BCMA system´s ability to minimise medication administration errors.

According to research nurses experienced additional emotional stress and increased mistakes when learning to implement a new technological system. This emotional stress led to disruption in their workflow. In 2017 a national research study with focus on EHR use in Finland found out that nurses reported high time pressure if the application was not reliable and less user-friendly. (Vehko et al. 2019). Nurses who had low IT skills also experienced more time pressure and they were psychologically distressed due to unreliable technology, low support, and low IT skills. In the study unreliability meant that the system was not stable, got stuck, or was slow in responding to commands. User-friendliness meant that users could find data effortlessly and that they could document information easily. (Vehko et al. 2019). Stress-factors included interruptions while documenting patient care, technical difficulties such as the breakdown of the network or the computer, challenges with signing-in, the requirement to sign-in separately for various systems, and the need to use multiple programs at the same time. Other issues were associated with an inaccurate medication documentation. Time was also a factor which caused stress. Healthcare professionals who were under time pressure documented care and patient data in abbreviated and potential unsatisfactory manner (Vehko, Hyppönen, Ryhänen, Tuukkanen, Ketola & Hepo-niemi 2018.)

Some studies also discussed the pharmacists' perceptions of BCMA using the "Technology Acceptance Model" (TAM). Holden, Brown, Scanlon & Karsh (2012) aimed to assess the association between how users regard and receive BCMA. Professionals who work in hospital pharmacies were asked to describe their perceptions and acceptance of BCMA. Data from twenty-nine pharmacists and ten technicians after the implementation of BCMA at a Midwest US pediatric hospital was collected. The study applied the TAM model developed by Davis in 1989 which aims to better predict and explain the users´ intention to implement new technology. (Davis 1989, 320.)

The results found by Holden et al. (2012, 509-522) showed that pharmacists and technicians did not see BCMA as a useful tool to improve patient care or job performance. Pharmacists complained that BCMA implementation was time-consuming. Each unit-dose of the medication had to be equipped with a barcode. If the physician changed the recommended dose of the drug, new labels had to be reprinted. In the study by Holden et al. (2012, 509-522) another issue addressed the timing of medication. Drugs were delivered to nursing units once every hour. Sometimes the doctor changed the time when the medication must be given. In these cases, the pharmacist had to select an appropriate time for the drug administration considering the hourly delivery time from the hospital drugstore to the ward. If the new time selected did not fit into the nurses` workflow, they would ask the pharmacists to change the time again in the BCMA system. Before the implementation of BCMA, nurses gave the drug as soon as possible after the drug order change and documented its administration. With BCMA a medication administration which was not performed at the correct time was marked as "missed dose".

Holden et al. (2012) observed issues that lead to additional work for pharmacists. Before introduction of BCMA, healthcare professionals could use paper sheets to record medication administration to patients in critical conditions. Using paper sheets for documentation was faster than electronic documentation. In critical situations, physicians often gave the medication order verbally. No further additional electronic documentation was required. After the introduction of BCMA, if nurses administered medications without an electronic order and documentation as it often occured when patients were in critical conditions, pharmacists had to document the drug order, dispensing, and administration afterwards. This required additional steps. In this situation, pharmacists ordered the medication afterwards electronically, scanned it, and discontinued the order because the drug was already given.

Another study by Bjornstad & Ellingsen (2022, 677) emphasizes that hospital pharmacists needed more resources since the BCMA/closed loop system was implemented. A semi-automated packaging system is used in Kalnes hospital in Norway, but manual steps were still needed. As described in the study by Bjornstad et al. (2022, 677), pharmacists had to manually open the drug packages to put barcode labels to the units, and then repack them again. The medication cartons had to be reorganised manually because BCMA system only accepts single dose medication. According to the study his process required more time and resources and included higher risk of mistakes.

A study was conducted by Mulac, Mathiesen, Taxis & Granås (2021, 1021-1030) in 2017 to observe the process of barcode medication administration in two hospital wards for three years. Information was collected through structured observation to gain insight of the number of BCMA procedure deviations, and through data from nurses´ opinions and through observation records to gather descriptions and explanations for the deviations. Nurses participating in the study worked on two medical units at a Norwegian hospital. Numerous deviations from the BCMA policy were identified. Deviations were described as task, organisation, technology, environment, and nurses – related. (Mulac et al. 2021). The highest percentage of task- related policy discrepancy took place during the dispensing (66%) and administration phases (71%). Other task-related policy alterations happened due to problems with scanning the barcode, therefore nurses did not scan 20 % of the patient

wristbands. Workarounds were also influenced by organisational factors which included vague description of policies, users´ unawareness or non-adherence to hospital´s policies, and practices not adopted to nurses` workflow. Deviations from standard procedures were also affected by technological aspects, such as hardware and software, inefficient design, improper charging of devices, no wireless or mobile scanners available, and environmental factors. For example, the patient rooms were located too far which led to a delay or an omission of medication, and some drugs were randomly stored in the drawers of nursing stations which increased the risk of mixing-up drugs. Drawers were too small for all medications needed, and therefore some drugs were left in the medication room. Nurse-related factors such as work experience, social influence, nurses who always use BCMA, nurses who use BCMA only partially or not at all, had also impact on nurses´ workaround. In this study, the BCMA system was used in only 50% of all observed medication administrations according to the organisation´s policies. Workarounds from standard procedures occurred the most during the dispensing phase. (Mulac et al. 2021)

5.2.3 Organisational factors

These factors include the organisation´s culture and context, policy and regulations, data security, economic factors, the organisation´s strength such as management, teamwork, quality of training, and quality of clinical evidence such as reporting systems of drug errors, workload, workflow, and workaround related behaviours.

Sakushima, Umeki, Endoh, Ito & Nasuhara (2015) analysed incident reports that were given voluntarily and were electronically stored at the Hokkaido University Hospital, Japan. These records contained various types of errors, such as falls, drug errors, or unpreventable complications. Sakushima et al (2015) analysed incident reports concerning medication mistakes that occurred between April 2003 and March 2012 further. Errors included wrong drug or patient, wrong time, or wrong route. The BCMA system for injection drugs was implemented in the Hokkaido University Hospital in April 2008. The impact of BCMA was evaluated by examining results before the introduction of BCMA between 2003 and 2007 and after the implementation of BCMA between 2007 and 2008. The results showed that mistakes associated with wrong medication and wrong patient were reduced by 40% after the BCMA system was introduced. Wrong patient errors were clearly reduced, but wrong drug preparation errors were not lowered so significantly. Reasons for wrong medication preparation were for example dispensing errors and confusion related to similar drug names. Sakushima et al (2015) emphasized that due to the introduction of the BCMA system, injection drug administration errors were reduced significantly, but mistakes in medication preparation still occurred. The researchers stated that at the time of the study the drugs were dispensed and prepared by nurses in the ward, and not by hospital pharmacists.

Dwibedi et al. (2012, 360-366) conducted a prospective pre-post time - and - motion study in a critical care unit in a highly specialised hospital. Data on paper-based medication administration (PBMA) was gathered by assigned data collectors in 2008 for one month. The researchers calculated the time nurses needed to perform and to document medication administration when using paper-based medication administration (PBMA). Data on BCMA was collected by trained data collectors in 2009 for nearly two months, 10 months after the implementation of BCMA. The time for

administration and documentation was measured and compared to the time taken when using paper-based procedures. Watches used to perform the measurements were calibrated. The total time for medication administration was counted from when the health professionals entered the patients` room to give medication to the patient, to when they left the patients` room again after the medication was administered. The results of the study by Dwibedi et al. (2012) provided evidence that BCMA helped staff to perform tasks more time- efficiently. The time spent on medication administration documentation was reduced when using BCMA.

Barakat et al. (2020) examined how BCMA affects the nurses´workflow and activities by conducting a study on two wards. Nurses who work in a London hospital on a gastrointestinal surgical ward unit where BCMA was implemented four days before the study, and nurses who work on a vascular surgical ward where no BCMA system is used, were observed, and the results were compared. Data was gained through direct observation of ten medication administration rounds at 8 a.m. in both surgical wards. The researchers observed the duration of drug rounds, patient identification, medication verification, workflows, and activity. In the study activities were defined as the nurses` walking patterns which were analysed using a spaghetti diagram which is a visualisation of the staff`s moving activities when performing tasks associated with medication administration. The findings suggesedt that patient identification rate increased from 74% in the non-BCMA ward to 100% in the BCMA ward and that 95% of the drugs were verified through BCMA. In the ward where BCMA was used, 87% of the medication was labelled. In 6% of the scanned drugs a visual alert occurred which indicated an error. In the ward where no BCAM was used, the spaghetti diagram showed that nurses spend more time moving between the patients´ rooms and the medication room. In the BCMA ward, staff´s walking patterns suggested that nurses had walked more frequently between the patients´ beds and less unnecessary activity in the drug room was observed. Workflow was identified as being smoother. According to the results gained by Barakat et al. (2020) the introduction of BCMA did not decrease the time spent on the medication administration process. The system did not change the length required for medication administration in overall, but it reduced the time spent on giving one dose.

Several studies investigated factors which lead to modifying the process of barcode medication administration by nurses. The three-step method to analyse and improve the BCMA process was applied in these research studies. The methodology "Prevent, Identify-and-Mitigate, Redesign" was developed by the Institute of Healthcare Improvement (IHI) which is a charitable organisation that aims to enhance wellbeing and services globally. IHI´s strategies include the acceleration of change, cooperation with health organisations and communities across the world, facilitation of global meetings and trainings, and sharing of knowledge, ideas, and practical tools. (IHI org 2022.) Van der Veen, van den Bemt & Wouters (2017) applied the IHI model to internal medicine and surgical wards in four health organisations in the Netherlands. The study gained approvement through the ethical committee. The participants` right of privacy was ensured by coding the study data. All four hospitals had implemented the barcode administration system, BCMA and the computerised physician´s entry system, CPOE. Due to differences in the software packages, procedures on barcoded medication administration varied between the hospitals. For example, in some hospitals surgical patients who stayed only a short time in the hospital were not provided with ID bracelets.

These were connected to the drug trolley. Data was collected from 6000 medication administrations between 2014-2016. Cases with one or more mistakes in the process of BCMA were included in the study. The researchers examined the number and the kind of workarounds and drug administration mistakes, and possible liabilities regarding inconsistencies in nurses´ activities. In the context of giving drugs, nurses performed workarounds when they bypassed a task due to an obstacle to administration of medication. The study was conducted as disguised observation performed by three trained undergraduate students from two Dutch universities and a pharmaceutic school. To prevent nurses changing workflow or behaviour, they were told that the system of medication distribution will be monitored. The gained data was reported into a repository which included case report forms for observational data on workarounds, medication administration errors, and possible liabilities associated with inconsistencies in nurses´ activities. (Van der Veen et al. 2017.)

The researchers observed 6021 medication administrations of which 228 were not completed and therefore not included in the study. 5793 drug administrations were included for further analysis. (Van der Veen et al. 2020.) In 62.7% of these cases the nurses deviated in their activities from the organisation´s policies. The time and the day when they gave drugs to patients had a significant impact on workarounds. Medication administration rounds in the afternoon shift between 14:00 and 18:00 o´clock and in the evening shift between 18:00 and 22:00 o´clock showed more deviations from standard procedures than the ones in the morning shift from 06:00 to 10:00. On Mondays, Wednesdays and Saturdays, nurses had more workload than compared to Sundays, for example. Therefore, more workarounds occurred on these days. The researchers observed that the most common errors in bypassing the organisational protocols were inconsistencies in procedures, such as the omission to scan the barcodes (36%). Other deviations were identified as omitting to verify the patients` ID because ID bracelets were not provided or attached to the patients´ wrists (28%). Some nurses verified the patients´ ID before actual drug administration, some nurses scanned several patients´ wristbands at the same time and overrode computer or scanner alerts (11%). The percentage of medication equipped with barcode labels and the staffs´ work experience did not impact workarounds. The study concluded that the factors which compromise successful barcode scanning such as not scanning at all, no wristband available, the patient-nurse ratio, time, and day of drug administration, must be addressed and processes must be redesigned to achieve higher scanning rates and to reduce workarounds. Less influencing factors included the type of nursing unit, how many nurses had to care for a patient, work pressure, or professional experience. (Van der Veen et al. 2020.)

Organisations which aim to build or improve their digital ecosystem need a prescriptive framework to achieve their goals. The Adoption Model for Analytics Maturity (AMAM) provides this framework. The "Healthcare Information and Management Systems Society" (HIMSS) created this model among other maturity models and measures the hospitals´ competences in analytics on seven levels from 0 to 7. The health organisations must be competent in at least 6 levels for the adoption of the closed loop medication administration system. The steps include for example data management and the creation of a central health information store and the saving of data as an enterprise resource instead of storing it in a silo. An analytic competency center manages analytic skills, standards, and education. If the quality of data is solid, standardised tools are available, and real-time analytics at

the patient´s bedside is applied. By achieving level 6 the hospitals show competency in predictive analytics and focus on clinical support. Organisations at level 7 are competent in using genomics and biometrics data to support prescriptive and personalised medicine and apply prescriptive analytics for mass customisation of care. By 2020 numerous hospitals in the U.S., one hospital in Canada and two hospitals in Saudi Arabia have achieved AMAM level 6 and 7. The organisations can apply AMAM to further enhance predictive analytics, administration, and human resources in digital health. (HIMSS Stage 6 and 7 achievements 2022.)

The seven stages or levels of the "Adoption Model for Analytics Maturity" (AMAM) are listed in the following table starting with the lowest and ending with the highest achievable level (HIMSS 2022).

TABLE 8. Adoption Model for Analytics Maturity, AMAM (HIMSS 2022)

Level 0	Gaining insight of the possibilities of analytics, demands, challenges and development
Level 1	The hospital collects, stores, and manages information in a central location
Level 2	A professional body for analytics, processes information via the central database is implemented
Level 3	The different units of the hospital manage information in a reliable ware, access to the central database is supported, the quality of the information is high
Level 4	High-quality of care, economics and functional fields are addressed and improved
Level 5	The hospital documents its achievements consistently and improves know how regarding the financial aspect of care
Level 6	The organisation uses machine-learning techniques and algorithms, and enhances clinical support
Level 7	The health organisation uses analytical high-level computing and bioinformatics to provide the best individual prescriptive care and treatments; personalised medicine

Hachesu, Zyaei & Hassankhani (2016) performed an observational-descriptive study of 10 hospitals at the Tabriz University of Medical Sciences to design a checklist for the use of barcodes. In all 10 hospitals staff lacked information on international standards for barcodes such as GS1 (Global Language of Business) and HIBCC (Health Industry Business Communications Council). Only 5 out of 10 hospitals in the study had adopted the barcode policy, and its use was compromised by inefficient planning during the implementation process. In 80% of the investigated hospitals staff did not acknowledge the policies and regulations needed for successful use of BCMA. The results showed that a supportive environment and education is essential for users to learn not only the steps of BCMA, but to also become educated about the integration of BCMA into other systems, and associated safety issues, including the regulations, policies, and guidelines needed for a safe use. If

healthcare professionals understand the whole picture, they are more adherent to procedures which promote patient safety.

Cultural and organisational issues identified in research articles included the reporting system for medication errors that affected the patient and for mistakes that were detected before they could harm the patient. The "Expert Panel on Effective ways of Investing in Health", EXPH, an independent body of the European Commission, recommended organisations apply a reporting system which does not punish healthcare professionals, but which encourages transparency and provides support. (European Commission 2014). In the U.S., drug regulations and policies have been reviewed and modified to be adapted to the development in technology and medication production to guarantee the human individuals´ safety. By 2006, medication packages and blood products for blood transfusion were required to be equipped with the barcode conforming to the rules by the United States Food and Drug Administration, FDA. The regulation is known under the name "Physician Labelling Rule (PLR). (FDA 2013.) The FDA is a body which aims to safeguard individuals` health by making regulatory decisions based on verified information to prevent and reduce harm caused by drugs and organic goods for people and animals, and devices used in healthcaresafety, and to support effective solutions. FDA rules include the labelling of unit doses of medication, and this has led to a more successful adoption of BCMA. (FDA 2011) In hospitals medicines are available in multiple dose packages. To administer the patient´s correct individual dose, nurses take only a single dose of the package. Without barcode, data about the individual dose is not available and accurate control of administration is not possible. The correct administration could be controlled through scanning the single medicine dose and not the whole package. Inconsistencies can be followed up easily through tracing the electronic data of the single medication. But problems still occur due to incompatibility between barcodes and hospital scanners, due to missing labels, or due to re-packaging into smaller doses. (European Association of Hospital Pharmacists 2020.)

According to the WHO (2019b), economic factors influence the successful adoption of BCMA and patient safety. In the OECD countries (Organisation for Economic Cooperation and Development) 15% of the hospitals´ spending and action are consequences of adverse events. Hospitals need adequate funding and financial income to be able to function, to provide high-quality healthcare services, and to facilitate research and innovations. The FDA aims to enhance patient safety through new innovations and the advancement of medical products by integrating the patients´ perspectives in the development of goods and devices. The 21st Century Cures Act (Cures Act) created in 2016 supports these aims by supporting the use of real-world data, for example. (FDA, 2020) The FDA´s medication label requirements were revised in 2006. Prior to this, barcode labels included information for the physician, but they were difficult for patients to understand. Improvements have been made by displaying the data in a patient-friendly format. The Drug Quality and Security Act (DQSA) regulates the drugs´ supply chain history for example through the 2D barcode labelling of medication as the standard barcode in healthcare and in BCMA. Besides the 2D barcode requirement used in the U.S. and Europe there are different regulations globally for barcode labelling medication. It is challenging for pharmaceutical manufacturers to keep up with innovations, and to address different requirements which change and develop together with new technology. A solution for drug

companies is to outsource barcode labelling to gain the latest technologies and data from experts. (FDA, 2018.)

In 2016 the U.S. Food and Drug Administration developed standards for manufacturers to contemplate safety issues associated with the design of the tool or service to minimise medication errors. This guide includes recommendations on design of the drug, labelling, packaging, and selection of drug names to eliminate mistakes. (FDA 2019) According to the guidelines, multi-dose medications such as creams, eye drops, and inhalers are labelled with barcodes which include the information about the patient and the drug. Sentinel System has been developed by the FDA and aims to enhance the safe use of real data in drug development and to evaluate how medical goods the market. The FDA Catalyst Program under the Sentinel System evaluates suitability of infrastructure, promotes RWD research approaches, and innovative methods, and runs pilots. The Sentinel System is a safety surveillance system which has been used by the FDA since 2016 and which provides evidence-based data to monitor the safety of medical products, for example. (FDA 2018) The goal of the Catalyst Program is to improve the implementation of real -world data in the drug development ecosystem by offering a platform which is used by the FDA to describe, test, and modify methods and standards for the drug development process. (Sentinel System Five Year Strategy A 14, A 15.)

Research on BCMA investigated data security and the risk of data breach during the process of barcode medication administration. During this process, the patient`s health information is vulnerable because of its transmission over wireless data networks online which increases the risk of information leakage. Infringement compromises confidentiality issues and is a serious risk to patient safety. Private data can be manipulated or sold for money, or the system can be slowed down in the event of a "cyber- attack". (Ducker 2013.) IT professionals must implement security measures, such as a security protocol to prevent data breach. Another safety issue can arise due to individuals who use opportunities to manipulate medication before giving it due to insufficient safeguards in the barcode medication systems. Mistakes in drug administration are reduced through attaching barcode labels on single doses of medication already in the phase of manufacturing. (European Association of Hospital Pharmacists 2012).

In numerous research articles, security issues of the Internet of Things, IoT are examined. Radio frequency identification (RFID) is a component of this network which is also sometimes used in the BCMA process. Research about this matter discusses that the IoT architecture is very stratified, and threats can occur in any of the dimensions within the IoT. An example of a safety concern is a cyber-attack from external networks. Pandey, Chandra & Upendra (2019, 313,317) explained in their study that security threats on RFID occur in three different dimensions, the perception, the network, and the application dimension. For example, sensor network, radiofrequency identification (RFID), parts of the hardware and corded or wireless connections, and applications and tools can be attacked.

The BCMA system which uses barcode scanning falls under the perception layer. According to research, security issues in the perception layer have been identified. Barcodes can be threatened through viruses, or cloning. Attacks can occur on different levels within the perception layer, for

example on the physical level and the network level. Invasions include for example destroying the RFID reader, temporary disabling the system, attacks on tags such as cloning the barcode label, tag modification, or unauthorised tag reading. (Pandey, Chandra & Upendra, 2019, 313 -319) Smart phones or tablets are used by nurses to perform BCMA and to collect health information from the patients. The applications on these devices then process and interpret the data. The data is transmitted to the Cloud by complex algorithms. Safety issues can occur regarding confidentiality, misuse of information, and legal issues. Moreover, devices, data transmission, and cloud storage are three factors that can compromise security. (Pandey et al. 2019, 322.)

The development project conducted by Ho & Burger (2020) used Kotter´s "8-Steps Model of Change" (Kotter 1995) to facilitate change within the organisation and to improve patient safety. The model provides eight steps that support managers in initiating, in managing, and in encouraging change. The study consisted of two parts which were conducted at Sierra View Medical Center in Central California. One part of the study discussed procedural deviations regarding pain reassessment and developed solutions to improve compliance to the guidelines. The other part of the research investigated inconsistencies in BCMA scanning procedures. The aim was to decrease divergencies in BCMA scanning policies and to increase scanning rates which will be described in this chapter in more detail. Pharmacist and nursing leadership who participated in the research study cooperated in regular meetings. Dashboards were created to visualise the data, and participants could use them to see weekly barcode scanning rates. These instrument boards helped with transparency and showed whether nurses followed scanning procedures, or whether they did not comply with these procedures. In the scheduled conferences, challenges associated with policy compliance, and limitations in documentation, and education were discussed, and solutions for enhancement were developed. Health care professionals received educational information via their work e-mail to improve their knowledge. Instrument boards that included data on staff´s deviations of the scanning procedure were created to address the nurses who did not comply to the procedures. Nursing and pharmacy managers and IT leaders continued to meet twice a month to examine aspects of security and quality of care to support the introduction of BCMA. As a result, scan rates increased and according to the dashboards, the number of nurses not adhering to scanning policies was reduced from 26 to 4 users in less than six months. The findings demonstrated that active and practical interventions helped to facilitate changes in policies and guidelines to improve patient safety. Ho et al. (2020) discussed that BCMA could be implemented in a safe and successful way by adequately trained staff, and with support of the health organisation which provided adequate education and frequent training.

According to Juste (2018), training of nurses must start at the beginning of the BCMA implementation process and continue during the whole process. Also, training 3-6 months after the introduction of BCMA is beneficial to improve nurses´ practice and the systems process. In the research article, Juste (2018) also noted that nursing leadership recognised the fundamental need for resources. Equipment must be available; and it must function properly. Healthcare professionals must be educated and receive practical training on how to use new tools and systems. An education module was developed by Juste (2018) and tested at a pediatric unit in an organisation in the North-eastern United States. Juste (2018) described the steps followed to develop the education

module. These steps included the review and identification of needs, the development of criteria for the staff education program, meetings with management to discuss needs, the verification of the staff education program, the evaluation by experts, and the finalisation of the education program. Furthermore, a Likert-scale questionnaire was created by Juste (2018) to evaluate and to revise the training module with the help of five experts, and to provide validity and reliability. The module´s goal was to enhance proper use of the system by improving the medication administration process, and to improve patient safety. The education programme contained several aspects such as the description and review of BCMA, recognition of proper procedures, analysis, barcode labelling, documentation, revision of policies, standardisation of strategies, and IT support. It aimed to help educate staff on the adequate implementation of BCMA. Juste (2018) suggested, that the guide created could be used by nurses at work when they needed guidance and support.

TABLE 9. Content of the education module (Juste 2018)

Description and review of BCMA	Revision of policy changes, standardisation of labelling for medication.
Recognition of the proper procedure to scan medication	BCMA problems and IT support
Enhancement of best practice to limit or prevent workarounds	Promotion of a positive culture regarding safety and support.
Barcode labelling on drugs (single unit dose and multiple dose drugs)	Standardised concentrations for infusions, warnings if nurses deal with hazardous medications, with medicine names that are alike, and standardised preparation of single unit dose medication
Documentation of medications unable to scan according to hospital policy	

Table 8 describes the content of the education model developed by Juste (2018). With the help of the program challenges regarding the introduction of the barcoded drug administration system can be discussed. Users gain more knowledge about BCMA and may participate in developing better standardised practices to be implemented for a more successful use of BCMA. Problems and challenges are recognised, addressed, and effective methods are created to overcome the challenges.

5.3 Improvements in BCMA

Research shows that barcode scanning procedures support nurses in providing safer patient care. The system allows nurses to document incongruencies or divergencies during drug preparation and during giving drugs and facilitates the reduction of mistakes, to minimise patient harm. Using BCMA, it is possible to document the real-time administration of medication. Since its inception, BCMA has been developed further and a feature for urgent or one-time medication was added. Wideman, Whittler & Anderson (2005, 437-451) described how the implementation of the older version of BCMA was challenging. Verbal or orders by phone were not accepted by the system. If medication had to be administered instantly after the physician entered the order electronically, this was not possible. The prescription was displayed in the nursing interface only 30 minutes after the physician`s order entry, that is why medication could not be administered on time. The researchers discuss that newer versions of BCMA include a feature called the "Nursing Medication Order Button" which accepts verbal physician´s prescriptions. If nurses receive a verbal medication order or an order via phone from the physician, they can apply this feature to order, scan, and document the

delivered medication in the electronic medication record, eMAR independently. This feature is essential in the intensive care unit, for example.

A solution to improve BCMA and patient safety have been workstations on wheels that are placed close to the patient. From them, nurses scan the patient wristbands, retrieve information from the EHR, and scan the medication barcodes. But they need space and are not convenient in the patient rooms. Mobility is an important factor in nursing. Computers on wheels have been improved, and tablets and mobile phones, and wireless scanners have been integrated into the BCMS system. These are small tools which do not need much space, and nurses can easily carry them. They are important and useful tools to help enhance BCMA and patient safety. The tablet or the mobile phone are equipped with the barcode scanning software. Scans are performed via the device´s camera. Moreover, improved applications make the electronic health record easier to access, generate, and save data in real time. (Justesen 2020).

Functioning devices and software are important, but also adequate training of users must not be neglected in enhancing the positive impact of BCMA on patient safety. According to Giraldo et al. (2018) nurses who have not used the BCMA system were often apprehensive about practice and guidance. During weekends and holidays or at night, there was often concern about receiving appropriate support when needed. Staff received training on the process of BCMA, but they did not get trained in the use of the mobile station itself. To receive better guidance in the use of BCMA and the mobile stations, the nurses created support channels such as "WhatsApp" online groups, email, or a telephone line. Giraldo et al. (2018) suggested to train selected nurses in BCMA and to have at least one of these "expert" nurses per shift who can then provide support for other nurses. According to the researchers, leadership needs to increase efforts in improving training and education resources for BCMA, and in establishing clear instructions and procedures to facilitate a successful adoption and integration of BCMA into nursing workflows.

Nurses often detect errors when receiving drug orders, or when dispensing medicines because of procedures such as double-checking with a colleague before drug is administered. Errors during the process of medication administration and medication transcription are less often detected. Barcode technology can fill this gap, it can serve as the verifier with support of the doctor´s order entry via the computer (CPOE), the electronic medication record (eMAR) and the electronic healthcare record (EHR). The electronic health record (EHR) contains for example the patients´ health information, diagnoses, medications, treatments, images, allergies, and laboratories. The patient himself and other authorised users have access to the record. It provides real-time data and information can be shared between various providers. The computerised physician order entry (CPOE) is a tool to electronically order medication by using standardised order sets. Drug errors due to poorly handwritten medication orders are eliminated. The system is efficient and helps to minimise mistakes, and to support the doctor in clinical decision making. Safety features are included, such as drug-drug interactions, the patient´s allergies, drug-disease interaction, and drug expiration dates. By integrating CPOE into BCMA, the order is then transmitted to the hospital pharmacy where the pharmacist reviews and verifies the prescription for dispensing of the medication. By automating

and standardising the medication order, errors in medicines prescription and transcription can be reduced. (Connelly & Korvek 2021.)

In their research article Garets and Davis (2006) discussed that barcode technology may not only be combined with the CPOE and EHR, but also with the electronic medication record (eMAR). As a component of BCMA, the eMAR system is integrated with the CPOE, the EHR, and the pharmacy information system. The eMAR system stores clinical data and medical vocabulary, helps users in clinical decision- making, and is used in medicines prescription and clinical documentation. (Garets & Davis 2006). The eMAR serves as a tool to track and record barcoded medication administration. In practice, when the physician enters a drug order, the medication is automatically added into the electronic medication record. Nurses scan the barcoded medicine and the patients` ID badge to ensure that the right drug is administered to the right patients. When nurses give the medication at the correct time, the eMAR/BCMA system documents it as administered. If the medicine is not administered, a visual alert occurs, and the drug is documented as not given. Nurses may write explanations for discrepancies (delays, omissions) associated with the barcoded medication administration in the eMAR´ s comment field. (Garets & Davis 2006.)

Poon et al. (2010) explored how the the barcode system when combined with the eMAR affected drug administration regarding mistakes. The study was an experiment which took place in 2005 on 35 wards (medical, surgical, intensive care) of a highly specialised hospital before the combination of BCMA and eMAR and after their combination. 14 041 cases of administering drugs and 3082 cases of transcribing drug prescriptions were observed over 9 months. The researchers compared the number of transcription and drug administration errors in units where BCMA/eMAR was used, with rates in units that had not used the system. After the fusion of barcode and eMAR systems, mistakes when giving medicines were reduced by 41,4%. Errors in transcriptions were eliminated. The findings show that the integration of the eMAR supports nurses in the safe administration of medication. Further, support from other healthcare professionals, administrators, training, and available resources all helped with the implementation of BCMA.

Burkoski et al. (2019) investigated the long-term impact of BCAM and the close loop medication system (CLMS) gradual implementation on reported drug mistakes and harmful drug-related incidents in three community care hospitals under the Humber River Regional Hospital Network in Canada between 2013 and 2018. According to the results of the study, the introduction of BCMA did not have an instant impact, but it had a consistent and notable effect on the reduction of mistakes and harmful drug-related incidents over time. The use of CLMS showed an immediate remarkable effect on the minimisation of errors. The findings of the study provided further evidence that smart technology enables safe medication administration. The results also showed that the BCMA system worked the best when combined with other systems such as EHR, eMAR, or CPOE. The researchers recommended that the adoption of this technology should be introduced into more hospital settings globally.

The study by Giraldo et al. (2018) showed that nurses face challenges due to functional gaps in the BCMA system. These included the inability to record nebuliser use, insulin corrections, and multidose medications such as eye drops, or oral suspensions. The process of administering medicines on the

patient´s demand, or if clinically necessary, was perceived as challenging. Research conducted by Thompson et al. (2018) discovered new obstacles in the BCMA system and addressed the impact of BCMA associated with the number of mistakes in drug administration that compromise patient safety. According to the researcher, nurses could not verify with the BCMA system that the insulin pens belong to a particular patient, and this created confusion when administering insulin using pens to multiple patients. In the study Thompson et al. (2018) also observed that nurses were required to scan one barcode to connect the medication order to the patient, and to scan a second barcode to link the insulin pen in question to the patient. Through performing these additional processes, health care professionals could verify the medication order and connect the right insulin pen to the right patient. Furthermore, cross-contamination between patients was reduced. Organisation culture and procedures changed after the introduction of BCMA. Staff put more focus on data and on integrating data and nursing documentation into their work routine. (Thompson et al. 2018)

Efforts are made to blend the BCMA into the clinical decision -making environment. Leaders must support cultural changes due to implementation of new systems and procedures. An example of an effective solution to improve patient safety is the closed loop medication administration system (CLMA) which serves as a tool to reduce errors and to recognise specific types of faults. CLMA is thus an effective tool in addressing risk factors that compromise safe medication administration.

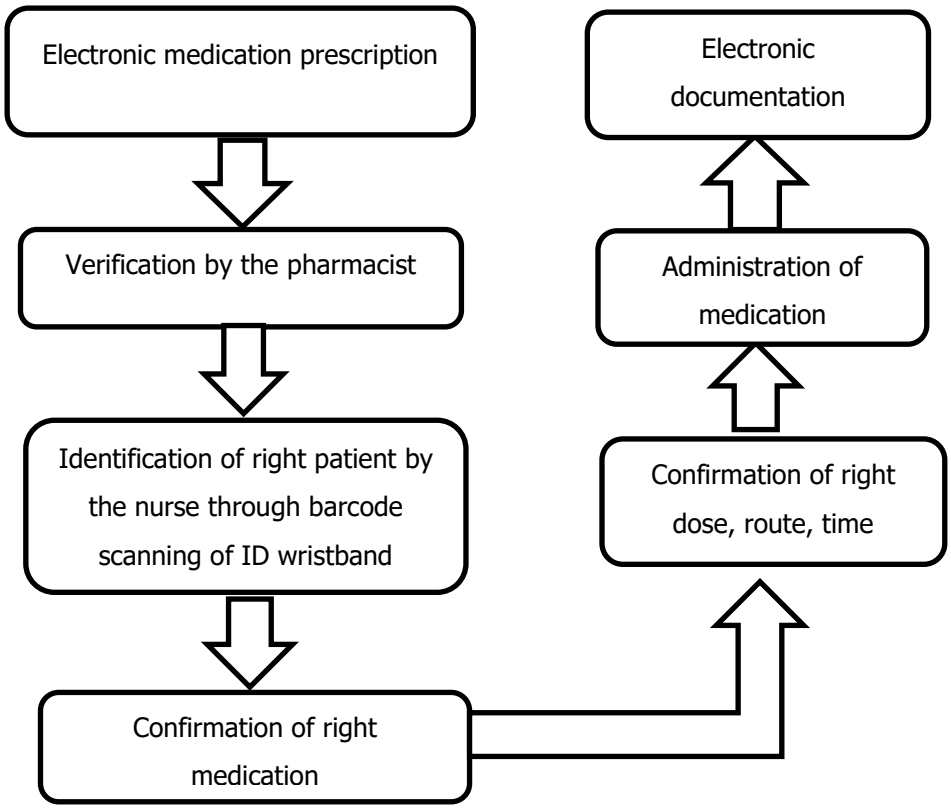

FIGURE 7. Closed loop medication administration (Bhatti 2019)

BCMA helps healthcare professionals in clinical decision making. When the physician prescribes the medication electronically, the system transfers the drug order to the EHR, and the doctor gets access to the client´s health information including contraindications, allergies, or other safety issues. In the hospital pharmacy these safety issues are checked automatically again. In case of contraindications, the hospital pharmacist prepares a different drug which is electronically documented. Closed loop means that the chain phases of medication prescription, processing, dispensing, and administration are electronically recorded and transmitted. Data is not printed at any time. The closed loop medicines administration system facilitates electronic verification of the right person, drug, and dose. The system also verifies that nurses give medication on schedule and via the right route. Aim is to prevent and minimise drug errors, and to enhance continuity of information transmission to improve patient safety. The right patient is confirmed by identifying the patient through scanning the barcoded wristband. This information is then assessed by the nurse. The barcoded medication is stored in a smart medicine cabinet which can be accessed only by authorised staff. The right drug is verified by the nurse through scanning the medication package´s barcode. The right dosage of the medicine, the way it must be given, and the scheduled time are confirmed with the e-prescribing system. In case of errors, the system gives a warning. After verification of all "five rights", the nurse administers the drug. The administration is documented electronically in the electronic health care record. (Figure 7.)

Ozturk, Kose & Ozge (2020) investigated the effect of closed loop medication administration on the number of medications that is sent back and on how the reclamation is reported. The study was conducted in three in-patient hospitals in Bolu Izzet Baysal Public Hospital in Turkey in 2017. The hospital was accredited stage 6 of the EMRAM model by HIMSS. The creation and the adoption of the closed loop medication administration system (CLMA) requires stage 6 of the Electronic Medical Record Adoption Model, EMRAM. The Healthcare and Information and Management Systems Society (HIMSS) created this model which consists of eight stages. Hospitals who are in stage 6 of the EMRAM stages, have automated the medication administration process without missing phases, and according to the requirements. EMRAM provides standards for health organisations to enhance efficiency and performance, and to assess the adoption and use of electronic medical record, eMAR. The goal is to support clinicians, to secure data, and to enhance patient safety by measuring the impact of electronic medical records, patient outcomes, and clinical outcomes. (HIMSS, 2022.) Ozturk et al. (2020) assessed data from the hospital information system (HIS). According to the results, the rate of medications returned to the hospital pharmacy increased and the quality of documentation on reasons for the return was enhanced after implementation of the closed loop medication administration system, CLMA. The study also concluded that the use of CLMA is essential in enhancing patient safety, in reducing costs, and that policymakers should encourage the adoption and introduction of the CLMA.

Improvements are also made regarding effective communication. The BCMA system has been enhanced, and new features are now available which support the interaction and communication between various users. Zebra Technologies Corporation is a company among many others that manufactures technology, develops, and offers tools in support of the BCMA process. These tools include hardware such as barcode scanners, handheld mobile computers and enterprise tablets, and

ID card printers and software like Workforce Connect, and Card Design Software. The software is very user- friendly and users do not need technical skills. It includes features which promote communication between users. Healthcare professionals can apply various modes such as voice telephony, push-to-talk, and text messaging. Developments in software usability improve BCMA and thus enhance patient safety. (Zebra ZIH Corp 2019.) Focus is put on the involvement of nurses in the development of standard operating procedures and in the phase of the implementation of the device. Demonstrations on the use of the tool help to gather feedback from users for further advancement of the device such as BCMA scanners, or workstations on wheels.

Pandey et al. (2019, 319) discussed data breach as a factor that impacts the safe use of BCMA. To improve safety of this smart technology, codes are necessary to secure the information. For example, cryptography serves to improve confidentiality, integrity, and authentication confidentiality by authorising only verified users the access to health information. By applying cryptography, data is safeguarded from infringement by changing written text into meaningless text and the other way around. Data cannot be changed, and the sender and receiver of the information need authentication. (Pandey et al. 2019, 319.)

6 REFLECTION

According to the findings from data analysis, there is a link between elements that affect the successful use of the smart technology BCMA and improved patient safety. Numerous academic articles discuss the effect of the BCMA system implemented as such, or when integrated with other systems, such as CPOE, eMAR and EHR. Themes recognised in the study were categorised into technological, social, and organisational factors that impact the safe and successful implementation of BCAM in hospitals. This approach was adopted from Sittig`s et al. (2010) model which explored health tools and services from a social and technological point of view.

There is evidence of ongoing efforts being made to enhance the BCMA system and to improve patient safety. The results suggest that the implementation of BCMA is beneficial and that if applied correctly it helps to reduce patient harm. However, this research also identifies risk factors in the introduction of BCMA that compromise patient safety. Poorly designed applications cause hazards and affect the quality of care. Drug errors still occur but are reduced when using BCMA. Interoperability issues and user problems are addressed by studies. Other problems include delayed or missed medication administration because interaction between users and the BCMA system does not work properly. Challenges in patient identification due to malfunctioning scanners or damaged wristbands were reported in several research articles. Research also discusses the use of paper sheets to document medication administration. If the system is down and patient data cannot be accessed, it is necessary to use alternatives such as paper nursing documentation and paper patient files to maintain uninterrupted healthcare management. This behavior is a risk to the safe implementation of BCMA and to patient safety. The processing and transcribing of the handwritten material into the BCMA system increases the risk of misinterpretation due to poor handwriting which may lead to medication errors.

Several technical factors were identified to have an impact on the successful use of BCMA. Staggers et al. (2015) identified 99 usability problems, of which 15 were essential problems, in a medical center of the Veteran Affairs in the Western U.S. Challenges occurred in chart medication, medication preparation, and screen design. Holden et al. (2012) identified the reliability of the system as a factor that impacts safe use of BCMA. For example, if deviations during the stages of medication administration occur, the BCMA system is blocked, and IT support is needed. Technical elements also include deficiencies in design, as discussed by Holden et al. (2012), or the failure to scan the wristband due to technical problems or damaged labels. Giraldo et al. (2018) identified connectivity as an essential factor which affects patient safety. Due to problems with wi-fi connection, the system has downtimes and standardised BCMA procedures cannot be performed. Deficiencies in design of the BCMA system were also investigated by Bjornstad et al. (2021).

Compatibility, interconnectivity, and integration of various applications and information have an impact on the safe use of BCMA. If the implementation of BCMA is successful, these factors facilitate the detection of drug errors and then BCMA improves patient safety. For example, the barcoding system is compatible with the electronic medication administration record (eMAR) and the electronic health record (EHR). Data gained from BCMA can be integrated into eMAR, and EHR. In the medication administration process, data is connected to medication orders from the EHR and

validated with help of the barcoding system. The journey of the drug from the physician`s order to drug administration can be analysed regarding the safety of the barcode medication administration system (BCMA), and how it affects the patient`s safety. Technology is effective in helping healthcare professionals to improve performance and efficiency, and to minimise medication errors. The study by Truitt et al. (2016) demonstrated the decrease of adverse drug effects by 20% after implementation of the BCMA and eMAR technologies together and integrated and a minimisation in transcription faults by 60%. Reduction of transcription errors is due to improved communication and transfer of information between pharmacy and nursing ward. Truitt et al. (2016) discussed that the number of mistakes that happen when giving drugs remained the same because BCMA facilitates the identification of administration errors. Poon et al. (2010) who determined rates of medications mistakes before introduction of BCMA and after implementation of BCMA combined with eMAR, states that medicines administration errors were reduced by 41,4% and that drug errors occurring during the transcription phase were eliminated after the implementation of the BCMA/eMAR system.

Patient safety is a priority for all stakeholders and therefore research is ongoing to develop and improve the BCMA system. Hospital pharmacies need drugs in unit-dose packages to comply with the BCMA system, but not all drugs are available as unit-doses. In an automatic packaging system, robots rearrange the medication into single unit doses. If a semi-automated wrapping system is used, multidose drug cartons delivered to the pharmacy must be repacked manually by pharmacists. Multidose medication packages must be opened and rearranged into unit-doses which takes more time and increases the risk of mistakes. Therefore, the closed-loop medication system (CLMS) was created as an additional safety system. Its aim is to further reduce medication errors and adverse drug events by increasing automatisation through integrating CPOE, eMAR, EHR, and pharmacy dispensing. In some hospitals there are automated dispensing robots blended into the BCMA system. The closed-loop system, CLMS is essential in the reduction of drug mistakes and in the enhancement of patient safety, but there are still many challenges to overcome. BCMA and CLMS are time-consuming systems to implement and require sufficient equipment and human resources. Integrating BCMA procedures well into nurses´ workflow and providing adequate appliances is necessary to reduce deviations from standard procedures and to improve nurses´ workflow.

Social and organisational factors are difficult to discuss individually because they are greatly interconnected and influence each other, such as deviations of procedures to overcome obstacles, the organisation´s culture, procedures and policies, or legal regulations influence the safe implementation of BCMA. For example, research by Sakushima et al. (2015) identified that the organisation´s culture and structure affected the successful introduction of BCMA. Sakushima et al. (2015) and van der Veen et al. (2020) discussed that the patient-nurse ratio has an impact on nursing workarounds and that nursing units with a better nurse-patient ratio showed a safer use of BCMA through a higher reduction in medication errors. If nurses are responsible to administer medication to a high number of patients, they are under time pressure and are more likely to create shortcuts within the BCMA system to work faster. Workarounds are processes that deviate from the standardised BCMA process and may compromise efficient BCMA and patient safety. BCMA must be smoothly integrated in the nurses´ workflow to avoid workarounds in case challenges occur and due to time pressure. Problems can be overcome through better training of personnel and process

standardisation. As Dwibedi et al. (2012) discussed, proper implementation of BCMA helps nurses to perform BCMA tasks fluently which saves time that can be used to care for patients.

Also, the quality of collaboration with hospital pharmacists may impact the effective implementation of BCMA. The policies and procedures of an organisation, and available resources may affect successful adoption of BCMA. The number of drug error incidences and the reduction of medication administration errors vary even between different nursing units, depending on how well new BCMA technology is adopted. By combining BCMA with other systems its impact on patient safety can be enhanced. A change in the organisation´s structure and processes would even more support the safe implementation of BCMA. For example, the integration of a pharmacy and an automated medication dispensing system into the BCMA system would minimise medication dispensing and preparation errors. The results of the research study by Sakushima et al. (2015) show that organisational factors such as nursing unit and hospital related factors affect the safe use of BCMA and on patient safety.

Numerous studies showed that the type and number of deviations from standard procedures and of drug errors vary, and that the percentage of reduction of medication administration mistakes varies among the nursing units and hospitals. (Sakushima et al. 2015, Mulac et al. 2021) Truitt et al. (2016) also discussed that in their study especially the rate of mistakes during the phase of transcription decreased after implementation of BCMA. The "wrong time" errors which means the transcription of the medication is delayed, showed a higher rate of error reduction than other types of mistakes in the transcription phase. In the study the type of drug error referred to the five phases of medication administration and included electronic medication order, transcription of the order into the electronic medication record, dispensing and administration of the drug, and monitoring its effect.

Many studies investigated the efficiency of BCMA regarding medication error reduction which directly affects patient safety. Numerous studies were also conducted to examine nurses´ workarounds, workflow, and how BCMA influences nurses´ tasks. Duties relating to documentation were seen to have an impact on patient safety as well. Workaround issues are influenced by technical, social, and organisational factors. Users of the BCMA system experience challenges in their workflow and take shortcuts or develop new workflows to reach their goal, the administration of medication. If deviating from procedures, nurses compromise patient safety by increasing the risk of medication errors. According to the results, more than 50% of the nurses observed did not follow the BCMA policies during dispensing (66%) and administering drugs (71%). Other problems in the use of BCMA were policy deviations because of technical factors, and environmental factors. Organisational deviations occurred because staff could not scan the medications (29%) and the patient s` wristbands (20%). (Mulac et al. 2021). The results show that the system needs to improve the implementation of the barcode scanning by nurses to avoid harm. The process of giving drugs should be consistent with the organisation´s guidelines. Inconsistencies with the procedure do not contribute to the enhancement of medicine error reduction and patient safety. Users try to find solutions by performing workarounds to overcome problems, but these solutions may not be according to established protocols and thus may compromise patient safety. By studying users´

problem-solving behaviours in more detail, the design of BCMA can be improved to reduce workarounds and risks to patient safety. The study by Holden et al. (2012) for example showed that nurses recorded medication administration before the medication was really given to make sure it was documented within the allowed timeframe. Features in documentation need to be improved to make recording of data in real-time more effective.

Additional research found that hospital policies do not always support workflows and the implementation of the system because they allow deviations from the procedure. As discussed by Bjornstad et al. (2022, 678), certain multidose medications from primary care were permitted. These multi-dose medicines did not match with the drug list in the electronic medication record which uses single dose medications. Each multidose medicine from primary care had to be compared with the drug chart in the electronic medication record to verify it. By increasing the manual processes in the system, the risk of mistakes is higher and the effect of CLMS on patient safety is compromised. The health organisation is responsible for reviewing policies and creating formalised requirements which do not compromise the successful and safe use of the barcoding system.

BCMA also affects collaboration, interaction, and correspondence. Hospital pharmacy and nursing units are connected more after the implementation of BCMA since it requires that communication and cooperation must be adapted and enhanced. Miscommunication and poor teamwork are factors which impact successful use of BCMA, as Holden et al. (2012) observed. Pharmacists, physicians, and nurses interact with each other by recording the medication administration process and by sharing health information on the EHR. The documentation must be done according to standard procedures. The BCMA system should improve teamwork, communication, coordination, and cooperation.

Cooperation and communication are important in developing for example new guidelines for education, training, and monitoring to enhance safe and secure implementation of the technology. Practical training in the use of the BCMA system is necessary to accustom nurses to the use of BCMA, immediate recording of health information, and the continuity of care. It is important to report challenges that occur during the BCMA process, and users must be trained and feel comfortable reporting these problems to be further addressed and tackled by IT professionals. Ho & Burger (2020) suggested that the BCMA system facilitates only surveillance but does not support communication between various healthcare professionals such as nurses, physicians, pharmacists, and patients. For example, there are constraints in selecting another nurse`s patient in BCMA. If the nurse asks a colleague for advice concerning a patient, the colleague needs to perform many steps to select the advice-asking nurse´s patient in BCMA. Communication between nurses, doctors, pharmacists, IT leadership, and manufacturers is essential for a successful implementation of the system and improvement of safe medication administration and safe health care. Healthcare professionals adopt BCMA and other smart technologies to retrieve and store relevant information and to use this real-time data to make clinical decisions. Hospitals and other health organisations must invest in hardware and software for the successful use of BCMA and other smart solutions. By implementing these technologies, hospitals operate better, are more efficient, and improve patient

safety. As described by Ho et al. (2020) meetings between nursing, pharmacy, and IT leadership, take place twice a month at Sierra Vie Medical Centre to discuss safety and quality issues to enhance implementation of BCMA. This is a good model other hospitals should consider.

Many studies on short-term effects of BCMA were conducted by Hassink et al. (2013), Hachesu et al. (2016), van der Veen et al. (2017), Barakat et al. (2020) and Mulac et al. (2021). Only a few studies investigated the long-term effect of BCMA and CLMS. Burkoski et al. (2019) examined the long-term impact of BCMA and CLMS and emphasized that the integration of various smart technologies has a significant and meaningful impact on the reduction of medication errors and that these technologies should be adopted around the world to improve patient safety. In the United States and many other countries, BCMA has been used for many years. The Humber River Regional Hospital Network was the first digital hospital in North America and received the HIMSS`s Accreditation with Exemplary Standing in 2018. The hospital uses a command center which focuses on patient flow and patient safety. (Humber River Hospital 2018.) In Europe there is still more effort needed by all stakeholders to enhance the use of BCMA.

The findings of the academic literature review are diverse. The different stages within the barcode medication administration that were investigated, the location (country, hospital), the kind of nursing unit (medical, surgical, intensive ward), and the training and education of the staff, had an impact on the results. The studies gained slightly different numbers associated with the reduction of medication administration errors. But all studies agreed, that BCMA has the potential to minimise drug mistakes. Hassink et al. (2013, 572-573) observed a reduction of mediation errors by 50%, and Sakushima et al. (2015) state that the medication administration error rate was reduced by 40%, but that mistakes in drug preparation were not impacted significantly. Mulac et al. (2021) discuss that the rate of workarounds and mistakes during the distribution of drugs was high because the dispensing of drugs was done by nurses and not by hospital pharmacists. Hachesu et al. (2016) noted that only 50% of the hospitals included in the study used BCMA and that 80% of the staff was not familiar with the hospital´s policies regarding BCMA implementation. These findings show the fundamental need of further education, training, and the enhancement of awareness for the potential and the benefits of the BCMA system.

Another prominent aspect investigated in academic literature was the users` acceptance of technology. Various models were developed to describe influencing factors regarding a person´s intent to adopt new technology. For example, Davis (1089) created the "Technology Acceptance Model", TAM which can be used to investigate doctors´, nurses´, and pharmacists´ expectations, perceptions, and motives to use BCMA. Individuals will apply technology if it is useful to them, if they believe that the technology improves their effectiveness at work, and if they think that it takes only little effort to use new tools. Some users may believe that they face too many challenges, that the effort to implement the technology is too high, and therefore they are more resistant to using new tools. The users´ acceptance of BCMA impact its successful introduction. Leadership of hospital organisations should apply more tools and models to better understand and address the healthcare professionals´ challenges, expectations, and perceptions of BCMA. Through gaining feedback from users and through growing understanding of the influencing factors, leaders can make effective

organisational and social changes associated with BCMA to improve its implementation and patient safety. The results of the study by Holden´s et al. (2012) demonstrate that the design and integration of BCMA into the clinical workflow and system must be done carefully by evaluating the processes and by measuring healthcare professionals` perceptions, acceptance, and factors that influence acceptance.

The implementation of BCMA changes the culture and organisation of the hospital´s systems. More cooperation between pharmacists and nurses or doctors is required. Pharmacists and clinicians depend more on each other. The process of BCMA connects hospital pharmacy and nursing units which affects communication, cooperation, and support. Challenges in the successful use of BCMA were identified as miscommunication between pharmacists and nurses. As the study by Holden et al. (2012) observed, healthcare staff may still use the paper medication administration records, especially in situations where they must react fast. This causes challenges for pharmacists. In emergency situations for example, doctors often order medication orally. Nurses give the drug to the patient and write down the process using a paper record, because it is faster than the electronic documentation, and they can keep the paper closer to them and the critically ill patient. Pharmacists must afterwards document this medication electronically which requires additional steps of entering the drug order, scanning the medication, and discontinuing the order. Hospitals must modify guidelines, regulations, policies, and nurses´ workflows concerning drug administration, the use of scanners in case of malfunction, and the five rights of patient identification to facilitate the use of BCMA. If policies and organisational changes are modified effectively, the successful use of BCAM is far more likely to improve outcomes

Research indicates also that support and easy access to information have a positive impact on the safety of BCMA and thus on patient safety. Assistance by IT professionals on the use of barcode scanners, or mobile applications for example, helps users and enhances their acceptance of BCMA which has a positive effect on its implementation. Technology must be well integrated into the nursing staff´s workflow, and into the nurses´ tasks and care plan. Healthcare professionals` perceptions and expectations must be addressed and positive attitudes strengthened for a successful integration of BCMA into the workflow. As Giraldo et al. (2018) emphasizes, a constructive communication is essential to manage change and to facilitate the adoption and implementation of new technology.

Healthcare professionals who are responsible for errors may feel guilt, anger, depression, and may be unable to work efficiently anymore or not at all. They may need psychological treatment which leads to more costs for the hospital. Health organisations with financial problems cannot buy enough high-quality equipment, supplies, and technology, or employ enough qualified healthcare professionals. Funding may be lacking for enhancing health tools and facilities and the standard of care may be compromised by reducing resources to save money. Financial considerations are important for a functioning hospital and for patient safety, and more solutions must be developed to minimise the health organisations´ expenditures due to medication errors. Due to medication errors, health organisations may be liable for financial damages because of lawsuits initiated by patients who have been harmed. Prolonged hospital stays due to drug mistakes also result in more costs.

Staff who deviate from standard procedures and are working in non-compliance with policies, create a risk of penalties and fines. A lot of research was carried out on the effect of BCMA regarding the reduction of medication errors to enhance patient safety. In these academic articles the financial aspect was not the focus but for example as the studies by Dwibedi et al. (2012) and Holden et al. (2020) showed, BCMA has the potential to minimise financial burden through automatisation, time-efficiency, and reduction of medication errors which leads to cost savings. If CPOE, eMAR, EHR and BCMA are combined, the potential is even greater.

Not all health organisations and staff are prepared to adopt BCMA or other smart technology. The organisations´ leadership must cooperate with other stakeholders who support research, innovation, and support with technical problems. Models such as the AMAM model are needed to recognise the potential of smart tools and to enhance efforts in achieving digital competence. Health organisations need to modify their policies, regulations, and workflows to better integrate the BCMA system into the clinical workflow. Leaders need to learn how to use tools that support the process of change to achieve better performance. A positive environment for change must be created and support tools developed during the process to help staff experience change as a benefit to sustain it. Academic articles discuss the need for hospitals to be active and to promote prospective change within the health organisation´s culture to improve the use of BCMA and patient safety. For example, by adopting tools such as Kotter´s "8- Steps Model of Change" (Kotter 1995) a supportive environment for change can be created. Regular meetings and open discussions on dashboards which openly presented non-compliant scanning rates data help encourage positive change. This transparency of information and ongoing education helps nurses and other healthcare professionals who use the BCMA system to change their behavior and to comply better with the organisation´s scanning policies. Also, the adoption of methods or tools such as IHI`s "Prevent, Identify-and-Mitigate, Redesign" methodology, helps to support the organisation in the process of change and to enhance the safety of BCMA. According to the IHI, processes that need to be enhanced and the factors that negatively influence the BCMA process must be identified, addressed, and errors must be minimised by developing a design to standardise the process. As discussed, nurses´ workarounds were identified as factors influencing the successful implementation of BCMA. It is necessary to understand why nurses bypass standard procedures. By applying the IHI model of reliability, process standardisation is facilitated.

Patient safety is improved by a high standard of quality of care which can be provided only by highly qualified staff. Thus, the quality of healthcare professionals´ knowledge, skills and training must be evaluated and enhanced. According to the research study conducted by Giraldo et al. (2018), nurses were not trained in the implementation of the mobile stations used in the BCMA process and searched for support by using other options such as support groups via WhatsApp. It is evident that many organisations are not prepared well enough to train staff and to introduce the barcode system successfully, and this compromises patients´ safety. Organisations must train and support their staff and be proactive and open to change cultural practices for the successful implementation of BCMA. BCMA has the potential to facilitate nurse patient interaction, patient guidance, and education. Patients who are informed about their care, and the benefits and risks of the medication they receive, are more alert to errors, incongruencies in drug administration, or to adverse drug events

which enhances patient safety.The importance of effective training and education was emphasized in numerous academic articles. According to Juste (2018), management must be active, and create an environment that supports coaching at the same time as BCMA is introduced. Training must continue through the implementation phase, and several months after the adoption of BCMA to guarantee a successful implementation of the system. For example, the education module developed by Juste (2018) would serve as an effective tool to support and to educate staff about BCMA, and on BCMA associated proper procedures, standardised strategies and policies, problems, and how to access IT support.

The research addressed the efforts of regulatory bodies to improve patient safety by developing guidelines and directives. Many hospitals have not yet reached the desired level of digital competence, as Hachesu et al. (2016) discussed. Only 20% of the investigated hospitals acknowledged policies and regulations for a safe BCAM implementation. Efforts are made globally to support health organisations reach a higher level in digitalisation and successfully implement smart technology such as BCMA. Guidelines are created that help hospitals to put requirements and recommendations into practice. The guide on safety issues regarding the styles of medical goods to reduce drug mistakes was published by the FDA in 2016 to provide standards concerning labelling, design, and packaging for medication manufacturers. The Drug Quality and Security Act (DQSA) follows the medications´ life circle from production to administration by requiring the labelling of medicines with a 2D barcode, the standard barcode used in drug manufacturing. Further, models such as HIMSS´S "Adoption Model for Analytics Maturity" (AMAM) were created to improve organisations´ analytics competence and digital development globally. The tools are available, it is the leadership`s responsibility to use them to achieve the organisations' goals regarding digitalisation and the introduction of smart technology.

Pharmacies, hospitals, and manufacturers must cooperate to assure a successful implementation of BCMA. More equipment must be provided, a BCMA mobile computer with a wireless scanner should be in each patient´s room. This poses a financial burden on the organisation, but research shows that healthcare professionals modify workflows if BCMA stations are not available. Insufficient appliances have a negative effect on the effectiveness and on the safety of care. Hospitals must test devices such as scanners and evaluate them when used with the barcodes implemented in the hospital. The quality of wristbands and barcodes must be tested, they must not get damaged easily in daily use. Damaged codes and wristbands compromise the successful use of BCMA. If the barcode scanning does not work, nurses skip steps, create new workflows, and neglect procedures all which can have a negative effect on the safety of BCMA and patient safety.

Technological, organisational, and social factors must be recognised, addressed, and modified to achieve an improvement in the use of BCMA and on patient safety. Effective strategies must be developed and implemented to address issues such as medication errors, poor compliance, inadequate training, technical complications, financial burdens, and nurses` emotional distress and workload. Various models can be applied to help promote positive change within the organisation. Close coordination and teamwork with regulatory bodies, IT manufacturers and healthcare

professionals enhances the successful introduction and use of BCMA, and this has a positive effect on the patient´s health and safety.

6.1 Limitations

Limitations in the thesis occur due to the researcher´s potential subjectivity in selecting the articles for the review. Although selection standards were utilised and the reliability and validity of the studies were investigated, the researcher´s previous knowledge, opinions, and expectations about the topic may have also influenced the selection of the articles. Furthermore, no relevant research articles were found on BCMA implemented in Finland. Barcode medication administration or closed loop system has not been implemented in Finland as it has been in other countries. In Finland barcode scanning has been used for other purposes such as using the automated dispensing cabinet where medication packages are scanned, identifying patients, and performing tests like electrocardiogram (EKG), or electroencephalogram (EEG).

In literature surveyed, elements influencing BCMA from the pharmacists` perspective were discussed, but not to such an extend as factors from nurses´ point of view. The literature search provided numerous articles regarding nurses` perceptions, expectations, or experiences. Numerous studies dealt with reducing drug errors by enhancing BCMA in the process of administering medication, but not many studies were conducted on the improvement of the BCMA process during the transcription and dispensing phase in the pharmacy, for example. Relevant literature on physicians´ perspectives could not be found. The author assumes this may be because physicians are the first point in the chain of BCMA. By prescribing the medication electronically, the BCMA processes are started. Errors may occur during the prescription phase when using a computerised physician´s order entry (CPOE) application. This review did not examine challenges in CPOE implementation in-depth. Further, relevant academic literature on the patients´ influence on BCMA could not be gathered. Based on the author´s practical experience, patients were observed to compromise the safe use of BCMA by removing their ID wristbands or damaging their bracelets accidently due to cognitive deficiencies. For example, elderly people do not understand why they wear a wristband and damage or remove it, or purposefully. These gaps in literature must be closed by conducting more studies on patients´ perceptions and experiences with BCMA. The nurse-patient relationship, the patient´s engagement in care, and the patient´s need for more guidance and information concerning BCMA safety, security, and privacy is not adequately covered in available research.

Another limitation in the thesis is the large variety of results, statements, and conclusions. Research was carried out in various countries and in years from 2010 onwards. Technology and knowledge develop quickly which may lead to limitations in validity and importance of an older study. Also, studies were performed in different nursing units and hospitals. The selected research examined factors that influence the use of BCMA from different perspectives, and thus research results varied. Although all findings suggest that BCMA minimises medications errors and enhances patient safety, there were variations in the scale and scope of these reductions. In some articles, the influencing factor of the hospital or nursing unit has been discussed, and in some of these studies, decrease in medication administration errors after BCMA has been less or there was no reduction of medication

errors at all. Clearly where and how BCMA is introduced matters. Some studies (Ho et al. 2020) included developmental projects which produce data that cannot be generalised but can be used as the basis for further research. Limitations in the study by Truitt et al. (2018) included for example that the nursing units were not randomised, and that the data was collected from voluntary incidents reports which represent only a small portion of episodes.

The way hospitals implement BCMA are still diverse, and policies often vary between organisations. According to academic literature some hospitals used the closed loop system (CLMS) with automated dispensing machines or with semi-automated systems, others rely on pharmacists dispensing the medicines. Other health organisations introduced BCMA without a closed loop system, and either nurses, or hospital pharmacists dispensed the drugs. In some hospitals the medication was transported to the wards from the hospital pharmacy by an automatic system a few times a day. In other organisations, nurses get the drugs themselves from the medication room. In most studies, nurses used mobile computers, wireless bar scanners, and the medicines were stored in individual drawers. Research was conducted in numerous hospitals at different development levels with respect to digitalisation. This also has an impact on study results and makes it challenging to make comparisons or draw parallels between the results.

6.2 Ethical considerations

Ethical aspects were respected during gathering information, evaluating the data, presenting the findings, and reflecting on them. Search engines, search terms, and keywords used are mentioned. Readers can follow the process of literature search and the selection of articles. The process of narrative literature review is long and must be carefully designed to avoid selection bias, but there are no strict guidelines that need to be followed and documented. The reliability and validity of the thesis is ensured by collecting academic articles in a structured way, and by using selected standards which are described in the thesis. Studies which include data bias and research errors are excluded. Only peer-reviewed, validated literature is selected for the review. It is recommended to use a systematic approach which means the author explains the methods of data collection and analysis, the concepts used, the theoretical background, and discusses the findings to create transparency. Literature reviewers utilise information gained from other studies. This information is openly accessible, it is not personal or confidential. Narrative literature reviewers use the data as raw material to make analysis and interpretations. The depth and scope of the narrative literature review depends on how detailed the author describes, analyses, explains and draws conclusions. Quotations and referencing are conducted according to Savonia AMK instructions. Plagiarism or self-plagiarism is avoided. The studies included in the thesis are relevant and appropriate to the topic.

Ethical consent from organisations or individuals is not needed in narrative literature reviews. But literature reviewers need to consider the participants and other stakeholders` interests. Researchers who carried out the original observations gained the participants´ consent and explain terms such as confidentiality, trustworthiness, and privacy before the beginning of their work. This process must be documented and described in detail in their research paper. Nevertheless, narrative literature

reviewers cannot be sure how well participants of the original study understood these ethical issues. They may have given approval for the original researcher to use the data gained, but the narrative literature reviewer cannot be sure whether they have given consent for further use and analysis.

Ethical concerns arose when analysing the research performed by van der Veen et al. (2018) on nurses´ workarounds during the implementation of BCAM. The original study used disguised observation as a method to collect data. Based on ethical concerns the study was at first not included in the narrative literature review. Concerns included the questions whether it is ethical to observe individuals who do not know that they are observed, or what observers investigate. Another concern was how observers may affect patients. The decision to include the study and its findings was based on van der Veen´s transparent discussion on ethical issues concerning the disguised observation technique. The reason to choose disguised observation as the method to gather information was supported by references. Moreover, the research study gained national permission, the participating hospitals were informed orally and in writing about the nature of the study, about the national permission, and there were no concerns from the participants` side. The observers received training to become familiar with the BCMA process and standard procedures of disguised observation to minimise bias. A pilot observation was conducted before the real study to ensure that standard procedures of data collection are applied. The information of the pilot study was destroyed. Patients did not know about the observers and were not affect by them.

When performing narrative research, the individuals` values are respected, the privacy, confidentiality, and dignity of the people who participated in studies is protected. The researcher must build a respectful relationship with the persons who are part of the study, but also consider the research´s goals, correctness, and legitimacy. This often causes disputes. (Josselson 2007, 538.)

The research study by Giraldo et al. (2018) who examined how nurses regard BCMA and what they expect from the introduction of BCMA, was included in the review because it discussed ethical issues regarding interviewing participants and thus demonstrated the integrity of the study. The data collection method was the open interview and conversations between participants which were recorded. The design of the study was described well and ethical issues such as protecting the participants´ identity and gaining informed consent were discussed. The requirements for obtaining informed consent were first documented in the "Nuernberger Kodex 1947", which emphasize that the participant must voluntarily give approval and understand the design and purpose of the study, and the consent is given in written form. (Ethikkommission DGP e.V) In the study by Giraldo et al. (2018) the participants gave only oral consent which creates the question of whether oral consent is sufficient and why the researchers did not provide written consent forms. According to the researchers the aim of the study was explained. Privacy was guaranteed, and the data gathered did not reveal the participants identity. Moreover, Giraldo et al. (2018) emphasize that the persons who took part in the study were not pressured or intimidated to communicate their ideas, and that their participation was voluntary. This approach adheres with The Institute's Institutional Review Board (IRB) ensuring the safeguarding of the human rights in research. Accepted ethical principles also insist that an individual should not be coerced into participation. The participant can step back from

the study at any time. The person who takes part in the study and the investigator may not be in a relationship which might suggest compulsion. The researcher is trained and educated and following ethical guidelines. (Finlandia University 2022.) Moreover, it must be explained that the thesis report is written based on the author´s comprehension and interpretation of the texts. The collected articles are analysed and reflected honestly, and the responsibility for the quality of the produced text lies with the narrative literature reviewer. As Josselson (2007, 549) explains, "the literature report is about the researcher`s meaning making". When reporting on the participants 'experiences and stories, the researcher analyses the texts and uses this information to draw academically relevant conclusions useful to readers. The author has strived to apply all the above best practices in this thesis work.

7 CONCLUSION

A narrative literature review on the smart technology "Barcode Medication Administration" and patient safety was performed to identify, assess, and understand various factors that influence the safe and successful implementation of the barcode medication administration system in the hospital and how it affects patient safety. Moreover, this narrative literature review aimed to present improvements or efforts that have been made to enhance the introduction of BCMA to reduce patient harm. The first research question "How can the factors that impact the safe use of BCMA in the hospital setting be described?" and the second research question, "How does BCMA affect patient safety?" are answered within the limitations discussed above. The thesis succeeds in identifying, analysing, and categorising the factors affecting the implementation of BCMA into technological, social, and organisational factors. These factors are described in more detail, and research studies are used to provide an evidence base. The greatest number of studies were found on social-organisational factors such as nurses´ perceptions and expectations about BCMA, workflow-related factors, or workarounds. A few studies examined the pharmacists´ opinions about the use of BCAM. Unexpected was the finding that the physicians´ and the patient´s aspects about the use of BCMA have not been studied so thoroughly. The third research question "How can safety issues be addressed and overcome to enhance patient safety?" is answered by emphasizing improvements that have been made to BCMA in some hospital settings and should be adopted where lacking. These enhancements include the development of BCMA into the closed loop system, mobile phone or tablets and wireless scanners, advancement in data security such as cryptography, the creation of education modules by Juste (2018) and the building of work processes as in the Thompson et al. (2018) study where new workflows were developed to connect the individual insulin pen to the right patient.

The factors which impact the safe use of BCMA can be applied as a frame to examine other smart technologies as well. More studies must be conducted to investigate elements which influence the successful adoption and use of smart tools. Technology develops rapidly and new systems are integrated into existing systems. These networks of tools must be studied in more depth. Automated medicine dispensing cabinets, CPOE, eMAR, and electronic healthcare records (EHR) are already or will be interconnected in the future, and new applications will be added. Since these technologies are interrelated in the closed loop system it is necessary to study these structures as single parts of one complex network. Most studies selected for this literature review investigated only one smart tool such as the BCMA system regarding its benefits and challenges, separated from other smart tools, as in a silo. The author suggests that these various applications should not be examined each individually but should be studied as connected applications.

Patient safety is the main priority of the WHO`s and other organisations´. Studies on the impact of smart technology such as BCMA on patient safety are essential in contributing to the reduction of patient harm. Many countries participate in the development and adoption of new smart tools in healthcare globally. But more research data is needed, and many hospitals still have the need to achieve the competence level in digitalisation based on the HIMSS "AMAM" model to adopt and implement smart tools. In Europe, a challenge to successful introduction of new technology is

probably the diversity of European State Members, different digital competence levels, lack of health data, and lack of common and clear guidelines.

The findings of this literature review may be useful to healthcare professionals who work directly with BCMA, because the thesis discusses many aspects that can be applied in practice. The results may also be relevant to hospital leaders, hospital pharmacies, other organisations providing healthcare services, and manufacturers or vendors of smart technology who are involved in the development of smart tools, and in research and innovation. The results may serve as a teaching tool in educational institutions to provide an insight into the effect of smart technology applied in hospitals on patient safety.

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