Economic Evaluation of Ready-to-use Injectable Medications by Pharmacy Department Compared with the Traditional System of Individual Preparation by Nurse

Prapaporn Noparatayaporn, M.Sc.*, **, Tanita Thaweethamcharoen, Ph.D.*, **, Apirom Laocharoenkeat, M.S., Panitta Narkchuay, M.N.S. ***, Anchalika Klinniyom, M.Sc. (in Pharm)**, Cherdchai Nopmaneejumruslers, M.D.****, Khemchat Wangtawesap, M.D. *****, Siriporn Pitimana-aree, M.D. *****, Darin Sakiyalak, M.D.******

Siriraj Health Policy Unit, **Department of Pharmacy, ***Department of Nursing, ** Department of Medicine, *****Department of Anesthesiology, ******Department of Ophthalmology, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok 10700, Thailand.*

ABSTRACT

Objective: To dispense medication in a form of ready to use (RTU) medication was recommended by the standards of Joint Commission International (JCI) and Standard Guidelines of Hospital Pharmacy for preventing the medication error. However, the cost and benefit were questionable. The costs may increase while benefits were unclear. Before making the implementation decision, the cost of investment and benefit between traditional (injectable medication is prepared by nurse) and RTU systems (injectable medication is prepared by pharmacy department) should be evaluated.

Methods: This study compared the cost and benefit of injectable medication administration between the traditional system and the RTU system within a large academic hospital. The decision tree was designed to produce comparable data on the hospital's perspective. The time horizon was 10 years thus all costs were discounted at 3% annually. Sensitivity analysis was performed to test the stability of the results.

Results: The cost of investment at 10-year intervals of the RTU system was lower than the traditional system by about 18,710,160 baht. The benefit was decreased 19.32 full time equivalents (FTEs) of nurse when compared with the traditional system. The result showed that the five most sensitive variables were number of doses, mixing time per dose (prepared by nurse), space for production, salary and fringe benefits of pharmacists, and mixing time per dose (prepared by pharmacist).

Conclusion: The RTU system saved 1,871,016 baht per year and 19.32 FTEs of nurse. Moreover, the RTU system enhanced the opportunity of nurses and pharmacists to play more professional role and promoted the efficient health care system.

Keywords: Ready-to-use medication; premixed medication; intravenous admixture; medication administration; economics (Siriraj Med J 2019;71: 25-30)

INTRODUCTION

The growing nursing workforce shortage has increased nurse workload and reduced the amount of nursing time available for patient care activities.[1] The prior study found that nurses time spend on specific activities such as documentation, medication administration,

Corresponding author: Tanita Thaweethamcharoen
E-mail: tanitath@gmail.com
Received 24 May 2017 Revised 27 October 2017 Accepted 8 December 2017
ORCID ID: 0000-0002-6093-779X
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care coordination, and patient care activities.[2] In the hospital view, some parts of nurses' activity especially admixing in step of medication administration would be considered to decrease workload of nurse. Some injection medications such as high alert drugs were prepared by pharmacy department and dispensed in ready to use dosage form. Thus medication would be administered to the patient without the admixing step by nurse. Totally, nurses could decrease their workload and have more times for patient care. From previous study, 73.3% of nurses agreed that ready to use (RTU) medication preparation reduced nurses' workload.[3]

For the pharmacist's role, dispensing medications in form of ready-to-use medications or premixed medications in order to decrease medication errors was recommended by the standard of Joint Commission International (JCI) and Standard Guidelines of Hospital Pharmacy.[4] Having RTU medications may help reduce admixing errors or administration errors.[5] Thus, to prevent the medication error, enhance pharmacist role, and decrease nurse workload, RTU medication was considered. Previous study found that advantages of RTU medications are as follows:

1. RTU medications assured that patients received accurate dosages, and reduced medication errors.[6-10]

2. RTU medications could be administered more quickly especially in a busy time in hospital. Thus they could reduce overloading in emergency rooms and other treatment areas.[10]

3. The cost of RTU medications preparation was less than cost of individual preparation by nurse.[10,11]

4. RTU medications reduced risk of microbial contamination and cross contamination.[10]

5. RTU medications could reduce needle-prick injury which was a major occupational health and safety issue facing healthcare professionals especially nurses.[10]

Previous studies [6-9] found that injectable medication preparation by pharmacist decreased medication errors whereas the system may increase cost of investment. However, the overall cost was expected to be decreased from prevented medication errors.

For this setting, the cost of investment for the RTU system and the evidence of benefit were controversial issues that provoke differing views from the relevant health care personnel. The costs may increase from the capital cost for the standard practice of sterile preparation and the involved personnel in the production process while benefits were unclear. Before RTU medication implementation, cost of investment and benefit of the system needs to be evaluated. Thus the objective of the study was comparison on the cost of investment and benefit of injectable medication preparation system between traditional and RTU systems.

MATERIALS AND METHODS

The study evaluated two intravenous admixture systems; the traditional system (injectable medications were prepared by nurse) and the RTU system (injectable medications were prepared by pharmacy department. Nine high volume antibiotics after reconstitution is stable under refrigeration (2-8 °C) for at least seven days were chosen for RTU medication. The recommended dose of preparation was the usual adult dose for treatment in the hospital. Cost of investment was analyzed in hospital perspective. Direct cost including capital cost, labor cost, material cost, and other costs incurred in ten years were accumulated and discounted to present value with 3% discounting rate.[12] To analyze cost and sensitivity analysis, TreeAge Pro Healthcare was used. The benefit in terms of full-time equivalents (FTE), of the number of staff required for work process, was analyzed for comparison. In medication preparation process, the traditional system required nurse, whereas pharmacist and pharmacy technician were involved in the RTU system. The FTE of the study was calculated based on 6 hours per day and 230 days per year. Data included in the study was extracted from the hospital data and directly recorded at ward and pharmacy department. (This study was approved by the Institutional Review Board Ethics Committee IRB. No. 558/2558(EC2).)

Traditional system

Injectable medication was prepared for administration with aseptic technique at ward environment by nurse. Then medication would be immediately administered to patient. Cost of investment comprised of labor cost and material cost. Labor cost including salary and fringe benefits of nurse was calculated from time spent in preparation process. Time spent of work process was collected at ward and calculated as full-time equivalent (FTE). Data of salary and fringe benefits were obtained from human resource unit and estimated that in every year salaries increased 5% (salary increase between 3-7% per year). Sterile syringe and needle were used and accumulated for cost per dose in preparation process.

RTU system

Injection medication was prepared by pharmacist (R.Ph) and pharmacy technician (Ph.Tech) in cleanroom as the standard practice of pharmaceutical compounding - sterile preparations. RTU medication was stored at controlled temperature (2-8 °C) and dispensed with cold

chain system. Cost of investment consisted of capital cost, labor cost, material cost, and other costs. Capital costs were fixed cost incurred in the production of RTU medication such as laminar airflow hood, vial roller mixer, sealer, repeater, pharmaceutical refrigerator, autoclave, hot air oven. For this study, a lifetime of 10 years has been chosen for all production equipment by an expert panel. Computer and printer would be changed every 3 - 5 years. Cleanroom and laminar airflow hood needed maintenance since the first year of production. For other equipment, for the first two years of implementation the support and maintenance were free. In this system, opportunity cost of space for production was included. Labor cost was defined as labor cost of pharmacist and pharmacy technician. Time spent in preparation and packaging process was collected at pharmacy department. Data of salary and fringe benefits were obtained from human resource unit and estimated that in every year salaries increased 5%. RTU medication was contained within the sterile packaging labeled medication name, concentration, lot number, and expiration date. Material including sterile syringe, sterile needle, packaging, and labeling was used for RTU medication.

Sensitivity analysis

Sensitivity analysis was used to evaluate how uncertainty in the model inputs affected the outputs of the model. There was a wide range of input data for sensitivity analysis as Table 1. The use of sensitivity analysis results were classified to four categories: making decision or development of recommendations for decision makers, communication, increased understanding or quantification of the system, and model development. While all these uses were potentially important, this study focused on decisions making or recommendations. When the optimal option was insensitive to parameter changes, policy maker considered higher confidence of implementing the optimal option. On the other hand, if the option was sensitive, sensitivity analysis could be used to specify the level of importance of changes and recommend solutions. Even if the levels of variables in the optimal solution were changed dramatically by a higher or lower parameter value, the stability of the outcomes should examine the difference in profit (or another relevant objective) between these solutions and the base-case solution.[13] One way sensitivity analysis was performed on all variables in order to test the stability of the outcomes and presented as the tornado diagram. Tornado diagram showed changes in the net present value under the feasible range of each variable.

RESULTS

The estimated number of medications per year was 300,827 doses. 10-year cost of investment for traditional and RTU system were analyzed and presented as present value. Direct cost was accumulated from capital cost, labor cost, material cost, and other costs. The total 10-year cost of the traditional system included labor and material costs which was 98.24 and 9.25 million baht, respectively. For the RTU system, total 10-year cost of labor and material were 39.52 and 5.07 million baht, respectively. Capital and opportunity costs were also included in the RTU system. Total 10-year capital and opportunity costs were 4.65 and 39.54 million baht, respectively. The cost of investment of the traditional system and the RTU system were 107,492,820 baht and 88,782,660 baht, respectively as shown in Table 2. The RTU system reduced overall cost about 18,710,160 baht in 10 years when compared with the traditional system.

For workload, the RTU system could shorten some preparation processes so lower human resource requirements per dose were needed. As Table 1, medication preparation time in the traditional system took 319 seconds per dose compared with 240 seconds per dose in the RTU system. The result showed that the traditional system required 19.32 FTEs of nurses while the RTU system required 3.63 FTEs of pharmacists and 10.90 FTEs of pharmacy technicians. Thus using the RTU system could replace 19.32 FTEs of nurses.

Sensitivity analysis

From the Fig 1, the most sensitive variable was number of doses per year of RTU medication. The RTU system saved cost when the minimum number of RTU medications was 211,346 doses per year. The following sensitive variables were nursing time for medication preparation, space of production, salary and fringe benefits of pharmacist, and pharmacy technician, respectively. Decreasing the nursing time for medication preparation from 319 sec/dose to 258 sec/dose, the lowest expected value changed from the RTU system to the traditional system. When the space of production was more than 552.46 square meters, the lowest expected value changed from the RTU system to the traditional system. Increasing the salary and fringe benefits per month of pharmacist and pharmacy technician to 77,018.29 and 28,191.26 baht, respectively, the lowest expected value changed from the RTU system to the traditional system. For the salary and fringe benefits of nurse with less than 31,418.62 baht/month, the lowest expected value changed from the RTU system to the traditional system. With the increase

TABLE 1. All variables and intervals used in the model and sensitivity analysis.

Variable	Value	Low	High
Number of medications (doses/year)	300,827	220,934	391,075
Working time per year (sec/FTE)	4,968,000	4,968,000	5,796,000
Increasing rate of salary per year (%)	5	3	7
Discount rate (%)	3	0	7
Traditional system			
Medication preparation time: nurse (sec/dose)	319	30	2,730
Salary and fringe benefits of nurse (baht/month)	38,809.96	23,250.00	124,257.10
Material cost (baht/dose)	3.50	2.50	5.00
Ready to use (RTU) system			
Laminar Airflow Hood cost (baht/piece)	400,000	300,000	500,000
Vial Roller Mixer cost (baht/piece)	25,000	25,000	30,000
Sealer cost (baht/piece)	25,000	25,000	30,000
Repeater	300,000	300,000	350,000
Pharmaceutical Refrigerator cost (baht/piece)	38,000	26,000	38,000
Autoclave cost (baht/piece)	350,000	350,000	400,000
Hot Air Oven cost (baht/piece)	130,000	130,000	150,000
Computer and Software cost (baht/piece)	25,000	20,000	30,000
Printer cost (baht/piece)	20,000	20,000	25,000
Refrigerator for storing RTU medications	128,000	104,000	152,000
Maintenance cost of Laminar Airflow Hood (baht/machine/year) *	7,000	4,900	9,100
Maintenance cost of cleanroom (baht/year) *	60,000	60,000	100,000
Maintenance cost of product equipment (baht/year) †	50,000	35,000	65,000
Space of production (square metre : Sq m)	375	255	555
Opportunity cost (baht/m^2/year)	12,000	12,000	18,000
Medication preparation time: R.Ph (sec/dose)	60	36	120
Medication preparation time: Ph.Tech (sec/dose)	180	120	180
Salary and fringe benefits of R.Ph (baht/month)	37,720.96	21,290.00	124,236.90
Salary and fringe benefits of Ph.Tech (baht/month)	15,092.14	11,422.00	54,291.30
Material cost (baht/dose)	1.92	1.51	9.00

Abbreviations: R.Ph = Pharmacist, Ph.Tech = Pharmacy technician

* Cleanroom and laminar airflow hood required maintenance every 6 months since the first year of implementation.

† Maintenance cost occurred in the third year after implementation.

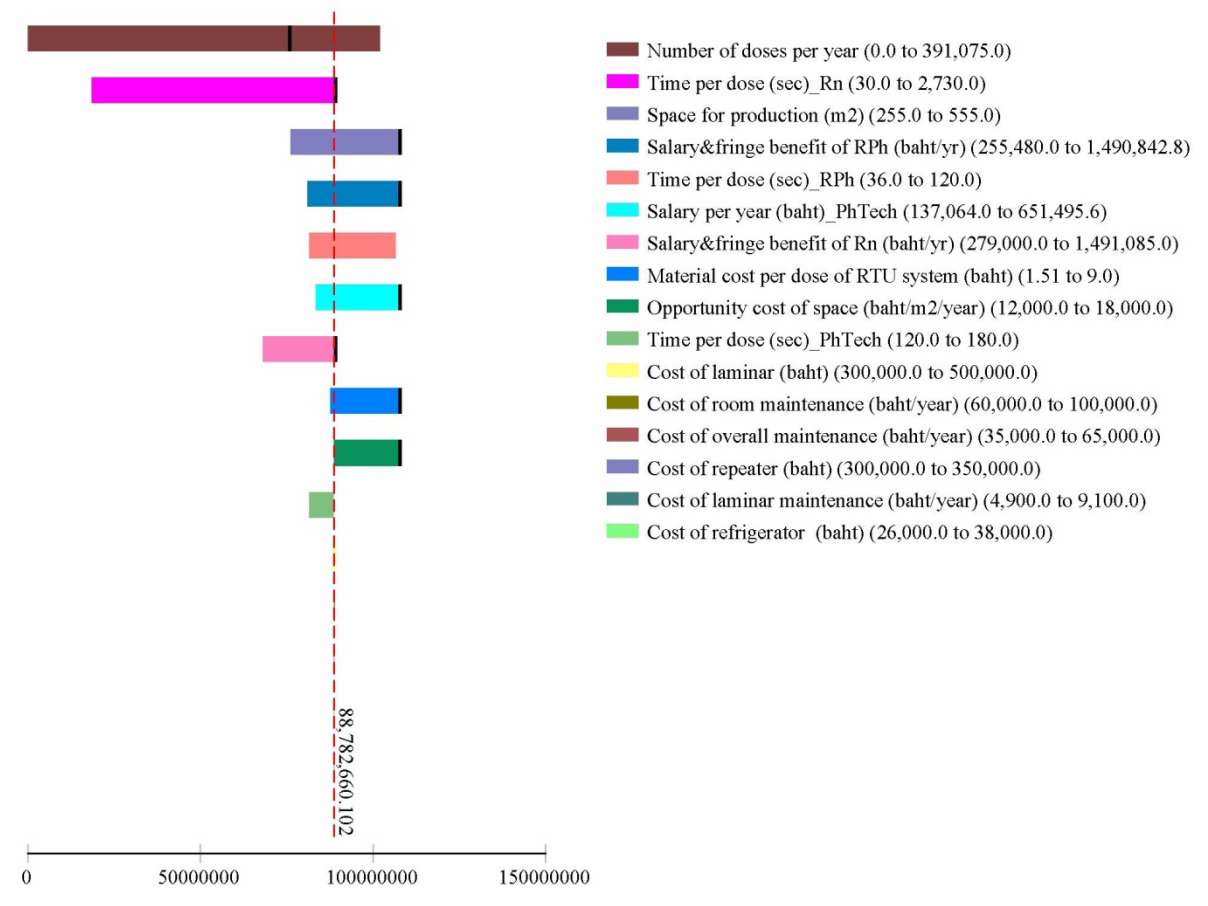

Fig 1. Tornado diagram

in material cost for RTU preparation to 9 baht/dose, the traditional system would be cost saving. Not only space of production, but opportunity cost of space also affected the alternative. Increasing the opportunity cost from 1,000 baht/m^2/month to 1,473 baht/m^2/month, the lowest expected value changed from the RTU system to the traditional system.

DISCUSSION

This study focused on medication in standard dose with extended shelf life at least seven days. The estimated numbers of medications per year were 300,827 doses. In the RTU system, capital, maintenance, and opportunity costs increased. However, the RTU system saved labor and material costs. Material cost per dose in the RTU system lowered from fewer needle and syringe volumes per dose preparation. As a result, cost saving of labor and material costs from the RTU system were 58,725,439 baht and 4,176,096 baht in 10 years, respectively. Overall in a 10-year period, the RTU system saved 18,710,160 baht. As a result, the RTU system could save nursing time 19.32 FTEs from reducing administration time while workload of pharmacist and pharmacy technician increased 3.63 FTEs and 10.90 FTEs, respectively. The benefits of the RTU system implementation were the opportunity of nurse to provide a patient care and pharmacists to play the role as the standard of JCI and good pharmacy practice. Moreover, the RTU system is able to enhance the safety of medication administration and promote the efficient healthcare system.

From sensitivity analysis, the number of medications was the most sensitive variable. To increase items covered by the RTU system could save more cost of the system. The result would be influenced by the change of number of medications, admixing time per dose by nurse, space for production and opportunity cost, salary and fringe benefits of pharmacist, pharmacy technician, and nurse, and material cost of the RTU system. To decrease labor cost in the RTU system, offering overtime compensation could decrease labor cost compared with full-time staff employment. When nurse took admixing time less than 258 seconds, the traditional system would be the lower cost alternative. In this observation, 44.43% of admixing doses took less than 258 seconds. However, nursed can be disturbed by calls and other notifications during administer or mixing injectable drug. The previous study

showed that the interruption event occurred one in 1.7 times of admixing. Thus nurse required more time in real practice during admixing from the interrupted event.

The study did not take into account the cost of medication and diluent which were equal in both systems. RTU medication was the dose of standard usually used with long stability, so cost from expired RTU medications was not accumulated. However, the efficient system would be planned for the RTU system implementation to prevent waste. Cost saving from unused medication in vial as prior study was not included because dose of RTU medication was similar to the company packaging.[3] Initially, the RTU system was implemented in nine antibiotics and cost saving from reducing of administrative errors was not accumulated as study from Colombia which explored in high alert medication which cause patient harm.[14]

CONCLUSION

The RTU system was the lowest cost alternative, saves time and workload of nurse by eliminating reconstitution at the point of care. As well as the economic interest, the RTU system could enhance the opportunity of nurses and pharmacists to play more professional role and contribute to patient safety improvement and hospital quality following the standard of JCI.

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REFERENCES

1. O'Neil E. Healthcare workforce in the US economy. San Francisco: Health Workforce Solutions LLC; 2007.
2. Hendrich A, Chow MP, Skierczynski BA, Lu Z. A 36-Hospital Time and Motion Study: How Do Medical-Surgical Nurses Spend Their Time? Perm J 2008;12(3):25-34.
3. Chanon V, Tangsitchanakul J, Watcharasukpho S. Pharmacy intravenous admixture (Prefilled Syringe) in Pediatric Intensive Care Unit (PICU). Khon Kaen Med J. 2003;27(1):34-41.
4. (Thailand) TAoHP. Standard Guidelines of Hospital Pharmacy 2013 [cited 2013 Jun 6]. Available from: http://www.thaihp.org/index.php?lang=th&option=contentpage&sub=29.
5. Flynn EA, Pearson RE, Barker KN. Observational study of accuracy in compounding i.v. admixtures at five hospitals. Am J Health Syst Pharm. 1997;54(8):904-12.
6. Webster CS, Merry AF, Gander PH, Mann NK. A prospective, randomised clinical evaluation of a new safety-orientated injectable drug administration system in comparison with conventional methods. Anaesthesia. 2004;59(1):80-7.
7. ASHP Expert Panel on Medication Cost Management. ASHP guidelines on medication cost management strategies for hospitals and health systems. Am J Health Syst Pharm. 2008;65(14):1368-84.
8. Crawford SY, Narducci WA, Augustine SC. National survey of quality assurance activities for pharmacy-prepared sterile products in hospitals. Am J Hosp Pharm. 1991;48(11):2398-413.
9. Salberg DJ, Newton RW, Leduc DT. Cost of wastage in a hospital intravenous admixture program. Hosp Formul. 1984;19(5):375-8.
10. Makwana S, Basu B, Makasana Y, Dharamsi A. Prefilled syringes: An innovation in parenteral packaging. Int J Pharm Investig. 2011;1(4):200-6.
11. Armoiry X, Aubrun F, Aulagner G, Piriou V. Economic impact of ephedrine prefilled syringes in anaesthesiology. Ann Fr Anesth Reanim. 2014;33(1):47-8. [Article in French]
12. Drummond MF, Sculpher MJ, Torrance GW, O'Brien BJ, Stoddart GL. Methods for the economic evaluation of health care programmes third edition. 2nd ed. Oxford: Oxford University Press, 2005.
13. Pannell DJ. Sensitivity analysis of normative economic models: Theoretical framework and practical strategies. Agricultural Economics 1997;16:139-52.
14. Rosselli D, Rueda JD, Silva MD, Salcedo J. Economic Evaluation of Four Drug Administration Systems in Intensive Care Units in Colombia. Value Health Reg Issues. 2014;5:20-24.