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Perspective

Barriers and facilitators of exploiting the potential of value-added medicines ›

Zsuzsanna Ida Petykó, András Inotai, Anke-Peggy Holtorf, Diana Brixner & Zoltán Kaló

Pages: 229-236

Published online: 29 Apr 2020

Abstract | Full Text | References | PDF (1063 KB) | EPUB |

118 Views

3 CrossRef citations

5 Altmetric

Review

Cardiovascular outcome trials of glucose-lowering therapies ›

Kamlesh Khunti, Melanie J. Davies & Samuel Seidu

Pages: 237-249

Published online: 13 May 2020

Abstract | Full Text | References | PDF (1323 KB) | EPUB |

199 Views

4 CrossRef citations

5 Altmetric

Original Research

Article

Cost-effectiveness of pan-genotypic direct-acting antiviral regimens for treatment of chronic Hepatitis C in the United States ›

Stuart Gordon, Janet Lee, Nathaniel Smith & Douglas Dieterich

Pages: 251-257

Published online: 17 Jun 2019

Abstract | Full Text | References | PDF (1000 KB) | EPUB | Supplemental |

226 Views

3 CrossRef citations

5 Altmetric

Article

Budget impact analysis of betrixaban for venous thromboembolism prophylaxis in nonsurgical patients with acute medical illness in the United Kingdom ›

Holly Guy, Vicki Laskier, Mark Fisher, Iwona Bucior, Steven Deitelzweig & Alexander T. Cohen

Pages: 259-267

Published online: 19 Jun 2019

Abstract | Full Text | References | PDF (949 KB) | EPUB | Supplemental |

119 Views

1 CrossRef citations

5 Altmetric

Article

Designing and Testing of a Health-Economic Markov Model for Prevention and Treatment of Early Psychosis ›

Ben F.M. Wijnen, Frederick W. Thielen, Steef Konings, Talitha Feenstra, Mark Van Der Gaag, Wim Veling, Lieuwe De Haan, Helga Ising, Mickaël Hiligsmann, Silvia M.A.A. Evers, Filip Smit & Joran Lokkerbol

Pages: 269-279

Published online: 20 Jun 2019

Abstract | Full Text | References | PDF (1805 KB) | EPUB | Supplemental |

Article

Cost-minimization analysis between intravenous iron sucrose and iron sucrose similar in hemodialysis patients ›

Arnaud Pagès, Céline Porteils, Isabelle Labadens, Matthieu Parmier, Samantha Oses, Damien Semely, Marion Bourdoncle, Bruno Seigneuric, Arnaud Del Bello & Blandine Juillard-Condat

Pages: 281-287

Published online: 01 Jul 2019

Abstract | Full Text | References | PDF (856 KB) | EPUB |

Article

Achieving cost-efficient management of drug supply via economic order quantity and minimum-maximum stock level ›

Ertha Kusuma Dewi, Maznah Dahlui, Djazuly Chalidyanto & Thinni Nurul Rochmah

Pages: 289-294

Published online: 24 Jun 2019

Abstract | Full Text | References | PDF (514 KB) | EPUB |

Article

Cost-effectiveness of Cladribine Tablets and fingolimod in the treatment of relapsing multiple sclerosis with high disease activity in Spain ›

J. L. Poveda, J. L. Trillo, C. Rubio-Terrés, D. Rubio-Rodríguez, A. Polanco & C. Torres

Pages: 295-303

Published online: 25 Jul 2019

Abstract | Full Text | References | PDF (1110 KB) | EPUB |

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Achieving cost-efficient management of drug supply via economic order quantity and minimum-maximum stock level

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ORIGINAL RESEARCH

Achieving cost-efficient management of drug supply via economic order quantity and minimum-maximum stock level

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ABSTRACT

Background: A good drug inventory planning system is important for an efficient budgeting, procurement, and cost control of drugs. When stagnant drugs in the inventory are too much, wastage due to expired and spoiled drugs could occur. These will not only cause loss of income but could also jeopardize healthcare service delivery.

Research design and methods: This study aimed to determine the most efficient and effective management of stagnant and shortage drugs by comparing three pharmacy logistic methods; the economic order quantity (EOQ), minimum-maximum stock level (MMSL), and the traditional consumption of drug inventory, at RA Basoeni Hospital, Mojokerto. Drug inventory was analyzed to calculate the opportunity loss, opportunity cost, and proportions of both stagnant and shortage drugs.

Results: We found that EOQ and MMSL performed best for control of stagnant drugs and shortage drugs, respectively. Both methods had proved as effective pharmacy logistic planning. In addition, EOQ produced the lowest opportunity cost for stagnant drugs besides the lowest opportunity loss for shortage drugs.

Conclusion: The study concluded that EOQ is the most effective and efficient method to manage stagnant and shortage drugs at hospital pharmacy.

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KEYWORDS
Economic order quantity; opportunity loss; opportunity cost; stagnant; shortage

1. Introduction

Pharmaceutical inventory refers to the register of purchased, movements, and availability of drugs and medical supplies kept by the hospital pharmacy [1]. Proper management of pharmaceutical inventory is important to ensure adequate stock of medicines and supplies for a smooth healthcare delivery services, and to get profits from the sale of drugs. It has been reported that pharmacy brings revenue via 50% of its activities [2]. The clinical pharmacy activities are a crucial component in the daily operation of a hospital [3,4]. As such, the effective and efficient pharmaceutical inventory is important because poor management would impact the amount of stagnant and shortage drugs [1].

There are three conditions in the control of pharmaceutical inventory; shortage, stagnant, and normal drugs [5]. Drugs are categorized as stagnant if the residual stock exceeds three times of the average usage per month and as shortage if the remaining stock was equal to zero as or less than the safety stock. Normal drug is when drugs availability is at the optimum amount, no less than the safety stock, and no more than three times the monthly usage [5]. Incidents of shortage drugs will jeopardize healthcare service delivery in the hospital, while a large amount of stagnant drugs will take up spaces and thus could increase the cost of storage [6]. These conditions lead to opportunity cost and opportunity loss in clinical pharmacy which subsequently affects the profit for the hospital [7].

Opportunity cost is defined as the highest alternative value which is sacrificed to earn something, while opportunity loss is the cost variance between the actual and the expected earned value due to stagnant and shortage drugs [8]. There are various methods that could be applied for drug inventory. The traditional method of drug inventory is based on the last period of actual drug need, adjusted, and corrected from previous period, and is commonly practice in many hospitals (also known as consumption method). Economic order quantity (EOQ) emphasizes an ideal order quantity for any item that strikes an optimum balance between inventory holding costs and incremental ordering costs [9]. Another concept related to EOQ is economic order interval (EOI) which depends on the value of the individual variables and decreases more orders per year [9]. Another two methods which are also related are the just-in-time method and material requirement planning that manage inventory requirement for medicines and supplies based on what is needed for the clinical pharmacy or annual usage [9]. Just-in-time is distinguished by ordering intervals, quantities, and inventory levels dependent on the projected production schedules [9]. The quantity discount model is particularly for fast-moving items that will definitely be used while taking advantages of the discounts within funding limits [9]. Minimum-maximum stock level (MMSL) is

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Article Highlights

- Stagnant condition causes negative impact such as increasing expired drugs, opportunity loss, and revenue loss for the clinical pharmacy.
- Shortage or shortage condition not only leads impact of reducing revenue but also impact of contributing mortality and morbidity for critical conditions.
- The reason behind opportunity loss is occurred due to inventory cost, ordering cost, and handling cost.
- Revenue loss is happened at stagnant condition due to inventory cost, ordering cost, and handling cost. Besides, revenue stock at shortage drugs causes the hospital lost the opportunity to sell the drugs.
- EOQ method showed more efficient inventory management at clinical pharmacy of the hospital than MMSL as it tackles problem of stagnant drugs and shortage drugs, increases efficiency and cost savings, and causes minimum opportunity loss and opportunity cost.

a theoretical maximum stock for each item to provide sufficient, but not excessive nor minimum to determine the point an order should be placed [9].

The drug inventory planning method applied by the pharmacy unit at RA Basoeni Hospital was consumption method. The consumption method is a drug inventory method to estimate drug requirements based on actual use of drug with adjusting and correction which are considered acceptable [10]. Unfortunately, the hospital experienced shifting consumption pattern every year due to disease trend that changed by year to year so this phenomenon affected the loss from drug inventory. For instance, this method turned out making loss of stagnant medications in 2014. The highest loss was from stagnant drugs by 90.8% while the expired drugs and shortage drugs were also contributed the loss. Not like many inventory challenges managing shortage drugs, the hospital experienced stagnant drugs that caused high economic loss [11].

Table 1 indicated the loss because of opportunity cost, opportunity loss by stagnant drugs, and opportunity loss from shortage drugs. We investigated there was less optimum in planning of drug inventory at the clinical pharmacy. Considering the simulation of the two methods, MMSL and EOQ, which have not been done by the hospital, is the objective of this study with the setting of one of public hospital in Indonesia. This study aimed to identify the efficient and effective drug inventory planning method taking into consideration the opportunity lost and opportunity cost of stagnant and shortage drugs. EOQ and MMSL had been selected as the methods for comparison with the existing consumption method. We simulated EOQ because it considers operational cost, financial cost, and determine the quantity of order to minimize overall inventory cost [12]. In addition, we had also simulated MMSL as a formula which is frequently used in scheduled purchasing with set order intervals [9]. As prior studies have investigated the costs, we expanded the study into economic and opportunity loss. This study may facilitate the managers by providing the alternative solutions particularly in financial management of healthcare and drug inventory planning. Furthermore, it will be valued to informing the decision makers to increase budget planning of the hospital in effective and efficient way.

Table 1. Amount of stagnant, shortage, and normal drugs according to drug inventory planning methods.

	Methods		
Variable	Consumption (%)	EOQ (%)	MMSL (%)
Normal drugs	7	34	20
Stagnant drugs	77	41	37
Shortage drugs	16	25	44

2. Materials and methods

This study is a simulation study used the pharmaceutical logistics data of 2015 from the clinical pharmacy of RA Basoeni Hospital, Mojokerto District during the months of January–December 2015. The hospital only allowed the study protocol to simulate the methods but equipped with actual data of pharmaceutical logistics in the clinical pharmacy in order to obtain high-quality research outcome. The methods of MMSL and EOQ were used to compare between two methods exploring the most efficient and effective for the hospital pharmacy that still used consumption method. Considering the methods of EOQ because it is the most common method and it applies easily particularly for this hospital, that has not been used any method to manage its pharmaceutical logistics. MMSL method has been selected for the study because it is able to determine optimum stock and it manages the stock based on component availability policy of minimum and maximum levels. Overall, both methods of EOQ and MMSL give low output of opportunity cost and opportunity lost so total cost occurring in drug logistic is low.

Ethics approval to conduct the study had been granted by the Health Research Ethic Committee of Faculty of Public Health, Universitas Airlangga (No. 590-KEPK) while permission to access the pharmacy data was obtained from the studied hospital. As the hospital was only able to provide a raw pharmaceutical logistic data, the extraction and calculation were conducted by the researchers using Microsoft Excel. Data extracted were classified into (1) early stock; (2) purchasing; (3) utilization; (4) last stock; (5) expired drugs; (6) purchasing cost for regular and emergency supplies; (7) shipping cost; (8) inventory cost; and (9) waiting time of drugs delivery. Drugs from list of A class which comprised of 80% from the total hospital drug budget were selected as the samples for analysis. There were 126 medication types in list A class.

The data were analyzed using Microsoft Excel along with the formula and mathematical calculation to determine effectiveness and efficiency of inventory management. The formula for EOQ and MMSL is as given by [9,13]

$$EOQ = \sqrt{\frac{2UO}{H}} \quad (1)$$

Where:

U = annual use, in units

O = incremental ordering cost

H = average holding cost (percentage of average inventory value).

$$S_{MIN} = (LTxC_A) + SS \quad (2)$$

Where:

S_{MIN} = minimum stock
LT = lead time
C_A = average consumption
SS = safety stock

$$S_{MAX} = S_{MIN} + (PPxC_A) \tag{3}$$

Where:

S_{MAX} = maximum stock
S_{MIN} = minimum stock
PP = purchase period
C_A = average consumption

$$Q_0 = (S_{MAX} + SB - (S_I + S_O) \tag{4}$$

Where:

Q_O = order quantity
S_{MAX} = maximum stock
SB = stock back order
S_I = stock hand in inventory
S_O = ordered stock.

The first step was calculating average of actual drug use per month from the data, and determining lead time and safety stock. Lead time comes from the mean of waiting time that begins from ordering activity to inventory activity. Safety stock equals to lead time multiplying daily consumption (C) that ensuring the available drug stock to anticipate unexpected need and demand of the medication. Continuing the step by dividing class A drugs into normal, stagnant, and shortage group. Stagnant condition means the drugs should be at least three times higher in volume than the normal stock. Normal stock means optimum stock availability of drugs in the logistics. Shortage occurs when the remaining stock was equal to zero as or less than the safety stock. Opportunity cost and opportunity loss were calculated for each stagnant and shortage drugs. Opportunity loss here is defined as the lost chance from wrong action or decision, while opportunity cost is a lost potential gain from acquiring something.

For shortage drugs, we calculated opportunity loss as shortage causes lost chance to obtain profit from the drugs that are unable to be sold. Opportunity loss of shortage drugs is derived from the lost sales, emergency purchasing loss, and waiting time loss. Each formula of opportunity loss for three elements is as given by,

$$\begin{aligned} \textit{Opportunity loss of lost drug sales} &= (\textit{volume of shortage drugs}) \\ &\quad x\ (\textit{prices of purchasingx } 25\%\ \textit{drugs}) x\ 25\% \end{aligned} \tag{5}$$

$$\begin{aligned} \textit{Opportunity loss of waiting time loss} &= \left(\frac{\textit{lost waiting time}}{\textit{mean of waiting time}}\right) \\ &\quad x\ (\textit{mean of earnings per perscribtion}) \end{aligned} \tag{6}$$

$$\begin{aligned} &\textit{Opportunity loss of emergency purchasing} \\ &= (\textit{volume of shortage drugs})\ x\ (\textit{base sale price})\ x\ 15\% \end{aligned} \tag{7}$$

The percentage of 25% is the margin established by the hospital for drug sales at the clinical pharmacy, while 15% is the margin for emergency purchasing because of unavailable drugs. Total opportunity loss is derived from each calculating result of lost drug sales, waiting time loss, and emergency purchasing loss.

For stagnant drugs, the condition causes opportunity cost including inventory cost and ordering cost for the drugs that should be sold. Opportunity cost of stagnant drugs was counted according to purchase and transport cost. The total opportunity cost of stagnant drugs was obtained by summing up the total cost of available stagnant drugs and its ordering cost. Each formula of opportunity cost for two elements is as given by,

$$\begin{aligned} &\textit{Opportunity cost from ordering cost} \\ &= \frac{(\textit{ordering cost per year})\ x\ (\Sigma \textit{frequency of ordering stagnant drugs})}{\Sigma \textit{frequency of ordering all drugs}} \end{aligned} \tag{8}$$

$$\begin{aligned} &\textit{Opportunity cost from inventory cost} \\ &= \frac{(\textit{inventory cost per year})\ x\ (\textit{volume of stagnant drugs})}{\Sigma \textit{volume of drugs at the inventory}} \end{aligned} \tag{9}$$

For total opportunity loss of stagnant drugs, it was counted by summing up opportunity loss of capital cost to purchase drugs, expired drugs, and failed to return expired drugs. Each formula of opportunity loss for three elements is as given by,

$$\begin{aligned} \textit{Opportunity loss from capital cost} &= (\textit{volume of stagnant drugs}) \\ &\quad x(\textit{base sale price})\ x\ 25\%\ x\ 0.8\%\ x \\ &\quad (\textit{using time of stagnant drugs in month}) \end{aligned} \tag{10}$$

$$\begin{aligned} \textit{Opportunity loss from capital cost} &= (\textit{volume of stagnant drugs}) \\ &\quad x(\textit{base sale price})\ x\ 25\% x 0.8\% \\ &\quad x(\textit{using time of stagnant drugs in month}) \end{aligned} \tag{11}$$

$$\begin{aligned} &\textit{Opportunity loss from failed to return expired drugs} \\ &= (\textit{volum of stagnant drugs that are failed to return}) \\ &\quad x(\textit{basesale price}) \end{aligned} \tag{12}$$

The percentage of 0.8% is the capital interest established by the hospital. Those formulas above were used to calculate the drugs outcome both in EOQ method and MMSL method. The process in each method in this study was used similar steps begin from identifying the drugs category until calculating opportunity cost and opportunity loss including margin and capital interest.

The most effective method was determined by finding the highest percentage of normal drugs. Meanwhile, the most efficient method was determined by calculating the lost values from opportunity loss and opportunity cost of stagnant and shortage drugs. The method that provides the lowest loss in

Table 2. Opportunity cost and opportunity loss according the various drug inventory planning methods.

Variable	Methods		
	Consumption (IDR)	EOQ (IDR)	MMSL (IDR)
Opportunity cost of stagnant drugs	102,957,621	20,441,595	21,975,216
Opportunity loss from stagnant drugs	473,733,147	31,301,702	25,510,891
Opportunity loss from shortage drugs	55,164,308	9,052,075	41,318,057
Total	631,855,077	60,795,372	88,804,164

opportunity cost and opportunity loss would be considered as the most efficient method.

3. Result

The amount of stagnant, shortage, and normal drugs according to the simulated (EOQ and MMSL) and studied (consumption method) drug inventory planning methods were as shown in Table 1. It could be observed that EOQ performed the best for the normal drug inventory. The normal drugs were available of 34% compared to only 20% and 7% via MMSL and consumption method, respectively. As for stagnant drugs, MMSL caused the lease remained drugs (stagnant) followed by EOQ and consumption methods. Consumption method was the best method in determining the least shortage drugs.

Table 2 showed the value of opportunity cost for stagnant drugs and opportunity loss for both stagnant and shortage drugs by applying the three drug inventory methods. It could be seen that the opportunity cost for stagnant drug was the least in EOQ method. The opportunity loss for stagnant drugs was the lowest in MMSL method but for shortage drugs the lowest was in the EOQ method.

4. Discussion

The hospital nowadays is looking for the proper method of pharmaceutical inventory that has well effect for financial operation. This issue has become main challenges for the hospital because the inventory management is inextricably linked with patient care and the cost [11]. Improving and/or changing the drug inventory management were believed to be a way avoiding excessive inventory investment [14]. It is better for the hospital to choose the method based on problem that mostly concerned. Identifying the problem will be complicated if the hospital does not have the design thinking framework and design pattern of inventory management [15].

Mostly, the costs associated in drug inventory are (1) shortage cost; (2) carrying cost; and (3) replenishment cost [16]. As recently technology becoming more sophisticated than before, the hospital that is equipped with computerized system have may maximize its inventory performance [17,18]. Assessing the outcome of good inventory management is likely being reviewed from economic or quantity measurement. The hospital could predict its net profit gross accordance to the margin return on investment [19].

Inability hospital to plan good inventory might cause stagnant condition that affected cost of drug storage. It caused unbalance of need and demand when the hospital could not decide the right amount of availability drugs stock. Eventually, the unbalance leads to overstock condition in clinical pharmacy [6]. The high stock inventory that associated with holding cost contributed most to inefficiency in the inventory management [20]. Stagnant drug has risk of becoming an expired drug. Although expired drugs could be returned to the drug distributors or manufacturers, some drugs are not considered. Opportunity loss of stagnant drug included capital cost, cost of potential expired drugs, and cost of failed returning of drugs (no redemption), when they had remained stagnant for certain duration of time. These were also reported by a study that stagnant drug can cause waste because of damaged especially if not stored properly, over its expiry date, cost incurred for surveillance, and from reduced drug price [13]. Thus, the lower the volume of stagnant drugs, the lower the opportunity loss and thus the subsequent loss of revenue to the hospital could be avoided. The right purchasing order of drugs in right time might reduce overstock drugs [6].

Too low volume of commonly used drugs could result in shortage drugs if not managed properly. Incidences of shortage drugs imply opportunity loss because the sales are missed due to unavailability of the drugs. It is recommended that pharmaceutical unit should identify the drugs which are in urgent need and for emergency use and also drugs which are most commonly prescribed with rapid turnover [21,22]. The impact of shortage drugs to hospital revenue could be substantial; it had been reported to reduce the revenue by up to 15% in the form of sale's lost [23]. Total opportunity loss for shortage drug is obtained from the summation of loss of sale, loss of waiting service time, and additional cost from emergency purchasing. It has been reported by another study that shortage drugs had caused some drug prescriptions were not being served. Thus, it impacted lost income for the hospital [24]. Further unacceptable impact, the shortage drugs also with its cost that used for critical condition might involve increasing mortality and morbidity [16].

Three methods of drug inventory planning: EOQ, MMSL, and consumption had been compared to determine which method would be most effective and efficient in the management and control of drugs at the pharmacy. The amount of normal, stagnant, and shortage drugs, along with the opportunity cost and opportunity loss, were used to indicate effective and efficient method. The study showed that in determining the availability of sufficient volume of normal drugs, EOQ performed the best. As for the stock of stagnant drugs, purchasing drugs via both the EOQ and MMSL methods resulted with the lowest volume of stagnant drugs.

The consumption method is reconsidered by the hospital when the disease prevalence frequently changed from year to year. The users should pay attention to any irrational consumption patterns that affected adjustment process [10]. It was because the method works by adjusting the drug stock based on estimation of last actual drug use [10]. The actual drug use does not mean identical to drug need [10].

Therefore, the implementation using the consumption method requires improving prescription in order to be correctly adjusted with drug need estimates [10]. The hospital should apply the advance inventory management based on actual data of hospital information system. So, the forecast of drug purchasing order and demand is better than the traditional method [20]. The better forecast, the lower economic loss and the higher cost saving for the hospital. Its advantage is that it does not require either standard treatment schedules or detailed data on patient morbidity [10].

Upon studying the three drug inventory methods, MMSL was observed as the method that caused the lowest opportunity loss pertaining to stagnant drugs. In this method, each drug item was determined by its maximum and minimum stock levels in which when the drug's volume had reached the minimum amount, it would be purchased immediately until the volume reach the optimal stock. This method is appropriate for drugs that are used commonly; as the actively used drug's volume reached the set minimum level, new purchase will be activated [25]. This method is suitable for the hospital that frequently used for scheduled purchasing inventory with adjustment of order interval [26]. However, the level of minimum and maximum stock depends on the average of drug used [26]. The period time of minimum and maximum stock also depends on drug classification either A, B, or C [27].

EOQ is very good method for the hospital that purposes to balance the carrying cost of inventory, avoid shortage drugs situation, and minimize the total cost inventory [17,28]. This method was introduced as an alternative for clinical pharmacy which has cyclical ordering system in a big hospital [29]. The method frequently used with ABC inventory analysis [17,29]. The development of EOQ using computerization model with online data base is more effective to reduce the inventory operation cost than without technology for the hospital [17]. We found the gap to applying the method that requires detailed calculation of drugs stock. The required process is difficult for small Indonesian hospitals that do not have digitalized information system on its pharmaceutical logistics. As such this hospital, only billing system has been operated with digitalized information system or management information system, while the clinical pharmacy used software of Microsoft Excel for its information system to record daily pharmaceutical logistics. Moreover, there is no alarm alert for such amount drug stock to avoid shortage drugs since the hospital uses only Microsoft Excel.

EOQ and MMSL proved to be effective methods to control the stock of stagnant drugs. A low volume of stagnant drugs will minimize both the opportunity cost and opportunity loss. Drugs that remained stagnant at the pharmacy incurred high cost of storage [6]. In order to minimize both the opportunity cost and opportunity loss, there is a need control the purchase of drugs in terms of the correct volume and appropriate frequency of purchasing drugs so that the drugs are available when needed without having too much stock stored at the pharmacy. All these losses were observed to be low when the EOQ method was simulated for shortage drug. It was observed that the reason for this was the use of ROP (Re-Order Point) that set the minimum limit for reordering in EOQ method. EOQ also is proven to be a method that can produce significant annual savings from low dollar value of drug lists which were being purchased frequently [28,29]. Another study support EOQ concept may be an effective inventory control system after the demonstration showed increasing efficiency and cost saving [28]. Thus, as was seen in this study, EOQ had caused the minimum opportunity loss and opportunity cost and is considered as the most efficient method to manage drug inventory. The hospitals located in Indonesia should apply EOQ particularly those hospitals remain used consumption method as this study set Indonesian hospital setting with similarity of health system, disease trends, and consumers. On the other hand, it is recommended for the hospital to begin implementation of management information system on its pharmaceutical logistic. For further studies, the effective management indicator might be seen from gross margin return on investment [19].

5. Conclusion

EOQ purchase drugs in an economical way allowing optimal volume of stock resulting in low stagnant and shortage drugs. It causes minimum opportunity loss and opportunity cost and thus is an effective and efficient drug inventory method compared to MMSL and usual consumption methods, at RA Basoeni Hospital, Mojokerto. It is recommended that EOQ inventory plan be applied in this hospital and other hospitals with similar set up.

6. Expert opinion

A good drug inventory might guarantee a good healthcare service quality. The indicator of a good inventory is normal that doesn't cause loss, unlike shortage and stagnant. A good healthcare service quality might increase the revenue of healthcare.

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Author contribution statement

EKD, DC, and TNR involved in conception and design of the study. EKD written the proposal of the study, collected and analyzed the data. TNR wrote the manuscript with support from all authors. EKD, DC, and TNR involved in analysis and interpretation of the data and did the drafting of the paper or revising it critically for intellectual content.

MD and TNR involved in final approval of the version to be published. All authors approved the version to be published; and agree to be accountable for all aspects of the work.

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