Reducing medication errors using lean six sigma methodology in a Thai hospital: an action research study

Title 'Reducing Medication Errors using Lean Six Sigma methodology in a Thai hospital: an action research study'

Abstract

Purpose The purpose of this paper is to illustrate the use of Lean Six Sigma (LSS) and its associated tools to reduce dispensing errors in an inpatient pharmacy of a teaching hospital in Thailand.

Design/methodology/approach The action research methodology was used to illustrate the implementation of Lean Six Sigma through the collaboration between the researcher and participants. The project team followed the Lean Six Sigma Define, Measure, Analyse, Improve, Control (DMAIC) methodology and applied its tools in various phases of the methodology.

Findings The number of dispensing errors decreased from 6 to 2 incidents per 20,000 inpatient days per month between April 2018 and August 2019 representing a 66.66% reduction. The project has improved the dispensing process performance resulting in dispensing error reduction and improved patient safety. The communication channels between the hospital pharmacy and the pharmacy technicians have also been improved.

Research limitation/implications This study was conducted in an inpatient pharmacy of a teaching hospital in Thailand. Therefore, the findings from this study cannot be generalized beyond the specific setting. However, the findings are applicable in the case of similar contexts and/or situations.

Originality/value This is the first study that employs a continuous improvement methodology for the purpose of improving the dispensing process and the quality of care in a hospital. This study contributes to an understanding of how the application of action research can save patients' lives, improve patient safety and increase work satisfaction in the pharmacy service.

1. Introduction

Medication errors are a global public health issue and have been reported worldwide (World Health Organization, 2016). Prescription errors in the UK reportedly affect 12% of all primary care patients and 38% of those aged 75 years and above (World Health Organization, 2016). Annually, 8,000 American people on average die as a result of medication error (Tariq and Scherbak, 2019), with approximately 1.3 million being injured because of such error (U.S. Food and Drug Administration, 2016). From a global perspective, the cost associated with medication error is in excess of $40 billion annually (Tariq and Scherbak, 2019). In Thailand, the rate of hospital medication error has not been estimated due to both a lack of national data (Chumchit *et al.*, 2015) and a system for reporting medication errors. Evidence shows that medication errors lead to patient mortality and morbidity and are a costly problem in hospitals. Errors often result from poor systems design in which the failure is the medication process itself, rather than the individual performance of the healthcare staff. Previous studies have implemented several approaches, such as using 'tall man letter' to differentiate between the 'look alike sound alike medications' by changing medication labels and promoting staff awareness about good practice on collecting and dispensing medications (Wittich, 2014; Stefanacci and Riddle, 2016). Despite such approaches, the root cause of the problems remained in the process and were not resolved. However, the use of process improvement methodologies can enable healthcare practitioners to both ascertain the problems in the medication process and identify and eliminate the root cause of such problems. For example, a study in the Netherlands employed Lean Six Sigma methodology to reduce medication administration errors. This resulted in a reduction of errors by 50 percent and therefore an overall decrease in the potential risk of harm (van de Plas *et al.*, 2017). Furthermore, as most of the medications errors in Norwegian hospitals occur in administration this area should be prioritised for improvement (Antony, Forthun, *et al.*, 2019)

The severity of medication errors ranges from the trivial to the life-threatening (Walsh *et al.*, 2013). Failures in the medication process can lead to decreased patient safety, decreased patient satisfaction with the reduced quality of care being provided and a distrust of the health care sector (Wittich *et al.*, 2014). Other patient outcomes resulting from medication error can include psychological and physical suffering (Whittaker *et al.*, 2018). Medication errors can occur at every stage of the medication process (Antony, Forthun, *et al.*, 2019). Unless a new approach is implemented by healthcare sectors to prevent medication errors, patients will continue to die or be injured as a result of such errors (Hussain *et al.*, 2015). Consequently, there is an urgent need to address health problem caused by medication errors. The World Health Organization (WHO) launched the Medication Without Harm global campaign in 2017, with the aim of addressing medication error at the prescription, transcribing, dispensing, administration and monitoring stages. Ultimately, the WHO want to halve the occurrence of avoidable medication related harm by 2022 (World Health Organization, 2017).

Quality in healthcare worldwide can be improved through increased patient care, reduced hospital stays and reduced hospital costs by employing a continuous improvement (CI) methodology (Lawless, 2016). CI methodologies are widely implemented in every type and size of organization, from manufacturing to the public sector with the aim of managing the achievement of quality (Brown *et al.,* 2008). However, the implementation of CI methodologies is not widely applied in the public sector compared with the private sector (Elias and Davis, 2018). Some of the major challenges identified in the application of CI methodologies in the public sector relate to changing the organization's culture, a lack of customer focus and the tensions between multiple stakeholders demanding different requirements (Fryer *et al.*, 2007). It is also unclear how public sector organizations select their CI methodology (i.e. which criteria are used to inform the selection) and why, for example, Lean is selected over Six Sigma (Rodgers and Antony, 2019).

The most popular business strategies for the employment of CI in the manufacturing and service sectors are Lean and Six Sigma (Albiliwi *et al.*, 2015). Lean originated from the Japanese automobile industry, principally known as the Toyota Production System and was then popularized by the book entitled 'The machine that changed the world' by Womack and Jones (1990). The customer-centric Lean philosophy focuses on the elimination of waste and non-value added activities from the process, thus increasing speed and reducing operational costs. The concept of Six Sigma was introduced by a scientist at Motorola in the mid-1980s (Antony, 2006). Six Sigma is a business management strategy and a data-driven methodology, which aims to reduce variation within a process that can result in defects or errors. It is a problem-solving methodology, which aims to identify and eliminate the causes of defects or mistakes in a process by focusing on customer requirements.

However, the integration of Lean and Six Sigma as Lean Six Sigma (LSS) can contribute to better outcomes rather than the implementation of each methodology individually (Bhat *et al.*, 2014; Salah *et al.*, 2010). The focus of this paper is to explore how LSS can be used to reduce dispensing errors in the inpatient pharmacy of a teaching hospital in Thailand.

2. Lean Six Sigma in Healthcare

LSS is a business improvement strategy which aims to improve quality, speed and customer satisfaction in order to maximize shareholder value (Gijo and Antony, 2014; Laureani *et al.*, 2013). LSS also addresses the root cause of the problems related to process flow and waste and aims to reduce variation within a process (Bhat *et al.*, 2014). Lean and Six Sigma were integrated from the 1980s (George, 2003). The combination of Lean and Six Sigma is important because Lean cannot conduct a process under statistical control and Six Sigma is not able to accelerate the speed of all processes without Lean (George, 2002). LSS is essential as organizations and individuals require a methodology for both process improvement and dealing with problems (Snee, 2010). Healthcare sectors can benefit from LSS to improve their complex processes, quality of care, patient safety and patient satisfaction. Key features that separate LSS from previous quality improvement approaches include: 1) the integration of human factors (such as leadership and customer focus) and process aspects (such as process capability and process management) of process improvement; 2) the improvement of bottom-line results and 3) the following of the DMAIC structure (Snee, 2010; Antony, 2011).

LSS has the potential to contribute as much within healthcare industries as it has within manufacturing industries (Al-Araidah *et al.*, 2010; Laureani *et al.*, 2013). After the first healthcare organization (Commonwealth Health Corporation, KY) successfully implemented LSS in 1998, LSS has been applied in other areas of healthcare organizations, in particular, hospitals. Laureani *et al.* (2013) affirm that the implementation of LSS in the healthcare sector has encountered similar barriers as in other industries. However, the successful implementation of LSS in hospitals has been widely published, for example, the reduction of patient waiting time in a registration process (Bhat *et al.*, 2014), the reduction of turnaround time in a medical records department (Bhat *et al.,* 2016) and the reduction of medication errors (Benitez *et al.*,2007; Esimai, 2005). Based on a review of four case studies on the application of LSS to the reduction of medication errors, the authors concluded that the greatest benefits were enhanced patient safety, greater patient satisfaction, cost savings and greater communication among teams leading to improved team dynamics (Trakulsunti and Antony, 2018). Figure 1 shows a timeline of the LSS application to different healthcare functional areas e.g. emergency care (Parks *et al.,* 2008), inpatient care (Yamamoto *et al.,* 2010) and administrative (Roberts *et al.,* 2017).

Figure 1 insert here

2.1 The application of Lean Six Sigma in the reduction of medication errors

Medication error is one of the primary causes leading to patient morbidity and mortality (Christopher *et al.,* 2014). Medication error is "defined as any preventable events that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of the health care professional, patient, or consumer" (Holmström *et al.,* 2015, p.1). It can occur at any stage in the medication process, stemming from prescribing, transcribing, dispensing and/or administration. A report published by the Institute of Medicine (IOM), *To Err Is Human: Building a Safer Health System,* has raised attention regarding the problem of preventable adverse drug events resulting from medication errors in the healthcare industry (Institute of Medicine, 2000). This report estimated that medication errors cause one out of every 131 outpatient deaths, one out of 854 inpatient deaths and result in a total of 7000 deaths annually. This report has been widely cited in many published studies as a key message in raising patient safety awareness. In the USA, medication errors cause at least one death every day and injure approximately 1.3 million people every year. Medication errors further contribute to a detrimental economic outcome as the cost associated with medication errors is US$ 42 billion each year, which represents almost 1% of the global expenditure on health (World Health Organization, 2017). The

World Health Organization aims to halve the incidence of medication error related harm by 2022 (World Health Organization, 2017).

A variety of technological interventions are being used to reduce medication errors including; computerised physicians orders entry (CPOE), automated dispensing cabinets and bar-coding (NR and BMY, 2013). However, as the installation of these interventions and their maintenance is very costly (NR and BMY, 2013), it is important for the healthcare sector to employ an appropriate process excellence methodology in order to reduce the number of medication errors. Lean and Six Sigma are two of the most powerful business strategies for continuous improvement in hospitals and are appropriate for solving specific problems in the dispensing process. Figure 2 presents a timeline of Lean, Six Sigma and LSS applications for reducing various types of medication error. Chan (2004) first implemented Six Sigma to reduce dispensing errors in a pharmacy department in Taiwan. The results showed that the number of dispensing errors was reduced by 30%. Afterwards, Esimai (2005) combined Lean and Six Sigma in a mid-sized hospital to reduce order entry errors. Five months post LSS implementation, the number of order entry errors reduced from 0.33% to 0.14%. This study also yielded a dramatic reduction in estimated labour costs of $550,000. Similarly, Hintzen *et al.* (2009) showed that hospitals can save the inpatient pharmacy $82,650 annually by reducing the number of errors and missing doses. A study conducted by Benitez *et al.* (2007) followed the DMAIC methodology to reduce transcription errors in the hospital. The results showed that order entry errors consistently improved by 90% after the deployment of a Six Sigma programme. A recent study has been conducted by Antony, Forthun *et al.* (2019) exploring how Lean Six Sigma has been utilised in the Norwegian public healthcare context to reduce medication errors. This study found that while the implementation of LSS in the Norwegian public healthcare context is still in its infancy, its successful implementation not only reduced medication errors, but also improved staff working performance, patient safety, overall satisfaction and hospital profitability (Ching, 2013; Hintzen *et al.*, 2009).

Figure 2 insert here

The majority of research to date has focussed on the investigation of medication error in the health care sector, with a number of studies relating to dispensing errors. However, these latter studies focus primarily on identifying the type of dispensing errors which occur without reference to the strategies which are employed to mitigate against such errors (Aldhwaihi *et al.*, 2016). Action research has not been employed in the healthcare sector to reduce medication errors through the implementation of continuous improvement methodologies. As identified by Antony *et al.* (2017), Lean is not always an appropriate methodology to solve complex problems that require a large amount of data collection and analysis, and advanced statistical tools. Six Sigma, on the other hand, is able to solve complex problems with unknown solutions which can result in defect and/or error reduction. Other approaches such as failure mode and effect analysis (FMEA) can be used to reduce the potential of medication errors, but the main weakness of this approach is the failure to address the root causes of problems in the medication process. The authors argue that LSS is considered to be the most appropriate approach for the purpose of reducing medication errors as Lean tools can be integrated with the Six Sigma methodology to improve the medication process which leading to error reduction, cost reduction, and patient safety improvement.

To date, no study has been conducted on the use of LSS to reduce dispensing errors in the inpatient pharmacy service. The growing body of research on medication errors largely focusses on reducing the number of prescription and administration errors (Kaosayapandhu, 2013). Although rates of dispensing errors are generally low, the potentially fatal consequences with any error necessitates further research, interventions and improvements in the pharmacy distribution system in order to reduce these errors (Cheung *et al.*, 2009). Therefore, this research aims to illustrate the use and implementation of LSS and its tools to reduce dispensing errors in an inpatient pharmacy of a teaching hospital in Thailand by using action research.

3. Research methodology

Action research "aims to produce knowledge that is both practical and scientifically relevant and maintain a normative orientation concerned with issues such as organizational development, democratic processes, equality and emancipation" (Elg *et al.,* 2020, p.2). Action research has been widely used in social settings such as organizational development, education, healthcare and social care (French, 2009). It is designed to bridge the gap between theory, research, and practice (Holter and Schwartz-Barcott, 1993). The key characteristics of action research include; the focus on solving practical problems, the interaction between the researcher and those practitioners who experience the workplace from the inside, the creation of change in the organization and the production of theoretical and practical knowledge (Waterman *et al.*, 2001; Coughlan and Coghlan, 2002; Reason and Bradbury, 2008). In contrast to a case study, action research provides a facility for potential interventions in order to solve problems, whilst a case study method provides a means for observing events, collecting and analyzing data and reporting on results (Farooq and O'Brien, 2015). In this study, action research is selected as the most appropriate methodology as

1) Action research provides the researcher with direct access to the area of investigation, namely the dispensing process;

2) Action research encourages participants to work directly with the researcher to solve problems in the dispensing process and also to implement evaluate change;

3) Action research can indirectly improve quality of care, patient safety, and increase staff satisfaction because it can bring about change in the inpatient pharmacy;

4) Action research is suitable for healthcare issues (e.g. quality patient care and system improvement) because real events can be solved in real-time (Coghlan and Casey, 2001).

In order to solve the dispensing process problem in a Thai hospital's pharmacy division, an action research process was carried out for a period of 10 months.

3.1 Research setting

This study was conducted in the inpatient pharmacy service in a teaching hospital in south Thailand. The hospital aims to provide a tertiary level of health care to people in 14 southern provinces of Thailand. The hospital's operating capacity can accommodate up to 855 beds with over 3,000 staff and can serve up to 3,500 outpatients every day. The main clinical pharmacy activities for the inpatient service consist of; ward rounds, medication reconciliation and drug therapy monitoring (Chaiyakunapruk *et al.,* 2016). The inpatient pharmacy implements the individual medication order system to distribute medication to 38 wards across the hospital. In the individual medication order system, a course of therapy is dispensed regarding the medication order for an individual patient (Management Sciences for Health, 2012). The advantage of this system is that the pharmacists can review a patient medication profile and an appropriate therapy (Management Sciences for Health, 2012). However, the disadvantage of this system is the high number of returned medications to the inpatient pharmacy.

3.3 Inpatient dispensing process steps

The inpatient dispensing process steps start from when the pharmacy technicians receive the medication labels until the medications are collected by the pharmacy technicians and dispensed/delivered by the pharmacists to the different wards. The five key steps of the dispensing process are as follows.

1) Receiving medication orders

Medication orders are automatically printed on labels when doctors enter medication orders into the computeized physician order entry (CPOE) from the wards. The CPOE allows physicians to electronically enter medication orders, laboratory, admission, radiology and transfusion orders (Kaushal *et al.*, 2006). Three computers are used to print different types of medications: computer 1 prints the home medications and STAT medications (i.e. medications that must be administered to patients within 30 minutes, blue label); computer 2 prints the new medications ordered by the doctors (green label); computer 3 prints the continuous medications (pink label).

2) Selection of medications from the shelves

After the medication labels are printed, one of the pharmacy technicians distributes the printed labels to the pharmacy technicians at the four locations (J40, J41, I38 and I39) where they can then select medications from the shelves. Pharmacy technicians select the medications based on the location identified on the medication label. For example. I39Ab means that the pharmacy technician has to collect medication from location I39, column A and row b. The final prepared medications are put together into the three baskets based on the particular colour of medications labels: blue, green and pink.

3) First check the prepared medications

The pharmacy technicians first check all the prepared medication against the labels. They then check the blue and green medication labels, whilst another pharmacy technician checks the pink medication label. Afterwards, they move the baskets to the pharmacists to double check the prepared medications.

4) Double-check the prepared medication by the pharmacists

The pharmacists further double-check all prepared medications. The continuous medications are double-checked by the pharmacist against the label. Home medications, STAT medications and new medications are checked by the front counter pharmacists against the medication orders from the CPOE system. If there are any questions arising from a medication order, the pharmacist must contact either a nurse/doctor to clarify the order (American Society of Hospital Pharmacists, 1994).

5) Dispensing and delivering of medications

After the prepared medications are checked by the pharmacists, the pharmacy technicians arrange these medications in the different ward baskets. Afterwards, the prepared medications are delivered to the wards. Only home-medications are dispensed by front counter pharmacists.

4. Findings

The findings from the action research methodology undertaken in the inpatient pharmacy in a Thai Hospital are presented based on the key phases of the action research methodology: problem identification; reflection; planning action; taking action and evaluation.

Phase 1: Problem identification

To identify problems relating to dispensing errors, a focus group was conducted with four pharmacists and two pharmacy technicians. Over a period of 90 minutes, the focus group participants discussed their opinions and perspectives based on their experience in the inpatient pharmacy. Subsequently, the researcher fed back the data to the participants for validation. Data from the focus group were audio-recoded, transcribed verbatim and analysed using thematic analysis, with the main problems being identified. The focus group indicated that the incorrect selection of medications from the shelves by the pharmacy technicians was the main problem leading to the occurrence of dispensing errors.

> '*The pharmacy technicians did not collect medication based on the location identified in the medication label. They collected medications based on their experience and familiarity' (Focus group, Pharmacists).*

> *'The pharmacy technicians worked rapidly. They collected medications without carefully reading the medication labels' (Focus group, Pharmacists).*

Pharmacy technicians further identified working behaviours that contributed to the occurrence of dispensing errors.

> *'While I was collecting medications, I had to collect the prepared home medications when it was required by the front counter pharmacists to dispense to the patients' relatives. I lose concentration when switching attention between tasks and this leads to the incorrect selection of medications' (Focus group, Pharmacy Technicians).*

Phase 2: Reflection

Participants reflected on the problems identified in Phase 1, in order to make a decision about whether such problems should be taken further, or whether the identified problems required redefining. Process mapping was presented to the participants and explained in detail. After the presentation, the participants indicated that they would like to solve the problem. The team decided to focus on the medication selection process step.

Phase 3: Planning actions

LSS was selected as an intervention tool to solve the identified problem. The participants were trained by the researcher to understand the principles and concepts of Lean and Six Sigma and its tools and techniques. The goal of this training session was for the participants to develop an understanding of the use of appropriate LSS tools and techniques.

Phase 4: Taking action

The researcher conducted three hours of LSS training in the inpatient pharmacy. This training commenced with the principle of Lean thinking and forms of waste in the process. The researcher then introduced Six Sigma and LSS philosophy. The researcher further explained the basic tools and techniques of Lean and Six Sigma (i.e. control chart, run, 5S, VSM, FMEA, Poka-yoke, Pareto, 5 why analysis, Cause and Effect analysis, histogram), the DMAIC methodology, critical success factors and the benefits and challenges of LSS implementation in healthcare. The researcher also presented examples of those LSS implementation case studies which resulted in successfully reducing medication errors. Studies show a general lack of training and education in LSS to reduce medication errors within the healthcare context (Antony, Forthun *et al.,* 2019). After the training session, LSS was employed with the researcher acting as consultant to help the participants solve the identified problems. The action research team followed-up with the DMAIC methodology (Define, Measure, Analyse, Implement and Control). The DMAIC methodology is easy to follow when determining the root causes of problems within the dispensing process.

Define phase

The define phase aims to identify the project scope and goals (Gijo *et al.*, 2013; Bhat *et al.,* 2014) in addition to the problems associated with the process that need to be improved. A project team was formed to include a researcher, a head of pharmacy, a head of inpatient pharmacy, pharmacists and pharmacy technicians. Firstly, a project charter was prepared to help the team focus on project goals and clarify the roles and responsibilities of each team member (Bhat *et al.,* 2014). The charter contained basic project details including; problem statement, project scope, goal, schedule etc. (Table 1).

Table 1 insert here

In the next step, an In Frame/Out of Frame tool was used to ensure that the project had a clear scope (Figure 3). The tool helped the team to have a clear understanding of the project scope.

Figure 3 insert here

The project team then used process mapping to identify problems within the dispensing process at the inpatient pharmacy. Figure 4 shows the flow map of the dispensing process. The researcher walked in both directions through the dispensing process (backwards and then forwards) twice a day in order to understand what had occurred in each of the process steps. During the walks, the researcher also examined how medication flowed from one workstation to the next. The researcher also observed the activities and talked to those staff who were involved in each process step. The researcher collaborated with the pharmacists and the pharmacy technicians to create an as-is dispensing process map. This process map includes six main steps:

1) the medication labels are received by pharmacy technicians;
2) the pharmacy technicians select medications based on each medication label;
3) the prepared medications are first checked by a pharmacy technician who was not involved in selecting the medications;
4) the prepared medications are double-checked by a pharmacist;
5) all of the prepared medications are arranged in different ward baskets
6) the medications are delivered to the different wards, except for the home medications which are dispensed to the patient's relatives by front counter pharmacists.

The team agreed that the incorrect selection of medications by the pharmacy technicians contributed to the dispensing errors at the inpatient pharmacy.

Figure 4 insert here

The incorrect selection of medications was recognised as the main process problem which resulted in dispensing errors. Dispensing errors occurred daily especially in the busy period (8-11 am) and break time (12-2pm). The identified process problems needed to be improved in order to reduce variation in the process of dispensing medicine and mitigate against potentially harming the patients (or even causing death) and financial costs to the hospital.

Measure phase

The project team decided to use dispensing errors as the critical-to-quality (CTQ) characteristics measured in the number of incidents. The team further defined CTQ as the errors that were undetected by the pharmacists in the inpatient pharmacy. The number of dispensing errors was collected to assess the performance of the dispensing process. The dispensing errors detected by the nurses had been reported to the e-hospital system daily. The nurses were trained to report the number of errors to ensure that the measurement of dispensing errors was valid and accurate. The errors were plotted on a P chart. Figure 5 shows that the average proportion of dispensing errors was approximately 0.0003. The results show that the dispensing process was unstable and showed variation. This may have been due to errors caused by newly trained staff or as a result of inadequate resourcing at peak times and break times. In order to reduce process variation and improve the dispensing process performance, the root causes of the problem needed to be identified.

Figure 5 insert here

Analyse phase

The project team held a brainstorming session to identify the potential causes of incorrect medication selection. All of the potential causes of these problems were then visually presented in a Cause and Effect diagram (Figure 6). These included; non-compliance with medications' selection standard procedure; being too rushed; workload; returning medications from wards; inadequate drug storage and pharmacy technicians did not keep tablet bottles in place after using them. Such potential causes were further categorised into three main categories: Methods; Environment and Personnel.

Figure 6 insert here

Using a multi-voting tool, the identified potential causes were further prioritized into the top three causes. Multi-voting procedure includes the following steps (ASQ, 2019):

1. Display the list and number of all the potential causes.
2. Decide how many potential causes must be on the final list and how many choices each team member can vote for.
3. Each team member selects the potential causes based on the number of choices they are allowed to vote for, then ranks the choices in order of priority, with the first choice ranking highest.
4. Record the votes by writing all of the individual rankings next to each choice.
5. Make the decision if the team member is in agreement. The team may further discuss if there is a dramatic difference in the voting.

Table 2 shows that the top three causes of incorrect medication selections were; being too rushed, non-compliance with medications' selection, standard procedure and workload. The team further used 5 Why analysis to identify the root causes of each of the three potential causes (Table 3) (Kieran *et al.*, 2017). The head of the inpatient pharmacy acted as a team facilitator who asked why the problem had happened and recorded the participants' responses. The team facilitator continued to ask why until there was agreement from the participants that the root cause had been identified. After using 5 why analysis, the root cause of these problems was identified as the unbalanced workload between each position of pharmacy technician.

Table 2 insert here

Table 3 insert here

Improve phase

Once the root causes were identified, the team conducted a brainstorming session to generate potential solutions for the selected root causes (Elbireer *et al.*, 2013). They then implemented the most appropriate solutions and observed the results (Gijo *et al.*, 2018). Table 4 presents the corrective actions which were identified in order to minimize the effect of the root causes when incorrect medications were selected. Following this, the team prepared a follow-up plan together with responsibilities and target dates for the completion of the potential solutions.

Table 4 insert here

The following is an explanation of the potential solution identified from the corrective actions which were in turn used to minimize root causes (Table 4).

- Evenly distribute the workload: The team decided to reassign tasks for the pharmacy technicians in order to balance the workload of each location. Two of the pharmacy technicians who were in the team, arranged a meeting with the other pharmacy technicians. The staff who were not team members explained the current workload which was unbalanced between each location. Afterwards, the pharmacy technicians fed the data back to the team. The workload distribution was finally identified as follows:

<u>Location J 40</u>

The following tasks are the additional work for the third pharmacy technician in this location.

- Select injection medication from 12.00 - 1.00 pm and 2.00 - 2.30 pm.
- Deliver total parenteral nutrition, TPN ("TPN; a food replacement given to patients who are not able to eat", Jackson and Wilson, 2005) to different wards.

Location I 38

- As the doctors' ward round is normally early in the morning, a high number of medication is ordered. The second pharmacy technician usually selects and delivers medication between 8.30 am and 9.00 am. The team decided to change the medication selection time to 8.30-8.45 am as the second pharmacy technician could assist the first pharmacy technician with the medication selection and delivery process during the 8.45 - 9.00 am period.

Location I 39

The following is the additional work allocated to the second pharmacy technician in this location.

- Generally, the first pharmacy technician selected the medication during lunchtime. The team decided to assign the second pharmacy technician to select the required medication during the 12.00-1.00 pm period. Moreover, the team decided to increase the number of pharmacy technicians in this location from two to three pharmacy technicians.

Control phase

To ensure that the improvement was sustained, the following measures were taken into account:

- Standard Operating Procedure (SOP) - An SOP was used in the control phase to ensure that the medication selection process steps were carried out correctly and consistently (Antony *et al.*, 2016). The medication selection SOP process was placed near the pharmacy technicians' workstation. The SOP provided the details of the task descriptions in each location, in addition to identifying the responsible person. The staff in the inpatient pharmacy were trained on how to use the SOP so as to ensure that all staff understood and followed the instructions correctly. After the SOP was implemented, it was evaluated and updated every month by a team member. Moreover, staff were monitored regularly by the head of the inpatient pharmacy to ensure that they followed the SOP.

- Control chart - The team developed a control chart to monitor the dispensing process every month and subsequently plot the P chart. When any signal for an assignable cause appeared in the control chart, the head of pharmacy discussed the associated issue with the staff and took corrective action to resolve the cause of variation (Bhat *et al.*, 2014). As a result of the improvements, the dispensing process started to behave as an in control process (Figure 7). The average proportion of dispensing errors significantly reduced ($p<0.05$) from 0.0003 to 0.0002. The variation of the dispensing process was considerably reduced. Morover, the numbers of dispensing errors reduced from 6 to 2 from April 2018 to August 2019. This represented a 66.66 % reduction. A Wilcoxon signed rank test was used to compare the proportion of dispensing errors before and after LSS implementation. The results indicated that the proportion of dispensing errors after LSS implementation was statistically significantly lower than before ($Z= -2.11$, $p=0.034$). The results also suggest that the implementation of the LSS methodology caused a significant decrease in the number of dispensing errors ($p=0.034$).

Figure 7 insert here

Phase 5: Evaluation

The researcher collaborated with the participants to evaluate the outcome of the LSS implementation. The participants reflected on the project and any outcomes of change to the dispensing process. Semi-structured interviews were conducted in this phase to evaluate the outcome of LSS implementation. Each participant was asked the same set of questions to express their feelings, perspectives and opinions after the implementation of LSS. Each interview was conducted in the meeting room in the inpatient pharmacy and lasted approximately 60-90 minutes. The interviews were audio-recorded, transcribed verbatim and subsequently analysed using thematic analysis. Two main themes emerged (Table 5).

Table 5 insert here

Change in dispensing process: The participants perceived a few changes in the dispensing process resulting from the implementation of LSS. A key sub-theme that emerged was that of dispensing process improvement. Participants who were pharmacists felt that there was a small change in the dispensing process. Two pharmacists described it as follows:

> *'Creating change in the dispensing process in a large hospital required several key factors such as top management support, or hospital's policy to require change'.*
>
> *'It was so difficult to change the pharmacy service. If we change these steps, it affects another step. If we want to change something that is related to technology, we have to wait for the IT department to help us'*

The pharmacy technicians expressed their positive views about their new tasks during the selection of medications.

> *'We were very satisfied with the new distribution of our routine jobs. It decreased the number of works that I needed to daily'.*
>
> *'We thought that the new assigned tasks for each position were better than the previous jobs that we received'*

These findings suggest that the pharmacy technicians perceived more change in the dispensing process because it decreased their workload and improved the quality of their working performance. However, in terms of the perspectives of middle managers, they did not perceive much about the change because they were not involved in the medications selection process.

Thoughts about DMAIC methodology and its applications in the dispensing process

Problem-solving methodology

Participants described that the implementation of LSS could help them understand where the problem lay in the dispensing process and within which process step. The participants' feedback included:

'The structure of DMAIC methodology was clear and easy to follow. DMAIC methodology helped us to understand which process step contributed to a high number of dispensing errors'.

'Every process could follow DMAIC steps. The application of LSS helped us to identify which process steps created a high number of dispensing errors. Once the root cause was identified with the data to support the decision, we could finally generate the solutions to solve the root causes of the problem'.

LSS can be used in the dispensing process

All participants were very convinced that LSS could be used in the dispensing process. The primary reason that participants were not applying LSS before in the pharmacy service was that they did not know about LSS. However, one of the participants indicated that some phases of the DMAIC methodology were regularly applied in the pharmacy services. Participants clarified that:

'We regularly applied some phases which were similar to the application of DMAIC methodology. These phases included define the problems and identify the causes of these problems. However, the solutions that we had generated never changed the dispensing process nor permanently solved the problems'.

5. Discussion

This study applied the LSS methodology to reduce the number of dispensing errors and improve patient safety and staff satisfaction in the inpatient pharmacy of a teaching hospital in Thailand. The results showed that the implementation of LSS can reduce process variation with dispensing errors being reduced by 66.66%. These results are in line with findings from the implementation of LSS within Norwegian Health public hospitals, which saw the main type of medication errors include dispensing errors (Antony, Forthun *et al.*, 2019). These findings were also reported by Chan (2004) who applied Six Sigma in the outpatient department, which resulted in a 30% reduction in dispensing errors. However, Chan's study does not include process flow benefits as the study was not integrated with Lean tools. This finding is also consistent with those of Ching *et al.* (2013) and Chiarini

(2012) whose implementation of the DMAIC methodology resulted in reduction of errors relating to administered medication doses and parenteral medication administration.

The results from this study indicated that the top 3 causes of incorrect medication selection were; non compliance with the medication selection standard procedure, and technicians reporting that they were too rushed and the workload was imbalanced. These findings are in line with those from Aldhwaihi *et al.* (2016) and Rajah *et al.* (2019). In a study of dispensing errors in an outpatient pharmacy in 6 Malaysian hospitals, distractions and an interrupted work environment were cited as the leading cause of dispensing error (Rajah *et al.,* 2019). Secondary causes were cited as a lack of knowledge and skills which resulted in non-compliance with standards (Rajah *et al.,* 2019).

The results of this study showed that the prevention of dispensing errors before reaching patients led to an improvement in patient safety. Furthermore, the staff involved were very satisfied with their new routine tasks and their improved quality of life. Similarly, Esimai (2005) implemented LSS in a hospital setting in order to reduce the incorrect entry of medication orders. He concluded that improved employee morale was one of the key benefits of this implementation.

The DMAIC methodology can be applied to an inpatient pharmacy in order to reduce dispensing errors. This is in line with key findings from Al Kuwaiti (2016) where DMAIC was applied in an outpatient pharmacy of a Saudi Arabian hospital. The results showed a marked reduction in medication errors (Al Kuwaiti, 2016). Meanwhile, Castle *et al*. (2005) demonstrated that the implementation of the DMAIC methodology resulted in a reduction in the dispensing rate and number of several types of medication. This finding is consistent with that of Chan (2004) who implemented the DMAIC methodology to reduce dispensing errors in a pharmacy department. However, in the analysis phase, Chan’s study has not incorporated Lean or Six Sigma tools to identify the root cause of the problems. This finding has important implications for using the correct tool in the relevant phase of the DMAIC methodology.

Lean and Six Sigma tools and techniques were implemented across the DMAIC methodology, mostly using non-statistical tools. Appropriate Lean and six sigma tools were selected based on the nature of the problem. Lean tools applied in this study included process mapping, standard operating procedure and line balancing. A similar finding was reported by Trakulsunti e*t al.* (2018) who identified that the top five Lean tools which are widely used to reduce medication were; process mapping, spaghetti diagram, visual process control, standard operating procedure and Poka-yoke. While Line balancing was used in this study, it has not been applied in the previous studies. The findings from the application of Line balancing show that the unbalanced workload between each position of collected medication was the root cause of the incorrect selection of medication. Therefore, evenly distributing the workload between the workstations was required in this study. Previous published studies are limited to the use of line balancing to balance tasks across all process steps.

The Six Sigma tools which were implemented across the DMAIC methodology mostly comprised non-statistical tools such as brainstorming and 5 Why analysis.

Understanding the LSS methodology and its tools was a key factor which led to the success of this project. It was also cited as a critical factor to successful project outcomes (Taner *et al.*, 2007; Manville *et al.*, 2012; Alhuraish *et al.*, 2017). However, the findings revealed that not only participants and the project team should understand LSS, but also all staff in the inpatient pharmacy. This finding is contrary to previous studies which have not mentioned that all staff in the inpatient service should understand and/or receive LSS training. The authors suggest that understanding LSS tools and its philosophy by staff at all levels in the healthcare organization, in particular, those involved in the medication process, is important to the success of an LSS project. However, the considerable investment in both time and cost for successful LSS implementation should not be ignored.

6. Conclusion, implications and directions for future research

The successful implementation of LSS resulted in improvements in the performance of an existing dispensing process in the inpatient pharmacy. The number of dispensing errors decreased from 6 to 2 incidents between April 2018 and August 2019, representing a 66.66% reduction. Importantly, this study has resulted in improvements in patient safety by reducing dispensing errors. It has also created a better communication between pharmacists and pharmacy technicians and increased patient satisfaction. This study has also increased participants and staff awareness of the implementation of LSS methodology to other areas in the pharmacy services and departments in the hospitals. The participants also noted that resistance to change was very challenging. Insufficient resources (e.g. time and budget) and knowledge of LSS were major challenges when applying LSS in the inpatient pharmacy. However, the study highlights that an understanding of LSS methodology and top management support were key success factors in overcoming challenges of LSS implementation. This is in line with findings from Antony, Lizarelli, *et al.* (2019) and Antony, Sony, *et al.* (2019) which demonstrate that a lack of top management commitment can result in an unsuccessful implementation and a failure to address the identified issues.

This is the first study applying LSS to the reduction of dispensing errors in the inpatient pharmacy in a teaching hospital. This study would be of interest to hospitals, with the dual aims of improving patient safety and reducing operational costs. A similar project in other hospitals has the potential to reduce errors in every phase of the medication use process, from prescribing, transcribing, and dispensing to the administration of the medication. It is vital to select an appropriately skilled team member to execute an LSS project and address medication process problems. Essential skills required for the project team members are; problem-solving, integrity and technical expertise (understanding data and analysis). Moreover, it is important for the project team to select the most appropriate LSS tools in addressing medication process improvement. Adoption of an LSS roadmap could help health-care organizations in the successful implementation of LSS. The success of an LSS project is also dependent upon the allocation of sufficient time from team members.

In this study, organizational learning theory has been applied within the context of medication error by considering how single-loop and double-loop learning can be facilitated for the purpose of reducing medication dispensing error. Single-loop learning can be described as the type of learning that takes place when we encounter a situation with problems and fix those problems without altering the structure of the system. Consequently, single-loop learning can result in behavioural changes and/or in taking actions to improve the situation so that the system will function better. However, one of the issues with single-loop learning is that whilst the symptoms may be removed, the root causes remain in the process (Reychav *et al.*, 2016). Meanwhile, double-learning, as developed by Argyris and Schon (1996), focuses on addressing the root cause of the problems. The implementation of double-loop learning can enable organizations to detect and/or correct the underlying root causes of problems. The authors contend that the systematic use of the DMAIC methodology for reducing medication errors in the Thai hospital creates a double-loop learning process (Antony *et al.,* 2020). This double-loop learning addresses the root causes of the problems in the dispensing process by changing underlying causes in areas including the medication selection procedures and also in inpatient pharmacy staff attitudes and behaviours.

The scope of this study was limited in terms of it being context specific. This study was undertaken in the inpatient pharmacy in a public hospital in Thailand. The findings from the action research methodology cannot be generalized beyond the specific setting (Montgomery *et al.*, 2015). However, the dissemination of findings could be applicable to or inform other similar contexts or situations. Another limitation of this study was that doctors and nurses did not participate in the project team. Given theses limitations, the authors contend that the scope of this research could be extended to;

- understand the key characteristic of LSS in different hospital settings, by applying LSS in private hospitals to reduce medication errors, and then comparing the key findings with those from public hospitals.
- reduce medication errors across hospitals to save cost by employing LSS to reduce errors occurring in every step of medication use process, including; prescribing, transcribing, dispensing and administration of the medication.
- study outpatient settings and inpatient wards for further improvement.

- deploy and analyse surveys or interviews to capture the higher-level understanding of healthcare staff by asking the following questions:
  - What Lean, Six Sigma, LSS or existing continuous improvement methodologies have hospitals been using to reduce medication error?
  - How many people have been trained on continuous improvement methodologies?
  - What training have people received with respect to quality and continual improvement tools?

The answers to these questions can be used to help project teams understand whether or not hospitals are familiar with Lean, Six Sigma, and LSS and whether or not there is a 'real' awareness of such tools. Project teams may also prepare an LSS awareness programme for physicians, nurses and pharmacies and/or other staff from different departments (Bhat *et al.*, 2014). Notwithstanding, it is critical to maintain the actions outlined in the control phase in order to sustain improvements (Al Kuwaiti, 2016). In conclusion, the calculation of the cost of the medication errors is necessary for future research, in order to evaluate the impact of intervention (i.e. Lean, Six Sigma or LSS). However, it is essential to understand the key stakeholders in order to evaluate this impact. Stakeholder buy-in is an important element in LSS project management (Sunder, 2016). The identification of stakeholders will assist the LSS project team to understand those influenced or affected by the project. The stakeholder analysis framework proposed by Elias (2016) is a very useful tool for hospital managers in the identification of stakeholders. Given the rising cost of medical care, it is increasingly important to reduce/eliminate un-necessary operational expenses which are within the control of the healthcare sector.

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