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Effectiveness of vendor-managed inventory system in drug inventory management in sub-district health-promoting hospitals

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ABSTRACT

This study aimed to evaluate the effectiveness of the vendor-managed inventory (VMI) system for the five highest consumption levels of chronic disease medication in the sub-district health-promoting hospitals (SHPHs) in Laemsing, Chanthaburi, Thailand. The research methods comprised qualitative research, which explored the current inventory management system, and quantitative research, which investigated the inventory control system and the effectiveness of the VMI approach. Effectiveness measured by comparing the difference between before and after VMI implementation and the difference between SHPHs using the traditional approach and those adopting the VMI system. Two indicators comprising inventory management and logistics were used to measure the differences. This study highlighted the advantages of VMI for the inventory of chronic medications, as a smooth demand product. The VMI approach used with a periodic review system was more effective than the traditional approach. It reduced the average stock rate, increased inventory turnover rate, inventory accuracy, and ensured products were delivered in full and on time (DIFOT). Further, the SHPHs staff and the community hospital staff were extremely satisfied with the time efficiency, convenience, practicality, and inventory accuracy.

Keywords: effectiveness; VMI; vendor-managed inventory system; medicines; hospital

1. INTRODUCTION

Vendor-managed inventory (VMI) is a supply chain approach that emerged in the retail industry in the late 20th century (Waller et al., 1999). Since then, it has been widely implemented in various sectors, among them the pharmaceutical industry (Bhakoo et al., 2012; Krichanchai and MacCarthy, 2017). The adoption of VMI requires some business process re-engineering, as customers no longer send purchase orders to the supplier. Instead, suppliers take responsibility for replenishment on behalf of the customers. The customers provide support by sharing information and generating demand and inventory information, enabling the supplier to efficiently perform inventory management (Krichanchai and MacCarthy, 2017). Expected benefits from this supply chain approach include efficient material handling, cost performance improvement, and service quality upgrades (Sumrit, 2019).

Yet, implementers also face several VMI adoption challenges, including information sharing. Several studies have highlighted that information needs to be shared with upstream suppliers without delay and that accurate information is a critical requirement (Niranjan et al., 2012; Turhan and Vayvay, 2012). In practice, customers are reluctant to share information with suppliers (Stanger, 2013). Regarding decision-transfer issues, clients prefer to remain involved with the replenishment process and impose minimum and maximum limitations on inventory

control on their suppliers (Claassen et al., 2008).

The relationship is another consideration. Even though it has not been highlighted in other industries, it is a critical issue for VMI implementation, particularly in hospitals. Without trust, hospitals are reluctant to outsource this core process to third parties, which may lead to obstacles in implementation (Krichanchai and MacCarthy, 2017; Stanger, 2013). Therefore, VMI is still not a one-size-fits-all approach. The benefits and challenges may differ between organizations, even in the same industry (Krichanchai and MacCarthy, 2017; Niranjan et al., 2012).

The VMI approach was first introduced to the healthcare sector in the 2000s. (Guimaraes et al., 2013; Kim, 2005; Mustaffa and Potter, 2009). Guimaraes et al. (2013) explored the differences in VMI implementation between a public hospital and its health services units. VMI was considered a lean solution for material management. It was discovered to improve both cost-saving and care quality. Mustaffa and Potter (2009) examined the inventory and delivery management process at a private healthcare company in Malaysia. The VMI approach appeared to enhance product availability and eliminate urgent ordering. Kim (2005) described the implementation of the VMI approach for pharmaceutical products in the healthcare sector and how the online procurement system and real-time information-sharing functionalities resulted in inventory optimization.

However, there remains limited literature on VMI for pharmaceutical products, particularly within the hospital context in Thailand. A published study in 2011 considered the implementation of VMI within the vaccine supply chain between public hospitals and the Government Pharmaceutical Organization. Consequently, the business process was shortened from five steps in the conventional system to three steps using the VMI approach, resulting in a total logistical cost reduction of 52-million-baht (Program for Appropriate Technology in Health (PATH), and World Health Organization, Health Systems Research Institute, and Mahidol University, 2011). Sooksriwong et al. (2019) explored the internal VMI model in a tertiary hospital in Bangkok, Thailand. Three medicine groups focused on Class A medicine items, medicine items with a high frequency of shortage, and medicine items with a high dispensing frequency.

The current study highlighted how VMI required a redesigned internal business process between the pharmacy warehouse and the main dispensing room. It enabled inventory cost reductions of 25.73%-30.98% and cut average daily stock inventories from 10 days to 6-8 days. VMI also enhanced service levels by 92%-100% (Sooksriwong et al., 2019). Additionally, Intoyos and Kessomboon (2013) adopted a quasi-experimental study to investigate the efficiency of modified VMI at ten primary care units. The results showed that modified VMI lowered the inventory turnover ratio from 6.67 months to 1.31 months and resulted in cost savings of 1,006,416 Baht. The same study found that VMI not only improved key performance results but also reduced staff workload, contributing to employee satisfaction (Intoyos and Kessomboon, 2013). The summary of previous VMI literature is presented in Table 1. These findings are based on previous VMI literatures and highlight research gaps.

Firstly, even though the VMI approach has been suggested to the healthcare industry in Thailand, VMI implementation studies at the primary care level are still limited. Furthermore, some previous studies have suggested the adoption of a continuous inventory policy to enhance VMI performance. Some may argue that this should be selected based on the context of VMI implementation. Additionally, chronic medications are high-value products in the healthcare sector. Literature focusing on VMI approach design for these chronic medications, particularly at the primary care level, remains limited.

The research questions addressed were: 1) how VMI would be designed for chronic medications within a community hospital and SHPH dyadic, and 2) which benefits would be gained from this implementation compared to the traditional inventory approach. Therefore, this study developed a VMI model for implementation in the dyadic context of sub-district, health-promoting hospitals (SHPHs), and a community hospital. The study further investigated whether VMI adoption was beneficial for medical supplies, particularly for chronic disease.

2. MATERIALS AND METHODS

The research methodology used a combination of qualitative and quantitative methods. The justifications of the mixed-method approach are as follows: the qualitative approach allows the researcher to examine the studied phenomenon and better understand the complex problem within the healthcare context, while the quantitative approach helps compare and quantitatively analyze the benefits deriving from the new approach. Mixed methodology allows researchers to benefit from the strengths of two (or more) approaches (Eisenhardt and Graebner, 2007). The key to successful VMI implementation is cooperation among partners, trust, and understanding of process and procedure (Krichanchai and MacCarthy, 2017). A qualitative approach helps gather stakeholder opinions, which contributes to a proper VMI approach design. With that, the quantitative approach is adopted to develop an inventory control policy for chronic medications, determine the maximum stock levels, and analyze the performance outcomes. From these, the researcher is able to design a sustainable VMI approach for the primary care level.

This study was conducted from January to November 2019. The study was approved by the Human Research Ethics Committee from the Faculty of Pharmacy, Silpakorn University. The approval number was 4/2562 and the approval date was February 21, 2019.

2.1 Phase 1: development of the VMI model

This phase emphasized the design of the VMI model, including the relationships between SHPH and a community hospital. Both qualitative and quantitative approaches were conducted to gather data and help design a feasible model.

2.1.1 Qualitative approach

The exploratory qualitative approach was employed to investigate the current inventory management approach to better understand inventory control management and medication supply within a dyadic relationship in a primary care context. The study focused on medication supplies for pharmaceutical products.

The research focused on multiple case studies, allowing for deeper exploration and theoretical elaboration than a single-case study would have done (Eisenhardt and Graebner, 2007). The multiple case studies were conducted at four SHPHs and a community hospital in the Laemsing district, Chanthaburi province, Thailand, which contributed to the external validity and integrated multiple perspectives.

Semi-structured interviews were used as a primary data collection approach. Observations and documentation were employed for triangulation purposes. Interviews were conducted with two public health employees, a nurse, and a dental employee responsible for inventory management at the four SHPHs. The interviewees provided insight into current inventory management processes at the SHPHs. The interview with the head pharmacist responsible for managing the procurement and inventory of medical supplies at the community hospital generated an understanding of medicine supplies between the SHPHs and the community hospital. Additionally, one public health employee responsible for inventory control at the district public health organization was interviewed to provide an overview of pharmaceutical supplies and current practical issues within the Laemsing district (Table 2).

Table 1. Summary of studies on VMI for pharmaceutical products

Author (year)	Objective	Research approach	Products	Inventory control system	Benefits gained from VMI
Kim (2005)	Designed and developed supply chain by VMI implement which composed of pharmaceutical companies, a wholesaler, and hospitals.	Quantitative approach	pharmaceutical products	Continuous review policy, and real time information sharing	Decrease total inventory more than 30%.
Mustaffa and Potter (2009)	Evaluated inventory management in between a wholesalers and clinics in Malaysia	Qualitative approach	pharmaceutical products	Continuous review policy	Enhance stock availability and reduce urgent orders.
Guimaraes et al. (2013)	Explored VMI benefits, risks, barriers and enablers.	Qualitative approach	pharmaceutical products	Continuous review policy	Enhance cost reduction and improve the quality of care.
Intoyos and Kessomboon (2013)	Implement VMI approach between a community hospital and 10 SHPHs	Quantitative approach	All medications in SHPH	Periodic review policy	Reduce the inventory turnover ratio from 6.67 to 1.31 months and improve cost saving by 1,006,416 Baht.
Sooksriwong et al. (2019)	Designed a model of the internal VMI system within a university hospital context.	Qualitative and quantitative approach	Three medicine groups: class A, a high frequency of shortage and a high dispensing frequency	Periodic review policy	Cost reduction by 25.73%-30.98%
Siha and Arpasrithongsakul (2019)	Evaluated VMI implementation between a community hospital and 10 SHPHs.	Quantitative approach	All medications in SHPH	Periodic review policy	Reduce withdrawal value from 225,904 Baht to 151,671 Baht.

Note: VMI = vendor-managed inventory, SHPH = sub-district health-promoting hospital

Table 2. Interviewee profiles

No.	Organization	Position	Experiences (Years)
1	SHPH A	Professional nurse	10
2	SHPH B	Public health technical officer	2
3	SHPH C	Public health technical officer	12
4	SHPH D	Dental assistant	3
5	District public health office	Public health technical officer	12

Note: SHPH = sub-district health-promoting hospital

2.1.2 Quantitative approach

During the development phase (Phase 1), the quantitative approach was employed both for classified medications and the design of the inventory control system. An ABC classification method was used to categorize medication according to its annual consumption value. Medicine consumption data for the 2018 fiscal year was collected, and the top five highest consumption values for chronic medications at all four SHPHs were selected.

Two SHPHs (SHPH C and D) were willing to implement VMI, whereas the other two (SHPH A and B) continued using the traditional inventory approach. Medicine consumption data was gathered from two established VMI hospitals to design the inventory control model. As the

clinics for chronic disease were set up monthly, a periodic review policy was used to control VMI inventory based on the product consumption characteristics. The average monthly consumption rate was used to estimate a minimum and maximum stock level. After the inventory control model was developed, the VMI model was extended into the second phase.

2.2 Phases 2 and 3: implementation and evaluation

Quantitative data, including average monthly stock levels, stockout rate, and drug and medicine consumption values, were collected in this phase of VMI implementation. The data were gathered from the four SHPHs over two sessions. Retrospective data were collected from December 2018 to May 2019 to gather the inventory data during the traditional-approach period from all hospitals. Then, prospective data were compiled from July to December 2019, so that both conventional and VMI hospital inventory data were compiled.

The community hospital acted as vendors responsible for managing the SHPHs inventories and making replenishment decisions. The SHPHs, now acting as customers under the VMI approach, were required to share demand and inventory information.

The replenishment process started with the SHPH staff checking the medicine consumption data. To ensure the information accuracy and make later replenishment decisions, the information was reported to the pharmacist at the community hospital. The pharmacist then visited the SHPH on-site to check the provided information against the actual inventory. The replenished quantity was equal to the determined maximum level minus the amount of inventory on hand. After that, a pharmacy assistant at the warehouse prepared medications, which were later picked up by SHPH staff on the agreed due date. The replenishment was scheduled to be once a month, as shown in Figure 1.

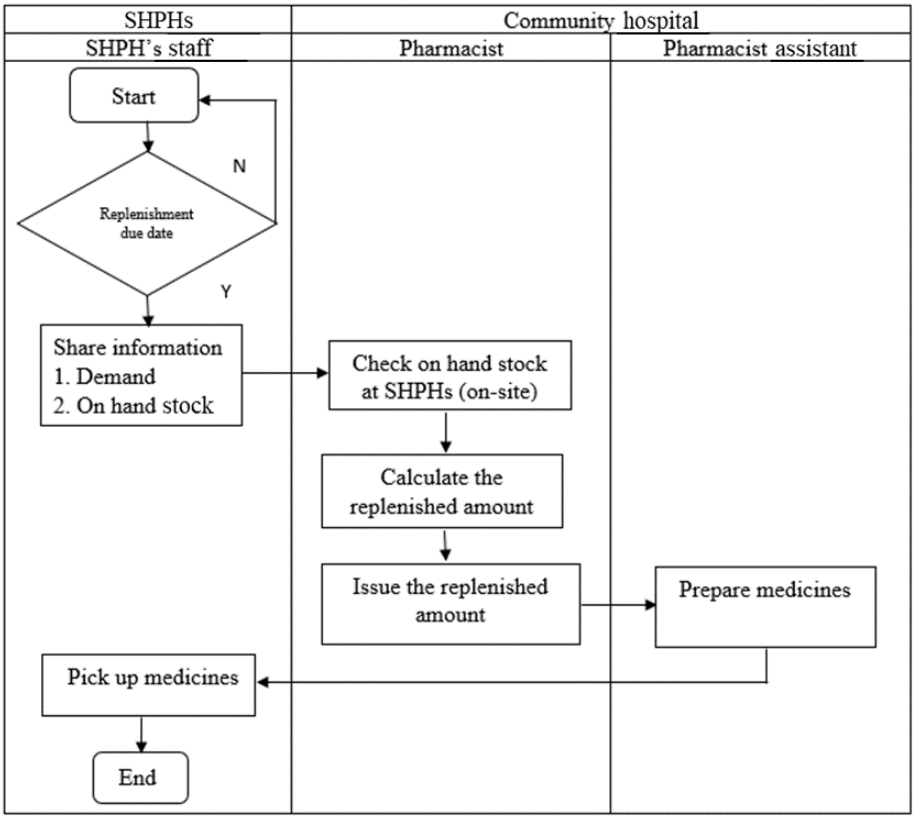

Figure 1. Replenishment process between community hospital and SHPHs under VMI approach
Note: SHPH = sub-district health-promoting hospital

This study then compared the results of the VMI approach versus the traditional inventory approach. Performance was evaluated using inventory control performance and logistics performance. The inventory management indicators were suggested by the Health Information System Development Office and Bureau of Logistics, Ministry of Industry. The indicators for inventory control comprise (1) the average storage period (indicating the adequacy of stock levels), (2) the number of stockouts (the ability to provide sufficient supply), and (3) the number of emergency replenishments (the ability to prevent insufficient supply). Three indicators were used for logistical performance, such as cost, time, and reliability: (1) stock turnover rate (performance of managing inventory), (2) delivery accuracy and on-time delivery (ability to deliver supplies accurately in a timely fashion), and (3) inventory accuracy (accuracy of the number of the existing and recorded supplies).

3. RESULTS

3.1 Qualitative data analysis

The analysis of qualitative data was based on a detailed review of the evidence gained from five interviewees. This evidence provided an overview of the current inventory

management control at the SHPHs. The qualitative data helped design the VMI model for a primary care unit.

3.1.1 The characteristics of SHPHs

All case studies were based on the SHPHs located in the Laemsing district, Chanthaburi province, Thailand. The SHPHs generally provide primary care services to villages in the district. This service enabled drug accessibility improved quality of care for patients as well as reduced overcrowding in the community hospital at the district level. The healthcare employees working at the SHPHs included public health technical staff, nurses, and dental assistants. As doctors and pharmacists were on duty at the hospital, the SHPHs only provided outpatient services for minor illnesses.

All SHPHs collaborated with the Laemsing community hospital situated in the same district. Typically, the community and the SHPHs had a relationship akin to a parent and subsidiary. A doctor from the community hospital regularly visited the sub-district hospital and provided services at the chronic disease clinic, held monthly for disorders such as hypertension, hyperlipidaemia, and diabetes.

3.1.2 Demand management process

The total number of chronic patients at each SHPH varied between 104 and 170 people. There were 20 items of chronic medicines. Given the limited number of healthcare staff, the clinic served half of the total number of patients each time. Patients were seen on a bimonthly basis. Doctors and pharmacists from the community hospital visited the clinic monthly. Healthcare staff members at the SHPHs prepared medicines for specific patients one to two weeks in advance. On clinic day, a patient had their blood pressure and blood sugar levels checked and a professional nurse then performed a physical examination and reviewed the patient history. If the patient was found to have blood pressure or blood sugar higher than the specified criteria, the nurse would consult the doctor in charge to consider drug adjustments or refer the patient to the hospital. The pharmacist reviewed the prepared medications and dispensed them to the patient. If the doctor adjusted the medication, the patient would receive a new prescription that same day. Typically, a one-month supply of medication was provided. The information was later noted in the family folder and recorded in the system.

3.1.3 Inventory management within the SHPHs

All SHPHs had two inventory locations, a warehouse and a service point-of-care. For the replenishment process within SHPHs, there were three methods for controlling the stock. First, medicines received from the community hospital were stored in the warehouse. The medicines are later withdrawn at the point-of-care and the replenishment form was filled to record the information. Second, medication received from the community hospital was transferred to the point-of-care. The replenishment forms were filled and the stock cards updated after the medicine was dispensed. Third, a nurse checked the physical stock at the point-of-care. The replenishment form was filled for the previously withdrawn amount. The SHPHs A and D used the first method, while the SHPHs B and C applied the second and the third methods, respectively. Typically, replenishment was performed monthly, one week before the clinic day.

3.1.4 Inventory and replenishment process between the community hospital and SHPHs

With the traditional approach, all hospitals managed the replenishment on the seventh day of the month. SHPHs A and C requested products based on the replenishment amount recorded on the stock card; SHPH B and C decided the replenishment quantity based on previous usage. They all used different approaches for replenishment management.

SHPH A replenished products when the inventory level was lower than the previous usage amount. Inventory information on the stock card was used to make replenishment decisions, including amounts, for a three to four-month supply. SHPH B replenished all products. The replenishment quantity was estimated based on the demand information of all patients scheduled for their next clinic appointments. SHPH C based its replenishment decision on the previous replenishment amount and the current inventory level. Lastly, SHPH D used previous demand usage recorded in a hospital information system and the current stock level at the warehouse to determine its replenishment quantity.

3.2 Quantitative data analysis

Based on the historical medicine usage data for the 2018 fiscal year for each SHPH, the results of ABC classification analysis revealed that chronic disease drugs were ranked in the top five for the highest value of medicine consumption. The top-five list of chronic disease drugs was shown in Table 3.

The qualitative data showed that two hospitals (SHPH C and SHPH D) were willing to implement the VMI approach, whereas the other hospitals preferred the traditional approach.

Table 3. The top-five list of chronic disease drugs

List of medicine	Value (Baht)			
	SHPH A	SHPH B	SHPH C	SHPH D
Amlodipine 5 mg	27,360.50	18,322.00	25,019.50	25,030.00
Simvastatin 10 mg	25,528.80	13,772.40	26,861.20	23,047.60
Losartan 50 mg	13,143.71	8,262.51	9,366.20	11,896.11
Metformin 500 mg	9,174.59	3,885.40	8,425.16	9,351.20
Enalapril 5 mg	5,019.19	3,201.05	5,307.35	6,139.25

Note: SHPH = sub-district health-promoting hospital

3.2.1 Determination of maximum inventory level

This study used an inventory control system as a periodic review policy for VMI adoption. The periodic review policy was derived from the agreement between staffs at SHPHs and those at the community hospital because it was relevant to the workload of those responsible not only for inventory stock but elsewhere. Accordingly, the maximum inventory level was determined from the historical inventory data for the previous fiscal year (2018) and calculated according to the maximum inventory level for VMI at the hospitals. The distribution of demand characteristics was examined using the Kolmogorov-Smirnov test at the 95% confidence level, with a significance level of 0.05. Microsoft Excel was used for data analysis. The analysis found that the demand data was distributed normally. The maximum inventory level and safety stock level (SS) were calculated by using Equation (1) and Equation (2):

$$\text{Maximum inventory level} = \left(\bar{d}x\ T\right) + \ \text{SS} \quad (1)$$

$$\text{SS} = Z\,\sigma\,(T + \text{LT}) \quad (2)$$

where $\bar{d}$ = average demand per month, T = Review period (month), LT = Delivery lead time, Z = Service factor, σ = Standard deviation demand per month, SS = Safety stock.

As the clinics were held once a month, the review periods were calculated monthly. To determine the average demand, calculations in this study were based on average consumption rates per month. There was no delivery lead time for this replenishment process. The service factor (Z-score) was 1.64 to achieve a 95% service level. To select the proper service level, the researcher analyzed monthly demand data from the previous fiscal year. Several service levels were employed to estimate the proper maximum stock level. These included 95%, 98%, 99.5%, and 99.99% service levels. It was apparent that the 95% service level determined the maximum stock level, which was greater than the previous maximum consumption rate. The calculated maximum stock level was later rounded-up to the size of a medicine container. A bottle contained 100 simvastatin or amlodipine tablets, 300 losartan tablets, 500 metformin tablets, and 1,000 enalapril tablets.

3.2.2 The proposed VMI model for chronic medication

The proposed VMI model for SHPH is presented in Table 4. Regarding the information aspect, in the traditional approach, the order quantity was shared manually through purchase orders. Decisions were based on previous demand information and inventory levels. With VMI, the initial approach was to share the demand information electronically for VMI products. However, the healthcare staff asserted that they could not operate both traditional and electronically controlled systems. Consequently, they suggested that the demand information be shared manually using the replenishment forms together with a printed document, ensuring a common understanding of the current inventory position. Also, under the VMI approach, the maximum inventory control level was set, and the replenishment quantity was calculated based on the actual demand and inventory position.

Lastly, material management focused on how the stocks at SHPHs were to be replenished. Under the conventional approach, material management still followed the periodic review policy, requiring seven days for the replenishment process. Unlike the VMI approach with a periodic review policy, advance information helped shorten the replenishment process as the receiving date was proposed beforehand.

3.2.3 Comparison between before and after implementation of the VMI approach

The t-test statistics compared the performance outcomes before and after the VMI implementation. The results are presented in Table 5. There was a significant difference in performance outcomes between the before and after implementation stages of the VMI approach. The results highlighted that VMI significantly decreased the average storage period to 0.42 months, compared to 2.59 months for the conventional approach (p<0.05). Even though stockouts occurred neither during the VMI nor the conventional approach, the results showed that the latter led to four cases of emergency replenishment. That said, there was no significant difference between the two approaches in this respect.

Additionally, the findings showed that VMI significantly enhanced logistical performances, inventory turnover, and DIFOT. The inventory turnover rate under the VMI approach increased to 12.43, compared to the traditional approach rate of 2.56. Likewise, the DIFOT rate in the VMI application increased by 100% versus the traditional approach rate of 41.67. The inventory accuracy rate was 93.19 before the VMI implementation, reaching 100% after implementation.

The one-way ANOVA results comparing the four SHPHs are presented in Table 6. Of note are the significant differences between the traditional and VMI approaches. The average storage period in the community hospital where the VMI approach was applied was 0.42 months, whereas the average storage period for those hospitals employing the traditional approach was 3.04 months. When VMI was implemented, stockouts did not occur, and emergency replenishments were reduced from two times to none. The study further found that VMI could increase logistical efficiency. Inventory turnover, i.e., the number of times a business sells and replaces its inventory, increased from 2.17 to 12.43. Another finding was that the DIFOT rate increased from 66.67 to 100. Similar to the inventory accuracy rate, it had improved from 32.04 to 100.

4. DISCUSSION

This research has identified a limited number of studies related to the collaborative replenishment approach in hospitals compared to the retail and manufacturing industries (Chen et al., 2013). Few studies have explored the VMI adoption in the pharmaceutical supply chain (Guimaraes et al., 2013; Kim, 2005; Krichanchai and MacCarthy, 2017; Watson et al., 2012). However, VMI has been implemented in the public sector in Thailand, particularly in the dyad of community hospitals and SHPHs (Fungsuk and Polnok, 2017; Intoyos and Kessomboon, 2013; Srilamart and Bouphan, 2013). Earlier studies highlighted the benefits gained from VMI adoption. This study, however, focused on the practical issues of VMI adoption, particularly for chronic disease medication in this dyad.

Table 4. The proposed VMI model compared with the traditional inventory model

Management	Traditional approach	VMI approach
Decision transfer		
Inventory control decision	Staff at sub-district hospitals' responsibility	Pharmacist at the community hospital
Responsibility of the community hospital	Prepare the medicine supply for all sub-district hospitals	Make a replenishment decision and decide how much to order for VMI sub-district hospitals based on demand and inventory information Check inventory information against physical stock at the sub-district hospital
Responsibility of SHPHs	Make a replenishment decision for its own inventory	Share demand and inventory information
Information management		
Shared information	Order quantity	1. Demand quantity from 2. Inventory level at the end of month
Order quantity or Replenished quantity	Order quantity was estimated based on previous demand data and inventory decision was made by the sub-district hospital's based on their experience	Replenished quantity was calculated by using maximum stock level minus by inventory on-hand
Information sharing channel	Manually: order quantity was specified in replenished order form to the community hospital	Manually: demand quantity through replenished form together with current inventory level data to the community hospital
Material Management		
Inventory control policy	Periodic review system	Periodic review system
Reviewed period	One month	One month
Inventory control setting	No maximum stock level	Setting Maximum stock level
When to received inventory	On monthly basis The sub-district hospitals' staff were informed when the inventory was ready	On monthly basis The receiving date is specified in advance.
Receiving process	Sub-district hospitals' staffs check stock after stock is arrived at the SHPHs	Community hospitals' staffs and sub-district hospitals' staffs check stock at the community hospital before the stock is deliverer
Replenishment process period	7 days	4 days

Note: VMI = vendor-managed inventory, SHPH = sub-district health-promoting hospital

Table 5. Comparison between before and after implementation of the VMI approach

No.	KPI	Criteria	Before VMI	After VMI	t-test	Significant
1.1	Average storage period (months)	<1.5	2.59	0.42	12.03	0.000***
1.2	No. of stockout (times)	0	0	0	N/A	N/A
1.3	No. of emergency replenishment (times)	0	4	0	1.30	0.220
2.1	Inventory turnover rate (times)	Greater	2.56	12.43	-18.98	0.034***
2.2	Delivered in-full and on-time: DIFOT (%)	>95%	41.67	100	-3.92	0.002***
2.3	Inventory accuracy (%)	≥99%	93.19	100	-2.31	0.042***

Note: VMI = vendor-managed inventory

Table 6. Comparison between traditional and VMI approaches

No.	KPI	Criteria	Traditional approach	VMI approach	ANOVA test	Significant
1.1	Average storage period (months)	<1.5	3.04	0.42	8.75	0.000***
1.2	No. of stockout (times)	0	0	0	N/A	N/A
1.3	No. of emergency replenishment (times)	0	2	0	1.48	0.001***
2.1	Inventory turnover rate (times)	Greater	2.17	12.43	-20.24	0.000***
2.2	Delivered in-full and on-time: DIFOT (%)	>95%	66.67	100	-2.35	0.000***
2.3	Inventory accuracy (%)	≥99%	92.04	100	-1.88	0.000***

Note: VMI = vendor-managed inventory

4.1 Information management

Previous studies have recommended that information sharing be done continuously and electronically (Simchi-Levi et al., 2008). However, this study contradicted those analyses, as information sharing, an essential factor of VMI adoption, should be designed based on demand patterns. It further showed that information sharing could be done manually and on a monthly basis, as demand for chronic

disease medicines is generated each month. Besides, this information was shared manually in this dyadic context. Watson et al. (2012) explored VMI in the public sector and noted that manual reports or data collection by sellers could improve VMI. Even though electronic data transfer was suggested for VMI adoption, a manual transfer might be feasible, particularly at the beginning of the project (Vigtil, 2008; Waller et al., 1999). Therefore, this study highlighted that when selecting the data transfer the product demands, the readiness of staff and IT should be considered to improve cooperation and build sustainability.

The current study found that an essential factor improving the effectiveness of VMI was the quality of data in SHPHs. The recorded demand data must be accurate, and the recorded inventory data should reflect the physical inventory to calculate the precise amount of replenishment. The pharmacists in the community hospital are required to regularly audit the inventory at the SHPHs to ensure that the inventory is consistent with the report. This finding coincided with the studies of Guimaraes et al. (2013) and Waller et al. (1999) that pointed to the quality of data as a vital factor in effective VMI implementation. Vigtil (2008) also suggested that providing accurate information should be a key performance outcome for VMI customers.

4.2 Inventory management

This study indicated that chronic disease medication at the SHPHs presented as a stable demand product as chronic disease required patients to take medicine regularly. Most patients who received medication from SHPHs had stable conditions. However, previous studies from different sectors recommended that demand visibility under the VMI approach enabled benefits to be gained from fluctuating demand products (Niranjan et al., 2012). The VMI studied in the healthcare industry accorded with the findings of these studies. The VMI implementation was designed for regular demand products in hospitals, as pharmacists knew the amount of usage and could forecast the replenishment amounts (Krichanchai and MacCarthy, 2017).

This study found that the periodic review system was applicable for adopting VMI. The SHPHs suggested that this inventory control system is suitable for the characteristics of chronic medication as it has a stable and regular usage pattern. Also, the staff at the SHPHs mentioned their high workload, which included healthcare and inventory management tasks. Using a periodic control policy and creating a maximum stock level to control the stock helped them control inventory more effectively and easily than the previous approach. This finding was supported by Watson et al. (2012) and Krichanchai and MacCarthy (2017), who noted that the periodic review policy could be applied to VMI adoption within the public sector.

4.3 Relationship management

When the SHPH staff allowed the community hospital staff to make decisions about inventory replenishment, it showed that the SHPHs trusted the community hospital and that the medication would be properly and adequately replenished. Therefore, good relationships and trust between the community hospital and SHPHs are crucial and include the willingness of SHPHs staff to share information with the community hospital. This aspect of relationship management is consistent with Vigtil (2008), who stated that having a good relationship reflects a positive attitude, a factor that makes VMI successful.

This study demonstrated how good relationships and trust between community hospital and the SHPHs enabled successful implementation. Trust can be built if the seller shows the partners the benefits of implementing VMI (Claassen et al., 2008). In this study, VMI was a new system that had never been used before. Trust had to be built by ensuring accurate amounts of replenishment and the timeliness of delivered medications. Pharmacists at the community hospital also collaborated on mutual checking of medications, allowing for emergency replenishment in the event of VMI adoption failure. Consequently, the new approach resulted in SHPH staffs perceiving fewer risks of stockouts.

It is vital that the involved staff know the benefits of using VMI, including reduced workloads and increased convenience resulting from an elimination of the need to tally medications each month. Besides, VMI adoption was designed based on the collective opinions of the SHPHs and the community hospital. This result complemented other study findings that a system developed by both parties enhanced trust and sustainable collaboration (Dong et al., 2014; Siha and Arparsrithongsakul, 2019; Vigtil, 2008).

This study determined that VMIs could be implemented between community hospital and SHPHs. As both entities were affiliated with the Ministry of Public Health, there was no conflict of interest. This finding was supported by the study by Krichanchai and MacCarthy (2017). They described how state hospitals were willing to apply VMI and exchange the medication or inventory data with the state producers as there was no conflict of interest involved. Therefore, a factor in convincing state hospitals to implement VMI was the agreement by community hospitals and SHPHs to create the system collectively. Also, the benefits of using VMI must be communicated to the affected staff as it will simplify their work, reduce stock, and abolish emergency replenishment.

This study showed that VMI was more effective than the traditional approach. The research found that the SHPHs, as VMI customers, benefited from VMI application in terms of stock reduction, increased inventory turnover, ensuring DIFOT, and inventory accuracy. The SHPHs held five- to six-times more stock in the traditional approach than under the VMI approach. With demand visibility and a stock control system, staff could replenish based on the actual demand and inventory level. Therefore, VMI resulted in stock reductions without any emergency replenishment. These findings accorded with the studies of Intoyos and Kessomboon (2013), Siha and Arparsrithongsakul (2019), and Youcharoen and Wasusri (2018).

Although a continuous review policy was recommended for Group A products, this study demonstrated that Group A, with its stable demand pattern, was suitable for a periodic review policy with the VMI approach. These findings were consistent with several previous studies (Intoyos and Kessomboon, 2013; Siha and Arparsrithongsakul, 2019; Youcharoen and Wasusri, 2018).

Furthermore, demand visibility and close monitoring of inventory enhanced stock accuracy by 100%, per Claassen et al. (2008). The quality of data enhanced the effectiveness of VMI implementation. This study also measured logistical indicators, including DIFOT. Information sharing enabled the

community hospital, as a VMI supplier, to deliver the products with 100% accuracy and timeliness. Consequently, no emergency replenishment was required. Watson et al. (2012) noted that VMI enhanced stock availability for VMI customers while allowing the supplier to manage stock and transportation more effectively, which benefited the supplier by saving costs on storage and transportation.

5. CONCLUSION

A VMI could be used for the inventory management of chronic medications within the dyad relationship of the community hospital and the SHPHs. These medications are categorized as Group A. They are costly and have stable and regular demand patterns. Although earlier studies suggested a continuous review policy together with electronic data transfer for VMI adoption, the findings in this study contradicted the previous statement. It is suggested that data transfer and an inventory control policy be tailored to the product demand patterns and the hospital context.

This study demonstrated that a periodic review policy is suitable for chronic medications, which have a monthly demand basis. Advanced information technology has not yet been deployed to control inventory; healthcare staff must do this task. Therefore, at the beginning of the VMI project, it is suggested that information be transferred manually, requiring the pharmacist from the community hospital, as a VMI supplier, to help check the physical stock and set the inventory control system. In the long term, however, information technology should be deployed to reduce the VMI supplier workload.

Further, this study suggested that VMI should be designed based on collaboration between both parties. Consequently, VMI implementation results in a reduction in average stock rate and an increase in inventory turnover rate, ensuring DIFOT and increasing inventory accuracy for the SHPHs.

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