ความคิดเห็นของเภสัชกรเกี่ยวกับประโยชน์ของหุ่นยนต์จัดยาอัตโนมัติ
Opinions of Pharmacists on Benefits of the Automated Medication Pre-dispensing Machine

นิพนธ์ต้นฉบับ **Original Article**

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วารสารไทยเภสัชศาสตร์และวิทยาการสุขภาพ2565;17(3):226-234.

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บทคัดย่อ

วัตถุประสงค์: เพื่อศึกษาความคิดเห็นของเภสัชกรเกี่ยวกับประโยชน์ของหุ่นยนต์จัดยาอัตโนมัติในด้านการให้บริการ การจัดการอัตรากำลัง และภาระงาน และการบริหารเวชภัณฑ์ **วิธีการศึกษา:** การศึกษาเชิงผสมผสานนี้ (Mixed Method Research) สัมภาษณ์แบบเจาะลึกเพื่อรวบรวมข้อมูลเชิงคุณภาพจากผู้ให้ข้อมูลสำคัญ 6 คน ที่มีประสบการณ์การใช้หุ่นยนต์จัดยาอัตโนมัติ โดยคัดเลือกแบบเจาะจง (Purposive) และใช้เทคนิคการบอกต่อ (snowball) จากนั้นนำข้อมูลที่ได้มาสร้างแบบสอบถามที่มีตัวเลือกแบบลิเกิร์ตจาก 1-ไม่เห็นด้วยอย่างมาก ถึง 5-เห็นด้วยอย่างมาก เพื่อศึกษาเชิงปริมาณซึ่งเก็บข้อมูลโดยใช้แบบสอบถามออนไลน์ รายงานวิจัยนี้นำข้อมูลของแบบสอบถามจากโรงพยาบาลที่มีการใช้หุ่นยนต์จัดยาอัตโนมัติเท่านั้น วิเคราะห์ข้อมูลเชิงปริมาณในส่วนความคิดเห็นเกี่ยวกับการใช้หุ่นยนต์จัดยาอัตโนมัติโดยใช้สถิติเชิงพรรณนา **ผลการศึกษา:** ในโรงพยาบาล 23 แห่งที่มีหุ่นยนต์จัดยาอัตโนมัติ ความคิดเห็นต่อการใช้หุ่นยนต์สูงสุด 3 อันดับแรก คือ การใช้หุ่นยนต์ทำให้ความคลาดเคลื่อนในการจัดยาลดลง ตอบสนองต่อการพัฒนาคุณภาพระบบยา และทำให้พยาบาลในหอผู้ป่วยพึงพอใจมากขึ้น (4.48 ± 0.59, 4.43 ± 0.79, และ 4.30 ± 0.70 คะแนน ตามลำดับ) หุ่นยนต์จัดยาทำให้จ่ายยาแบบ unit dose ได้ ยกระดับการให้บริการ ลดความคลาดเคลื่อนทางยา เพิ่มคุณภาพและประสิทธิภาพการทำงานในฝ่ายเภสัชกรรม สำหรับการจัดการอัตรากำลังและภาระงาน กลุ่มตัวอย่างเห็นว่าการใช้หุ่นยนต์จัดยาใช้อัตรากำลังเท่าเดิมในการจัดยาผู้ป่วยใน แต่ได้คุณภาพงานมากขึ้น (3.96 คะแนน) สำหรับระบบบริการผู้ป่วยใน ทำให้ภาระงานของวิชาชีพพยาบาลลดลง พยาบาลบริหารยาแก่ผู้ป่วยถูกต้องมากขึ้น ขณะที่ภาระงานของเภสัชกรขึ้นอยู่กับบริบทของโรงพยาบาล โรงพยาบาลบางแห่งเภสัชกรมีภาระงานลดลง และสามารถเปิดงานเภสัชกรรมด้านอื่นเพิ่ม ขณะที่บางโรงพยาบาลเภสัชกรยังต้องตรวจสอบยาก่อนจ่ายให้แก่หอผู้ป่วยเช่นเดิม **สรุป**: หุ่นยนต์จัดยาอัตโนมัติเพิ่มคุณภาพการให้บริการโดยลดความคลาดเคลื่อนทางยา เพิ่มความปลอดภัยแก่ผู้ป่วย แต่อาจไม่ช่วยให้เภสัชกรมีภาระงานลดลง แม้สามารถเปิดงานบริการเภสัชกรรมด้านอื่นได้อย่างชัดเจน

คำสำคัญ: หุ่นยนต์จัดยาอัตโนมัติ, เภสัชกร, ความคิดเห็น, บริการทางเภสัชกรรม , การจัดการอัตรากำลัง, ภาระงาน, ความคลาดเคลื่อนทางยา

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Abstract

Objective: To explore opinions of pharmacists on benefits of the automated medication pre-dispensing machine on pharmacy service, workforce allocation, workload, and pharmaceutical administration. **Methods:** In this mixed method research, in-depth interview was used to obtain qualitative findings from six key informants with experience of the robot use recruited by purposive sampling via the snowball technique. Findings were used to create questionnaire with a Likert-type rating scale ranging from 1-highly disagree to 5-highly agree for an online survey targeting hospitals under the supervision of Thailand Ministry of Public Health. In this research report, only responses from hospitals with robot use were included in analysis. Results were presented with descriptive statistics. **Results:** Of the 23 hospitals with the automated medication pre-dispensing machine, the most agreed issues were the machine could reduce medication errors, offer medication system development, and enhance satisfaction among workers (4.48 ± 0.59, 4.43 ± 0.79, and 4.30 ± 0.70 points, respectively). In addition, the machine allowed for unit dose dispensing, elevated pharmacy service, reduced medication errors, and improved quality and efficiency of pharmacy work. For workforce allocation and workload, respondents thought that similar workforce was needed for in-patient pre-dispensing even with the machine in use but work quality was improved (3.96 points). For in-patient service, workload of the nurse was reduced and drug administration by the nurse was more accurate. For pharmacist workload, it depended on individual hospital's context. Specifically, robots could reduce workload in certain hospitals and allow for implementing other pharmacy services; while for other hospitals, pharmacists still needed to check prepared medications before dispensing. **Conclusion:** The automated medication pre-dispensing machine improved service quality by reducing medication errors and improving patient safety. However, pharmacy workforce could not be reduced even though more pharmacy services could be allowed.

Keywords: automated medication pre-dispensing machine, pharmacist, opinions, workforce allocation, workload, medication errors

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Introduction

Automated medication pre-dispensing machine or medication preparing robot has been adopted in some hospitals in Thailand. However, whether the robot helps improve medication dispensing efficiency, patient safety and workload burden among the pharmacist has not been known. Understanding on such issues could help steer the development using this pharmacy automation for healthcare service to the right direction.

Smart Hospital is a major policy of the Ministry of Public Health (MoPH) of Thailand. The policy emphasizes the application of digital technology in hospital service systems to reduce steps and improve efficiency of services and staff performances. The ultimate goals are to achieve more accurate, timely services, fewer errors, less waiting time, more safety and more satisfaction.[1] One of the service systems is medication management system which is under the supervision of pharmacy department. Among a wide variety of digital technology applications is the use of the automated medication pre-dispensing machine to prepare and package prescribed medication for each patient. The pre-dispensing robot is assigned to receive prescription information of each individual patient (i.e., medication name, dose, and dosing frequency), package such doses in plastic pouch for each meal, and verify the packaged medications in the pouch before being dispensed by the pharmacist. In Thailand, this kind of robot has been used mainly for preparing medications for in-patient medication distribution.[2]

The robot allows for unit dose distribution, i.e., a pouch containing medication(s) for a single administration meal. This development of unit dose distribution is in accordance with the pharmacy profession standards which recommend that unit dose should be mainly used to reduce steps of errors in medication administration.[3] In Thailand, the automated medication pre-dispensing machine has been continuously adopted in more hospitals for more than 20 years. The installation and operation plan with the robot needs experience transfer from those well experienced.

Previous research shows that in Thailand there have been a limited number of studies about the automated medication pre-dispensing machine in specific hospitals. In a study by Srikusalanukul and colleagues, operating cost and medication errors of the unit dose distribution system carried out by the machine and human workforce were compared. [4] They found that the operating cost of the machine was higher than that by the workforce but the reduction of medication errors by the machine was superior. A study by Piangpen in a medical school hospital assessed efficiency and safety of medication dispensing before and after the automated medication pre-dispensing machine with the handset electronic picking in the transition from the 3-day dose dispensing to the 1-day dose dispensing.[5] It was found that waiting time for continued order prescriptions significantly increased because more continued order items were increased in the post- intervention period and the medication distribution system was changed from the 3-day dose to one-day dose which led to decreasing time for nurse to prepare medications for patients. However, waiting time for stat orders decreased significantly. Medication errors decreased significantly with statistical significance, especially for those continued order prescriptions.[5]

It has been shown that the automated medication pre-dispensing machine could reduce medication errors. The complicate process of adopting the machine exists including planning for management and problem solving from installation, workflow, and pharmacy workforce allocation. These tasks allow the robot to work efficiently. Since the success in adopting the automated medication pre-dispensing machine is inevitably influenced by the human workers, especially pharmacists, the main direct operator of the machine and the coordinator of the medication distribution system, it was crucial to learn about the use of pre-dispensing robot from well-experienced pharmacists. This study aimed to specifically explore pharmacist's perceived benefits of the automated medication pre-dispensing machine in pharmacy service, pharmacy workforce allocation and related workload, and pharmaceutical administration from these pharmacists. Findings could be useful for other hospitals to better adopt the automated medication pre-dispensing machine.

Methods

In this mixed method study, exploratory sequential design was used.[6] In the first phase, qualitative study was conducted to explore issues regarding the effects of automated medication pre-dispensing machines on pharmacy service management, workforce allocation, pre-dispensing and dispensing process improvement, medication errors, waiting time and pharmaceutical administration. This qualitative phase we conducted from August 2019 to January 2020. Findings from the qualitative investigation was used to develop a survey questionnaire for the online phase two nationwide quantitative study. The online survey was conducted from February to March, 2021. This study was approved by the Committee for Ethics in Human Research, Khon Kaen University (approval number: HE621298; approval date: July 31, 2019; extended approval date: August 8, 2020).

Study population and sample

Of 896 public hospitals under supervision of the MoPH of Thailand[7], only hospitals with upper-low size (e.g., 60 beds or higher) and at least one medical speciality were more likely to have pre-dispensing robots. Target study population was thus pharmacists working in 289 hospitals under supervision of the Office of Permanent Secreary, 30 under Department of Medical Science, and 20 under Department of Mental Health, resulting in a total of 339 hospitals. All of these hospitals were the study target since this research report was a part of our project surveying hospitals with and without the robot. This present report aimed only to determine the benefits of robot use only among hospitals with the robot.

These hospitals are classified according to size and specialty. Among 289 hospitals under the Office of Permanent Secretary, there were 33 large medical centers for advanced tertiary care, 50 general hospitals with all major specialties and sub-specialties, 34 mid-level general hospitals with all major specialties and some sub-specialties, 86 large community hospitals with some specialties, and 86 first level community hospitals. Of the 50 hospitals under supervision of other departments, 30 hospitals were under the Department of Medical Services[8], and 20 hospitals under the Department of Mental Health.[9]

In the qualitative study, six informants were recruited by purposive sampling with snowballing technique. These informants for in-depth interview were from hospitals with at least one year of robot adoption. In case of more than one pharmacist eligible for participating the qualitative interview, head of pharmacy department was asked to assign the one with the experienced with the robot.

In the quantitative study, pharmacists from all 339 hospitals who met the inclusion criteria and willing to answer the online questionnaire were contacted. They were expected to complete the whole set of the online questionnaire for our comprehensive project. However, only pharmacists from hospitals with robot adoption of at least one year were eligible to answer this section of the whole questionnaire which was about the benefits of robot use only. In case of more than one pharmacist eligible for participating the online survey, head of pharmacy department was asked to assign the one with the experienced with the robot.

Research instruments and their quality assurance

For the qualitative study, a set of probing in-depth semi-structured interview questions was approved for content validity by congruence with study objective by three experts from the Faculty of Pharmaceutical Sciences, Khonkaen University specialized in hospital pharmacy service management. The questions asked about effects of using the automated medication pre-dispensing machine on pharmacy workforce allocation, improvement in pre-dispensing and dispensing process, medication errors, and waiting time. The questions also asked about the reasons for adopting the machine and problems and limitations relating to the machine adoption. Revision according to suggestions was made before use.

For the quantitative study, the survey questionnaire asked the informant to provide general information of the hospital and issues relating to the automated medication pre-dispensing machine developed from the qualitative study. There were 5 questions for pharmacy service, 5 questions for workforce allocation and workload, 4 questions for medication errors, 2 questions for waiting time, and 4 questions for pharmaceutical administration. The response for each question was a Likert-type rating scale ranging from 1-highly disagree, to 2-disagree, 3-neutral, 4-agree, and 5-highly agree. This questionnaire was tested for content validity by three experts consisting of two instructors from the Faculty of Pharmaceutical Sciences, Khonkaen University specialized in hospital pharmacy service management, and one hospital pharmacist who had been working with the automated medication pre-dispensing machine for five years. All suggestions were taken for revision. The final form was placed for online survey on the Google Form™.

Data collection procedure

In the qualitative study, six informants were recruited by purposive sampling with snowballing technique. The in-person in-depth interview took about 45 – 60 minutes to complete. The consent was obtained before the interview conversation was voice-recorded. The interview was conducted from August 2019 to January 2020. In the quantitative study, the researcher requested permission from the MoPH for recruiting informants from hospitals under its supervision. The invitation letter was mailed to all target hospitals by the Office of the Permanent Secretary. The online survey was conducted from February to March, 2021.

Data analysis

In the qualitative phase, data obtained from the six informants were analyzed by identifying issues relating to the study objectives including the use of automated medication pre-dispensing machines, sources of budget support, operating costs, and associated problems. Data from the quantitative study were presented using descriptive statistics including frequency with percentage and mean with standard deviation. Scores of pharmacist's opinion were classified into five levels of based on the average of adjacent levels of opinion. For example, for the highest level of agreement, the range for such level was 4.51 – 5.00 points which was based on the cut-off of 4.50 points calculated from 4 plus 5 divided by 2. As a result, average score for each aspect could be categorized as highly disagree, disagree, neutral, agree, and highly agree (1.00 1.50, 1.51 – 2.50, 2.51 – 3.50, 3.51 – 4.50, and 4.51 – 5.00 points, respectively). Quantitative results were accompanied with relevant qualitative findings from the key informant to show in-depth understanding on the issue.

Results

In the qualitative study, the six informants had a wide range of years of experience working with the automated medication pre-dispensing machine from 1.5 to 22 years. Three of them were from large medical centers with a capacity of 500 – 1,000 beds, two from general hospitals (240 - 600 beds), and one from a medical school hospital for tertiary care (1,400 beds).

In the quantitative study, of a total of 339 target hospitals, 144 hospitals completed the online survey resulting in a response rate of 42.5%. Informants from large medical centers were the group with the highest res4ponse rate (81.8%) followed by those from general hospitals (68.0%), and mid-level general hospitals (61. 8%) (Table 1) . Of the 144 respondents, 23 of them used the automated medication pre-dispensing machine (16.0%). Of these 23 hospitals, 18, 2 and 3 of them used the robot for out-patient, in-patient, and out-patient together with in-patient dispensing, respectively.

Opinions on adopting the automated medication pre-dispensing machine

The findings were from pharmacists overseeing the robot use from 23 hospitals. The findings were divided into two parts. The first part concerned opinions on robot benefits on pharmacy service performance while the second part was on workforce allocation and pharmaceutical administration.

Opinions on benefits of the automated medication pre-dispensing on pharmacy service performance

The six most rated aspects of robot use on pharmacy service performance included reduced medication errors in the pre- dispensing step with a mean score of 4.48 ± 0.59 points, followed by improved medication system performance, enhanced in-patient satisfaction among nurses in medical wards, decreased dispensing errors, reduced medication administration, and faster in-patient dispensing, in a descending fashion (4.43 ± 0.79, 4.30 ± 0.70, 4.17 ± 0.83, 3.83 ± 0.89, and 3.83 ± 1.03 out of 5 points, respectively) (Table 1). This finding suggests that pharmacists agreed that pre-dispensing robot could reduce medication errors from pre-dispensing error, to dispensing error and administration error. The finding was consistent with the qualitative result stated as follows.

" *The best thing for pharmacy department is the robot reduces medication errors … This could be beneficial for pharmacy work system. For hospital administrators, they like medication error reduction the most since it is the clearest benefit, especially dispensing error and pre-dispensing error.*" (Key informant 6)

" *This robot is suitable for in-patient dispensing and unit dose dispensing. If connected to the medical ward, administration errors by nurses could also be reduced. Medication administration time could be recorded in the real-time fashion with the use of barcode scanner.*" (Key informant 2)

" *The robot really reduces medication errors. Once pre-dispensing errors are reduced, dispensing errors are then reduced. Yes, errors are really reduced. It's the truth.*" (Key informant 5)

The reduction in medication errors could also be attributable to the fact that the robot use was in accordance with the improvement in the medication system. The qualitative finding also suggests adopting the automated medication pre-dispensing machine to improve pre-dispensing and dispensing process in the in-patient service could enhance quality and efficiency of pharmacy service tasks.

"A that time, the head of the pharmacy department told me that if there is no robot, don't implement the unit dose dispensing. We did it anyway and we were suffered with the

overloaded. Even with the robot, don't expect the decrease in workload. We compared with what we did which was the three-day dose, the one-day dose dispensing caused too much workload. With no robot, it could be even worse." (Key informant 4)

"We used to prepare a pouch for one kind of medication. Now we prepare a pouch for one meal containing more than one item of medication. The chance the nurse would miss a medication in a given meal is reduced. In the past one or two medication items in separated pouches were missed." (Key informant 1)

All findings indicate benefits of using robot to improve quality of pharmacy service. The transition of three-day dose to one-day dose dispensing or one-day dose to unit dose dispensing posed a 2 to 3 folds increase in workload. With the constant workforce available, robot could handle such increased workload with more accuracy, less errors in preparing and dispensing, less time needed to complete the task, less workload for pharmacy assistants, less stress in checking the packaged medications, and more opportunity for cross-checking by the nurse before administration. In addition, with less time needed for preparing medications for each meal, nurses are more satisfied with less hectic tasks, and less administration errors. However, at the initiation phase of adopting the robot, pharmacist's observation indicates that satisfaction among pharmacy personnel and in-patient nurses was not obvious. This could be due to the fact that the early phase of robot implementation was complicate both in the machine operation and the control software which could cause a lot of cautions. The change in workflow could also cause confusion. Once most workers understood and adapted to the new workflow, the satisfaction became obvious.

The finding, however, indicates certain uncertainty among these respondents. For example, whether the robot could help fasten out-patient dispensing or shorten the out-patient waiting time was uncertain (Table 1). However, more respondents in future studies could help depict a clearer opinion on these issues.

Opinions on the benefits of the automated medication pre-dispensing on workforce allocation, workload and pharmaceutical administration

The three most agreed benefits of adopting the automated medication pre-dispensing machine were improved work quality with the same workforce (3.96 ± 0.82 points), reduced workload in in-patient medication preparation from pre-dispensing to checking and dispensing (3.61 ± 1.23 points) and improved quality in pharmacist's work (3.61 ± 1.12 points) (Table 2). The last two benefits were somewhat more uncertain with their wider standard deviation. This means that certain portion of respondents had different opinions about the issues whether the robot could reduce workload in checking in-patient prepared medications or free more pharmacist time.

The amount of more work done with the robot is obvious. This was evident based on a larger number of patients serviced both in in-patient and out-patient departments, expansion of medical wards, and demands on more accurate and quality work system improvement by transitioning from traditional dispensing to unit dose dispensing. The robot allowed all of these improvements possible with the same

Table 1 Opinions on benefits of the automated medication pre-dispensing on pharmacy service performance (N = 23).

Issues	Levels of opinions, n (%)					Mean	Standard deviation	Level of agreement
	Highly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Highly disagree (1)			
Patient service								
Out-patient service								
Robot could reduce waiting time	5 (21.7)	6 (26.1)	11 (47.8)	1 (4.3)	-	3.65	0.88	Agree
Robot could offer more convenient medication administration for the patient	2 (8.7)	8 (34.8)	8 (348)	5 (21.7)	-	3.30	0.93	Neutral
In-patient service								
Robot use is in accordance with medication system development policy	13 (56.5)	8 (34.8)	1 (4.3)	1 (7.3)	-	4.43	0.79	Agree
Robot could result in more satisfaction among nurses in medical wards	10 (43.5)	10 (43.5)	3 (13.0)	-	-	4.30	0.70	Agree
Robot could provide faster dispensing to medical wards	6 (26.1)	10 (43.5)	5 (21.7)	1 (4.3)	1 (4.3)	3.83	1.03	Agree
Waiting time of the patient								
Robot could allow faster dispensing to medical wards	5 (21.7)	10 (43.5)	5 (21.7)	2 (8.7)	1 (4.3)	3.70	1.06	Agree
Robot could reduce waiting time of out-patients	4 (17.4)	4 (17.4)	13 (56.5)	1 (4.3)	1 (4.3)	3.39	0.99	Neutral
Medication errors								
Robot could reduce medication pre-dispensing errors	12 (52.2)	10 (43.5)	1 (4.3)	-	-	4.48	0.59	Agree
Robot could reduce medication dispensing errors	9 (39.1)	10 (43.5)	3 (13.0)	1 (4.3)	-	4.17	0.83	Agree
Robot could reduce medication administration errors	5 (21.7)	11 (47.8)	5 (21.7)	2 (8.7)	-	3.83	0.89	Agree
Robot causes medication errors	1 (4.3)	2 (8.7)	7 (30.4)	11 (47.8)	2 (8.7)	2.52	0.95	Neutral

Table 2 Opinions on the benefits of the automated medication pre-dispensing on workforce allocation, workload and pharmaceutical administration (N = 23).

Issues	Levels of opinions, n (%)					Mean	Standard deviation	Level of agreement
	Highly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Highly disagree (1)			
Workforce allocation and workload								
Robot could allow for the same workforce but more quality service initiated	5 (21.7)	14 (60.9)	2 (8.7)	2 (8.7)	-	3.96	0.82	Agree
Robot could reduce workload in pre-dispensing, checking and dispensing	6 (26.1)	9 (39.1)	2 (8.7)	5 (21.7)	1 (4.3)	3.61	1.23	Agree
Robot could allow pharmacist to do more qualiy service	6 (26.1)	7 (30.1)	5 (21.7)	5 (21.7)	-	3.61	1.12	Agree
Robot could reduce in-patient medication checking by the pharmacist	7 (30.4)	5 (21.7)	3 (13.0)	5 (21.7)	3 (13.0)	3.35	1.47	Neutral
Robot could allow more free time for the pharmacist	5 (21.7)	6 (26.1)	2 (8.7)	8 (78.3)	2 (8.7)	3.17	1.37	Neutral
Pharmaceutical administration								
Coordination between in-patient dispensing unit and inventory unit when changes in dosage form	6 (26.1)	12 (52.2)	3 (13.0)	2 (8.7)	-	3.96	0.88	Agree
Criteria available for selecting medication products to suit the robot use	5 (21.7)	7 (30.4)	4 (17.4)	7 (30.4)	-	3.43	1.16	Neutral
Robot use affects medication procurement, e.g. shared procurement	4 (17.4)	5 (21.7)	7 (30.4)	7 (30.4)	-	3.26	1.10	Neutral
Robot could promote accurate inventory	1 (4.3)	4 (17.4)	10 (43.5)	6 (26.1)	2 (8.7)	2.83	0.98	Neutral

amount of workforce and time as stated as follows.

"A that time, the head of the pharmacy department told me that if there is no robot, don't implement the unit dose dispensing. We did it anyway and we were suffered with the overloaded. Even with the robot, don't expect the decrease in workload. We compared with what we did which was the three-day dose, the one-day dose dispensing caused too much workload. With no robot, it could be even worse." (Key informant 4)

"The benefit of it is faster packaging. In the past, we spent almost 4 hours for preparing medications for administration around breakfast. Now it takes only about an hour or less than an hour." (Key informant 3)

Key informants also provided certain views on the robot. **Pharmacists** revealed that workload of the pharmacist depended on the hospital context. Certain hospitals could free more time for the pharmacist to initiate other pharmacy services with the same number of workforce as follows.

"The robot could reduce workload obviously. Whether the workload is transformed is unclear. We found the workload could be transformed. I could assign different tasks to pharmacists other than pharmacy dispensing services which could not be done in the past. With the robot, pharmacists have more free time, at least two or three hours before the end of the dayshift which could be assigned for other tasks or services, for example, intensive adverse drug reactions prevention. To be specific, these quality proactive works could be done before and after operating the robot. The robot and related automated machines help reduce the workload of service." (Key informant 4)

"Since I was told to change from the three-day dose to the unit dose dispensing with the same number of workforce. It should be more workers for such more tedious workload. With the same number of workers, I have the robot to help me and I could assign my staff members to do other things." (Key informant 4)

"I believe that with no robot, we wouldn't be able to achieve such high efficacy of the output. Our workflow could not be that active. Before the robot, we finished the work at 4 in the afternoon. With robot, we finish as early as 2 in the afternoon. After that, staff members could do quality work and finish document work. The robot frees us to do more tasks obviously." (Key informant 4)

It was found that in a hospital in-patient pharmacy service was improved with reduced errors on pre-dispensing and dispensing. However, workload for pharmacy department was still the same with no reduction. This was because pharmacists were still expected to identify, analyze, and correct any problems in the prescriptions before transferring the prescription information to the robot. Pharmacists were still expected to verify medications in the pouches packaged by the robot. The reason for such pharmacist manual operation was the trust toward the robot despite its minuscule errors. The errors could also generated from human errors in filling the medication into the robot. Pharmacists still inspected the expiration date of the packaged medications before dispensing to the medical wards as stated as follows.

"Robot doesn't reduce workload of pharmacy department. Pharmacists still manually check medication dispensing. It doesn't reduce pharmacist's workload but medication errors for sure." (Key informant 6)

"It should be reduced, but pharmacists are detail-oriented persons. We check every small detail. Even packaged medications in the pouch already verified by Vizen™ (the automated machine to optically verify the tablets or capsules), pharmacists still recheck the medications. Workload is not reduced." (Key informant 6)

In addition to pharmacists thought that the robot could not replace **pharmacy technicians and assistants** in all steps of work. The robot was however able to reduce the workload at packaging tablets and capsules by the technicians. It could also make the process faster and more accurate. Certain steps still needed human workforce such as feeding tablets and capsules into the robot, robot maintenance and taking the tablets out of the plastic pack.

Finally, pharmacists also throught that the robot obviously helped reduce workload of the **nurse**. With the three-day dose or one-day dose dispensing, nurses had to prepare medications for each meal. With the robot, pharmacy provided unit dose dispensing which helped reduce workload for the nurse, enhance accurate medication administration (right dose and right patient), and reduce administration time which allowed more time for nursing care as follows.

"Workload for nurses was significantly reduced, or almost completely gone for preparing medications to administer. They could just cut the pouch and give tablets to the patient. This is what nurses want. They want to spend more time for nursing care. Pharmacy could cover most of dispensing and preparing medications for administration. We know what we should do which could benefit nurses as co-workers. This is an opportunity to take responsibility on all of our works." (Key informant 6)

"Based on the existing manual system, we prepared medications for countiued orders. For one day orders, nurses needed to open each pouch for each medication. For the new system, nurses could just open the pouch and medications are ready for administration. Administration time is reduced." (Key informant 2)

In terms of pharmaceutical administration, respondents reported that coordination between in-patient dispensing service and pharmaceutical inventory unit was needed when medication dosage from was changed (3.96 ± 0.88 points). In some hospitals, coordination between the two units for tablet changes annually or periodically. The change in tablets needs changing in outlet holes which takes at least a month to mold. Responents thought that the robot could affect selecting brands of medications suitable for the robot. Robot also helps accuracy of the inventory. However, pharmaceutical administration was affected by the robot at a level lower than other aspects as mentioned above.

Discussions and Conclusion

With a response rate of 42.5% (144 out of 339 hospitals), our findings could be somewhat, if not highly reliable. However, with only 23 hospitals with the robot use, findings on some aspects could not be highly conclusive. In the future, more opinions from pharmacists in hosptals with and without the robot could be studied.

Response rate was found even lower among hospitals under the supervision of the Department or Medical Sciences and Department of Mental Health. This could be due to an inadequate public relation to these hospitals. The researcher had encouraged these hospitals through online communication but it was somewhat futile. Future studies could focus more on these hospitals separately because hospitals under departments other than the Office of Permanent Secretary and private hospitals usually have different administration system. Broader and more precise picture of robot use among hospitals from all sectors could be better understood.

Since robots have not been widely in hospitals in Thailand, findings could be somewhat diverse. For example, for out-patient service, diverse answers were found and a large portion of respondents were inconclusive or neutral. Since the respondents could answer both the in-patient and out-patient services but the respondent usually worked in one service or another, certain answers could be based on guessing, i.e., those working in out-patient service probably guess what should be in the in-patient service, and vice versa.

Most hospitals did not use the robot in out-patient service with full system. Other accessory machine were used including automated dispensing cabinet for injectables in the emergency department, and unit dose dispensing for psychiatric patients. As a result, waiting time for out-patient service could not be answered decisively by the respondent. Whether faster dispensing to medical wards could be achieved was perceived as neutral or disagreed by the respondent.

Unclear waiting time was also consistent with the study of Srikusalanukul and colleagues.[4] They found that unit dose prepared by the robot was time-consuming than manual

preparation. This was because the robot operator had to with with the robot feeding tablets to the pouch caused an increase of 24.5% of the time for all process. In hospitals with the robot for out-patient service, respondents agreed that the robot could reduce the patient's waiting time, but not more convenience for medication administration. This indicates more studies on the benefit of the robot on out-patient service.

For workforce allocation and workload after the initiation of robot adoption, findings from qualitative and quantitative studies were consistent. Workload could be reduced of which the three-day and one-day dose dispensing could be fine-tuned to unit dose dispensing with the same workforce. However, workload on checking before dispensing was varied depending on hospital work management and automated accessory machines available, such as machine to verify prepared medications in the pouch using image comparison. This is consistent with the previous work of Noparatayaporn and Sakulbunrungsil where workforce of pharmacist and pharmacy technician in in-patient distribution service between manual medication dispensing and automated dispensing was compared.[10] They found that the automated dispensing used less work of pharmacy technician and more work of pharmacist when compared with the manual distribution.

The use of the automated dispensing could allow for more quality pharmacy service such as rational drug use (RDU) or drug use evaluation (DUE) after the robot adoption. However, qualitative results suggest inconclusive trend of more quality service that the robot use could offer. In addition, different hospitals distributed workload differently, therefore it was difficult to figure how much the quality service was a result of more free time from the robot use. Furthermore, all hospitals have been expected to develop these quality service by the policy of the MoPH. To quantify the beneft of the robot on development of quality service, well designed studies are needed.

It was almost unanimous that the robot use could reduce medication errors from pre-dispensing error, dispensing error and administration error. This is consistent with the previous study of Srikusalanukul and co-workers where medication errors with unit dose dispensing using the robot was 0.65% of prescriptions while that with manual dispensing was 1.93%.[2] the study of Chanathepaporn found a 51.1% decrease in medication dispensing errors as prescription and 52.3% as medication items with statistical significance (*P*-value < 0.001, for both comparisons).[5] Automated pre-dispensing machine was also associated with reduced medication errors by 70%.[11] A systematic review revealed decreases of medication errors from 0.6 - 2.7% to 0 – 1.0% after the robot use, and 37% decrease in preventable medication errors.[12] A non-systematic narrative literature review in England showed that the automated machine for pre-dispensing and dispensing could reduce medication errors in dispensing by 16 – 20%.[13]

Opinions on pharmaceutical administration were diverse and inconclusive. The issues were coordination between units when changes of tablets and capsules, discarding and returning the packaged medications. These issues were handled differently by hospitals. More in-depth studies on pharmaceutical administration in hospitals with different levels of care should be conducted.

In conclusion, the automated medication pre-dispensing machine improved service quality by reducing medication errors and improving patient safety. However, pharmacy workforce could not be reduced even though more pharmacy services could be allowed.

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