Development of a notification system for intravenous-to-oral antibiotic switch therapy in pediatric wards using value stream mapping

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ABSTRACT

Objective: This research developed a notification intravenous-to-oral antibiotic switch therapy system using value stream mapping (VSM) through the Plan-Do-Study-Act (PDSA) method. **Materials and Methods:** The action research took place in two target groups: Group 1 included a multidisciplinary team and Group 2 included pneumonia patients admitted to two pediatric wards. The system had two phases: In Phase I, Situation analysis reviewed 400 medical records and In Phase II, a system was developed that used PDSA as follows: Plan: analysis of the methods. Do: The demonstrated process used VSM. Study: A system designed. Act: Comparing each step used VSM. The system was evaluated by time measurement, the rate of switching intravenous to oral, length of intravenous therapy, and length of stay display using descriptive statistics. **Results:** Development of notification system by an integrated information system and electronic trigger tool to identify cases eligible for switch therapy that showed an increase in the activity ratio and reduced the total lead time from 175 to 159 min, reduced the length of intravenous therapy and length of stay. **Conclusions:** Notification systems rapidly screen patients and reduce the time process and can apply to hospitals using electronic health records and suggested in the form of policies.

Keywords: Antibiotic, notification system, pediatric ward (value stream mapping), switch therapy

INTRODUCTION

Switching intravenous antibiotics to oral therapy is a policy for promoting rational drug use.[1,2] It helps reduce exposure to the adverse effects of using intravenous therapy, the physician's preparation and drug management workload, the cost of intravenous therapy, the length of intravenous therapy, the length of stay, and hospital costs.[3,4] The development of a system to promote antibiotic rational drug use requires cooperation from relevant staff in the hospital.[5]

Several health-care services have used the lean process to help improve the quality of services by working cooperatively to deliver a valuable outcome to recipients based on the concepts "value," "waste," and "value added." Using value stream mapping (VSM) as an initial analysis tool through staff and recipient cooperation is an essential step in the Plan-Do-Study-Act (PDSA) method to solve problems with efficacy by taking opportunities for planning and improving the existing system. It could be stated that VSM is a tool to facilitate the lean process.[6] A scoping review of 80 journal articles between 2015 and 2019 revealed that in the United States, 70% of large medical centers have used VSM to improve several departments, including emergency departments, oncology departments, and radiology departments. They had accomplished this by following up on patients' lead time, waiting time, and process time using VSM alongside other problem-solving tools.[7] A study of the improvement of the cervical cancer screening system showed that the processing time was reduced from 54 h to 31 h, medication errors reduced from 7.6% to 4.4%, and no labeling errors were undetected.[8]

An analysis of the drug inventory management instituted in Bora Bue Hospital in Maha Sarakham Province showed that out of ten activities, there were three value-added activities, four non-value-added activities, and three non-value-added but essential activities. The time required to create valuable work was 30.60% of total time, with an overall systemic time of 8.340 min. The total time of each process was 6,220 min, which is a full-time equivalent of 1.004 FTEs. This led to a redesign of the system by removing unnecessary activities, merging activities, and designing technology to work on data management in place of humans.[9] The emergency Outpatient Department of Srinagarind Hospital had compared time requirements for each model. It was observed that of 15 models created and tested, Model 15 reduced the average time of discharged patients who did not undergo procedures, discharged patients who passed X-rays and laboratory examinations, and discharged patients who passed laboratory examinations by 15.99%, 21.29%, and 18.85% on average, respectively.[10]

The previous studies have proven the efficiency of promoting a switch from intravenous to oral therapy, such as staff training, staff feedback, computerized decision support system, or documentation system. The recommendations from pharmacists to prescribers printed checklist which contained intravenous to oral switch criteria to patients' medical notes in Malaysia district hospitals helped improve the timeliness of switching from intravenous to oral therapy, reducing the duration of IV, reducing the length of hospitalization, and increasing antibiotic cost savings[11] similar to the effects of as the audit, feedback, and verbal reminders in Lampang hospital.[12] The efficacy of promoting a switch from intravenous to oral therapy in pediatric patients is still unclear from a lack of studies. Nevertheless, there is a possibility of reducing the risk of adverse drug event exposure for patients receiving IV therapy. Some Hospital physicians in Thailand decide when to switch from intravenous to oral therapy, yet there are still no official guidelines. Because there is a lack of computerized physicians' order entry (CPOE) and regularity pharmacists in some wards, pharmacists have to review medication profiles from different sources: computer-based, doctor order sheets, or medical charts for selected patients eligible for switch therapy. Therefore, this study was done to promote the switch from intravenous to oral therapy in pediatric patients by pharmacists using VSM and the PDSA method to seek the opportunity to reduce waste and integrate the data to promote rational drug use. The objectives were to develop a notification intravenous-to-oral antibiotic switch therapy system using VSM through the PDSA method, a cooperative design, and a less complicated system.

MATERIALS AND METHODS

Study Designs

This action research was conducted in Khon Kaen hospital at Pediatric wards. Ethical approval for the study was sought from Khon Kaen University.

Population and Sample

There are two target groups. Group 1 includes a multidisciplinary team in Khon Kaen Hospital involved in system development, and Group 2 includes pneumonia patients admitted in two pediatric wards that received the target intravenous therapy.

Study Protocol

The development of the system was in two phases. Phase I involved a retrospective study for situation analysis about intravenous-to-oral antibiotic switch therapy obtained from reviewed medical records on an intravenous antibiotic drug that was replaced with oral therapy in 400 patients who were prescribed targeted IV drugs and admitted to Khon Kaen Hospital in August 2019 and September 2019. The necessary information gathered for the description included the name of the departments, physician diagnosis, the rate of switching from intravenous to oral, and the length of intravenous therapy.

Phase II involved a system developed using the PDSA method and VSM. The PDSA method followed a four-stage cyclic learning approach to adapt changes aimed for improvement in Figure 1. The "plan" stage simply involved planning a change, the "do" stage carried out the change, the "study" stage examined the results, and the "act" stage identified adaptations and ran through the cycle again.[13]

VSM displayed all critical steps in a specific process and volume taken at each stage to identify, remove, or reduce waste. The current system shown in VSM was then reviewed in detail by the team to identify waste that could be eliminated and identify opportunities to minimize the potential for errors. Processes identified three types: (1) Non-value adding (NVA) operations refer to processes that should be eliminated, such as waiting. (2) Necessary but NVA (NNVA) operations are wasteful but necessary processes under current operating procedures. (3) Value-adding (VA) operations are processes that add value to the procedures.[14] A development notifications system was presented in VSM to show the new workflow. Team development setup and configuration of the notification system selected electronic data, such as medications data, laboratories data required discussions, and decisions by the team of pharmacy clinicians and management. This introduced the team to the new workflow.

The PDSA Cycle of this Study Was as Follows

Plan

Analysis of the methods performed intravenous-to-oral switch therapy in the pediatric department, staff capabilities, and the

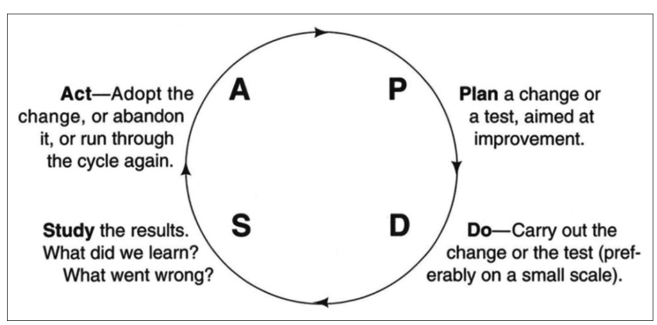

Figure 1: The Shewhart cycle for learning and improvement (the PDSA cycle)

data system. Data were collected from pneumonia patients admitted in pediatric wards who received target intravenous therapy within 48 h between 1 January 2020 and 31 March 2020.

Do

The pre-development process was represented by VSM, collected and analyzed data, identified improvement opportunities, and selected opportunities that should be targeted for the future state.

Study

The notification system was designed for intravenous-to-oral switch therapy and collected information from relevant staff meetings.

Act

After developing the notification system, all process was compared using VSM (Model 1). Data were collected from September to November 2020. Then, the developing team discussed and evaluated the opportunity for system development by VSM, time measurement, rate of switching from intravenous to oral, length of intravenous therapy, and length of stay.

Statistical Analysis

All data were entered into Microsoft Excel for analysis of descriptive summary statistics.

Ethics Approval

This study was approved by the Khon Kaen University Ethics Committee on human research study based on the Declaration of Helsinki and the ICH good clinical practice guidelines.

RESULTS

Phase I: Situation Analysis from Medical Records

A retrospective study of 400 patients' medical records admitted in Khon Kaen Hospital from August 2019 to September 2019 was included: 145 patients from the general medicine department (36.25%), 135 patients from the surgery department (33.75%), 70 patients from the pediatric department (17.50%), 20 patients from the orthopedic department (5.00%), and 30 patients from other departments (7.50%). There was a 55% overall switch rate from intravenous to oral therapy. The department with the highest ratio for switch therapy was the pediatric department (77.14%), with a length of intravenous therapy of 5.39 ± 5.56 days, followed by the surgery department (54.48%) with a length of intravenous therapy of 6.00 ± 3.90 days. The department with the least ratio of switch therapy was the general medicine department (33.10%), with a length of 5.17 ± 2.41 days. Unfortunately, only 19.25% of patients had received intravenous therapy throughout the treatment, and 7.5% were referred back to receive intravenous therapy at primary hospitals. Therefore, the encouraging of switching from antibiotic intravenous therapy to oral therapy in these patients could promote the hospital's rational drug use.

Phase II: A System Developed Using the PDSA Concept and VSM

Analyzing and planning (Plan)

The baseline data revealed that from 70 patients admitted to the pediatric wards of Khon Kaen Hospital, the switch therapy ratio was 77.14%, whereas the length of intravenous therapy was 5.39 + 5.56 days. The infection that saw most switch therapy was pneumonia (65%) because there were official guidelines on the treatment of acute respiratory infection in pediatric patients that vividly state the diagnosis, treatments, and strength of the intravenous therapy and oral antibiotics used.[15] Therefore, the physician would switch therapy considered physical examinations, laboratory examinations, and pneumonia treatment guidelines to improve the patient's conditions. Therefore, the design of a system that permits access to patient information, such as laboratory examinations, treatment start date, the length of using intravenous therapy, especially dosage strength, and side effects, was necessary to provide support for physicians.

Regarding staff capabilities, there were professional infectious disease physicians, but there were no pharmacists. Pharmacists communicated with physicians and nurses through consultation from or telephone calls.

Regarding drug information system capabilities, Khon Kaen Hospital did not have a computer decision-supporting system to promote rational drug use. The laboratory examinations and medication records were unlinked and accessing them was complicated.

Developing a system (Do)

VSM was used to create a figure from the customers' point of view focused on work and relevant staff, the flow of resources, and the information service system. According to Figure 2, there were nine activities in the switch therapy process from when the patients were admitted into the hospital until the patent received the drug.

The idea of designing a system that involved trigger tools to help screen for patients who surpassed the criteria to switch from antibiotic intravenous therapy to oral switch therapy was initiated by examining multidisciplinary team data requirements. There were two types of data in the hospital's computer program: Documented data and electronic data. Both data sets were used to develop trigger tools to support the screening. Adequate trigger tools needed to be the data recorded in the hospital electronic system that people in the multidisciplinary team selected based on literature review and the availability of data from Khon Kaen Hospital that can be applied to the aforementioned task, as shown in Table 1.

Studying and reviewing (Study)

The design of an intravenous-to-oral switch therapy system was made possible through the cooperation of a developed team. Nine key activities of the system were categorized based on relevant important issues: policies, internal process development, or accessibility to necessary information. It also involved three groups of processes: NVA, NNVA, and VA**.** The limitations of each activity then created a possible intervention for improvement, as shown in Table 2.

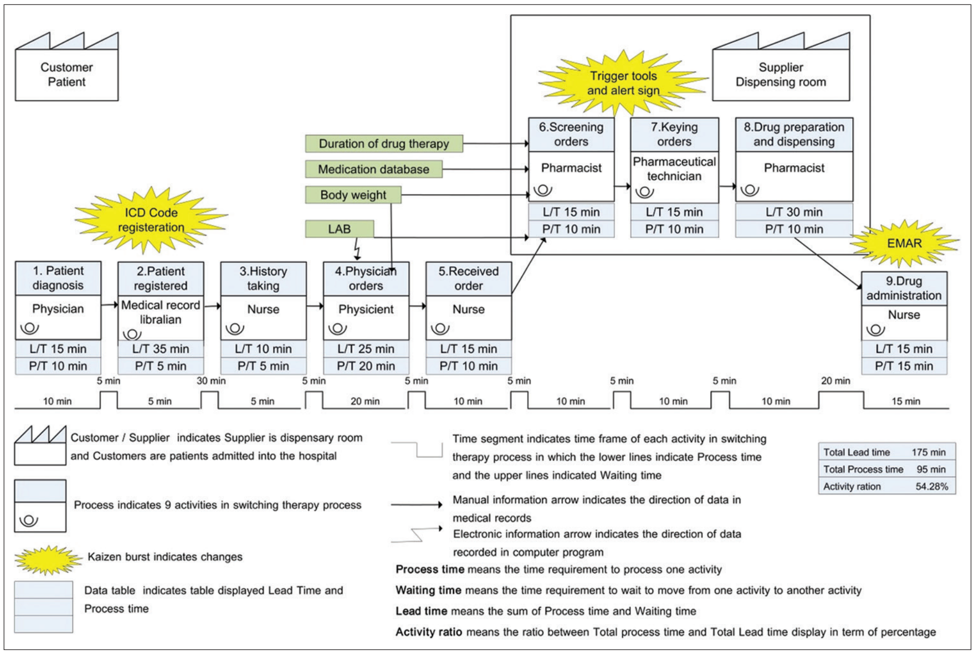

Figure 2: Workflow of performing switch therapy before system implementation

Table 1: Comparison of trigger tools from reviewed literature and selected trigger tools

Trigger tools	Calloway	Fischer	Availability of data	Selected trigger tools
Diagnosis			Incomplete data	
IV to PO conversion	/		official guidelines	
ADR Alert	/		Electronic data	/
Target drugs orders	/	/	Electronic data	/
Bacterial cultures	/		Electronic data	
Fungal cultures	/		Electronic data	
Oral medication orders		/	Electronic data	/
Antibiotic start date			Electronic data	/

The areas that needed to be improved focused on 3 issues.

1. Issue 1: Accessibility to necessary information (information system)

   Accessibility to necessary information was the first issue where a developed team could create an improvement by selecting trigger tools, such as medical records of target drugs, oral medication orders, and adverse drug reaction (ADR) alerts, to allow the pharmacist to screen for patients who surpass the criteria for switch therapy. In addition, the computer program was assigned to calculate the length of intravenous therapy; link the data to laboratory examinations, especially electrolyte tests; and show the result on the recorded data page. If the length of the target drug therapy was more than 3 days, the pharmacist would create a symbol by highlighting the name of the drug and the length of therapy to communicate with physicians and nurses through the patient's medication profile. Furthermore, using Microsoft Excel to calculate dose regimens for pharmacists and nurses will benefit antibiotic recheck doses. This advancement was supported by 38 studies published between 1980 and 2015 that found that decisions on rational antibiotic use were influenced by the process of ordering antibiotics (76%), integrating electronic medical record systems (74%), and correlating with hospital policy (76%).[16]

2. Issue 2: An internal process on patients' data recording

   An internal process on patients' data recording was a problem related to registration activity. Patient information was incomplete, prohibiting the pharmacist from screening for eligible patients. Consequently, the team had established a rule that stated a primary ICD code needed to be recorded within 24 h by medical record librarians or nurses in the patient wards. This information, along with the patients' medical records and laboratory examinations, would be displayed in the dispensing program as well. Hence, the pharmacist could rapidly screen for patients who passed the criteria for switch therapy and inform the medical staff.

3. Issue 3: Hospital policy

   A problem related to the hospital's drug system, including recording CPOE and the electronic medication administration record (EMAR) requires a hospital policy change. The development team had suggested information to the pharmaceutical and therapeutics committee (PTC)

Table 2: Areas needed to be improved with process activities and possible interventions

Areas	Activities	Type of process	Limitations	Intervention
Hospital policy	Activity 1: Physician diagnosed pneumonic patients according to professional standards	VA	Handwritten documentation	Recorded orders using computer program, computerized physician order entry (CPOE)
An internal process on patient's data recording	Activity 2: Register admitted patients' data	VA	The completeness of ICD code registration	Settled a rule that primary ICD code needs to be recorded with 24 h by medical record librarians or nurses at the patient wards
Hospital policy	Activity 3: Nurse performs patient's history taking according to professional standards	VA	Handwritten documentation	Policy recommendation and planning electronic medical administration record (EMAR) system
Accessibility to necessary information	Activity 4: Reevaluate the patient's conditions; the information system for physicians to access laboratory examination is available	VA	-	-
Accessibility to necessary information	Activity 5: Nurse receives the order	VA	The medical strength was rechecked by calculating each medicine one by one using a calculator	Computer software for dosage regimens calculation using Microsoft Excel Nurse recorded the patient's weight in a copy of orders Policy recommendation and planning EMAR system
Accessibility to necessary information	Activity 6: Pharmacist rechecks the orders	VA	Lack of patient's weight and laboratory examination	Development of a dispensing program that includes trigger tools Computer software to calculate the duration of therapy automatically A computer program that can display a patient's weight Link the database with laboratory examinations Pharmacist examined the following trigger tools: intravenous antibiotic used and drugs in inotropic drug groups
An internal process on patient's data recording	Activity 7: Recorded orders by pharmaceutical technicians	VA		Added patient's weight in the recorded data into the program
Internal process in dispensary room	Activity 8: Drug preparation and dispensing	VA	-	-
Hospital policy	Activity 9: Drug administration	NVA	Nurse copied doctor order in medication administration record before drug administration	Policy recommendation and planning EMAR system

NVA: Non-value adding operations, NNVA: Necessary but non-value adding operations, VA: Value adding operations

to promote these changes.

Evaluating System Performance (Act)

When comparing the outcomes before and after applying the system development, it was observed that the total process time was reduced from 95 min to 88 min. The activities that could reduce the time included activity 5, when the nurse received the order because there was computer software to assist with dosage regimen calculation, and activity 6, when the pharmacist received the order, because there was a computer program to calculate the duration of the therapy automatically, trigger tools observed, and patient's weight observed on the doctor's order sheet. This helped pharmacists reduce the time requirement for rechecking orders and screening for patients who surpassed the criteria for intravenous-to-oral switch therapy. It also reduced the waiting time between when the nurse received the order and sent it to the dispensary room and when the pharmacist rechecked the order and recorded it, which resulted in the reduction of the total lead time from 175 min to 159 min. The activity ratio also increased from 54.28% to 55.34% after the system development. The details are displayed in Figure 3. From the development of a system using VSM, the developed system was applied to the intravenous-to-oral switch therapy system in the pediatric wards of Khon Kaen Hospital. A comparison of the data between the outcomes before and after the system was applied showed that the length of intravenous therapy was reduced from 4.5 to 3.7 days and the length of stay from 5.8 to 4.5 days, as shown in Tables 3 and 4.

DISCUSSION

Antibiotic intravenous-to-oral switch therapy is a policy used to promote rational drug use worldwide, including in Thailand.

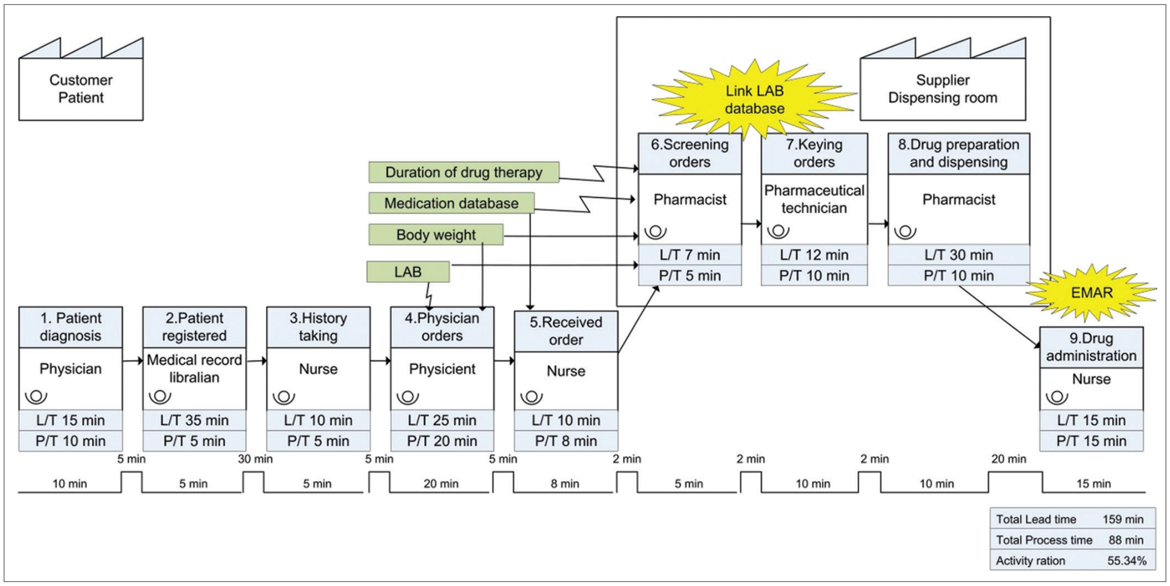

Figure 3: Workflow of performing switch therapy after system implementation (Model 1)

Table 3: Patients' characteristics and outcomes before and after implementing the developed system

Population characteristics	Before		After	
	N (70)	Percent	N (50)	Percent
Gender				
Male	49	70.00	33	66.00
Female	21	30.00	17	34.00
Age				
1–2 months	7	10.00	5	10.00
3–12 months	15	24.40	16	32.00
1–5 years	43	61.40	28	56.00
More than 5 years	5	7.20	1	2.00
Amount of intravenous therapy used				
1 item	50	71.40	46	71.50
2 items	16	22.90	3	22.80
3 items	4	5.70	1	5.70
List of intravenous therapies initially started				
Ceftriaxone	51	72.80	39	78.00
Ceftazidime	5	7.10	2	4.00
Ampicillin	9	12.90	2	4.00
Cefotaxime	3	4.30	6	12.00
Piperacillin+sulbactam	2	2.90	1	2.00
List of switched oral therapies				
Amoxicillin	19	33.90	22	61.10
Cefdinir	2	3.60	-	-
Amoxicillin+clavulanic acid	34	60.70	13	36.10
Erythromycin	1	1.80		
Levofloxacin			1	2.80
Methods of treatments				
Switch therapy	56	80.00	36	72.00
Continuous intravenous therapy	11	15.70	12	24.00
Referred back to received intravenous therapy at primary hospitals	3	4.30	2	4.00

Table 4: The outcomes of switch therapy

Outcomes	Average (SD)	Average (SD)
Length of intravenous therapy (day)	4.50 (2.50)	3.70 (1.90)
Length of stay (day)	5.80 (3.40)	4.50 (2.40)

SD: Standard division

The development of a notification system for intravenous-to-oral antibiotic switch therapy in pediatric wards through the PDSA concept, using VSM to help evaluate the process. According to the evaluation, there was one non-value-adding activity in which the nurse would copy handwritten documentation into the nurse's medical record. Therefore, this activity was replaced by policy recommendations and planning by an electronic medication administration record system. An internal process on patient's data recording and accessibility to necessary information was developed by an integrated information system to create an easier work process, electronic trigger tools (an intravenous antibiotic used and drugs in inotropic drug groups), and information (duration of the target drug therapy, ADR alert, and laboratory results) for pharmacists to identify cases eligible for switch therapy.

Applying PDSA and VSM to develop an intravenous-to-oral switch therapy in pediatric wards showed an increase in the activity ratio. Total process time was reduced from 175 min to 159 min, reducing the length of intravenous therapy by 1 day, which was similar to developing a pharmaceutical distributor process that used VSM to acquire and reduce waste from the inventory control process in Bora Bue Hospital.[9] The reduction in the length of intravenous therapy and length of stay agrees with Muenpa R *et al*., who studied the efficacy of pharmacists' involvement in the promotion of intravenous-to-oral switching.[11] Kong and Sze, who reported a reduction in the length of hospital stay through the printed sticker antimicrobial stewardship recommendations.[12]

In both studies, pharmacists identified cases eligible for switch therapy through daily screening of the medication charts, laboratory results, and medication prescribed, but in our study, the notifications developed helped pharmacists detect switching candidates by the trigger tools on the screens that record medication orders at the dispensary that applied a computer notification system. In Brazil, a computer notification system that consisted of displaying a message in the computerized prescription on the 3rd day and suspension of the prescription on the 5th day of antibiotics intravenous antimicrobial therapy was implemented, and pharmacists collaborated with physicians to confirm the drug orders in the Brazilian university hospital, reducing the duration of intravenous antimicrobial therapy by 1 day.[17] However, the switch therapy ratio was increased from 80% to 72% after applying the developed system due to patient conditions, such as fever, shortness of breath, and age being between 1 month to 3 years.

Although the research on the development of an intravenous-to-oral switch therapy system under the concept of increasing accessibility to necessary information and integrating information systems can help increase the switch therapy ratio in large medical schools and several countries abroad, there are only a few pediatric studies in Thailand that employ all the relevant data, such as patient's medical records, drug management, and trigger tools, to help with patient screenings. Therefore, the advantage of this research study is the evaluation of the process before and after developing a system in pediatric patients that involves relevant staff and the use of VSM to reflect the recipients' views, the direction of data flow, and the overall picture under the lean concept. Moreover, we also designed the developed system through the PDSA concept, which supports seeking areas that need to be improved, and suggests policies to the pharmaceutical therapeutics committee to encourage switch therapy to promote the hospital's rational drug use.

The limitation of this research is that the developed system is designed under the limited technical capabilities of the hospital and a restricted recipient's view because the development team can only apply the developed system in pediatric wards. The development of the overall system policy needs to be approved by the pharmaceutical therapeutic committee. Yet from the result of the developed intravenous system to the oral switching system, the information will be presented as a baseline for further development of the drug information system in the hospital.

The possible opportunities for improvements in the future include the speed of accessing necessary information for pharmacists. Even though the database is connected, pharmacists still need to switch windows to the computer screen to gain the information. A patient's weight recorded in the system is still not connected with the dispensing system, and nurses still correct it, whereas medical orders are handwritten medication administration records. Nevertheless, the most important aspects that should be improved are the connection of databases between laboratory examinations and the dispensing program as well as the encouragement of using the EMAR system and CPOE as suggested in the form of policies to the PTC.

CONCLUSION

Notification systems developed by the PDSA method allowed step-by-step analysis and identification of areas for improvement in the workflow and data flow. Integrating drug information service technology to rapidly screen patients who pass certain criteria can help reduce the time-consuming process and reduce the length of intravenous therapy and length of stay. This notification system can also apply to hospitals using electronic health records and creating electronic systems, such as electronic trigger tools integrated into the electronic health records system, and it extends to the organization to reflect areas that need to be improved and suggested in the form of policies.

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CONFLICTS OF INTEREST

The authors have no conflict of interest to declare.

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