International Journal for Quality in Health Care, 2019, 31(3), 219–224
doi: 10.1093/intqhc/mzy152
Advance Access Publication Date: 11 July 2018
Article

Article

A centralized automated-dispensing system in a French teaching hospital: return on investment and quality improvement

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Editorial Decision 17 May 2018; Accepted 20 June 2018

Abstract

Objectives: To evaluate the return on investment (ROI) and quality improvement after implementation of a centralized automated-dispensing system after 8 years of use.
Design: Prospective evaluation of ROI; before and after study to evaluate dispensing errors; user satisfaction questionnaire after 8 years of use.
Setting: The study was conducted at a French teaching hospital in the pharmacy department, which is equipped with decentralized automated medication cabinets in the wards.
Participants: Pharmacy staff (technicians and residents).
Intervention(s): Implementation of a centralized automated-dispensing robot.
Main Outcome Measure(s): The true ROI was prospectively and annually compared to estimated returns calculated after implementation and upgrade of the robot; dispensing errors determined by observation of global deliveries and the satisfaction of users based on a validated questionnaire were evaluated.
Results: Following the upgrade, we found little difference for the ROI (+1.86%). The payback period increased by almost 3 years. There was a significant reduction of dispensing errors, from 2.9% to 1.7% ($P < 0.001$). User satisfaction of the robot by the pharmacy staff was reported (score of 5.52 ± 1.20 out of 7).
Conclusions: These systems are worthwhile investments and largely contribute to improving the quality and safety of the medication process.

Key words: centralized automated-dispensing system, return on investment, medication process, satisfaction

Introduction

Centralized and decentralized automated-dispensing systems have been developed in hospital pharmacies to secure drug dispensing and administration process [1, 2]. In 2014, 37% of surveyed hospitals with more than 600 beds in the United States had a dispensing robot and all had automated-dispensing cabinets [2, 3]. These complementary systems are widely established in the European hospital medication process and many studies have demonstrated their contribution to decreasing iatrogenic injuries by reducing potentially preventable events [4–6]. However, the high cost of these available technologies must be balanced against their efficiency.

Despite nominative unit-dose dispensing is largely promoted in European healthcare institutes, this dispensing process is less developed in France. Global dispensing still persists but presents a high risk of error in the medication process and needs to be secured. Consequently, a centralized automated-dispensing system was implemented in our hospital in July 2008, in addition to decentralized automated cabinets, before the growth of unit-dose delivery. We calculated the return on investment (ROI) and evaluated medication errors and user satisfaction to evaluate the financial impact of this system and quality improvements due to its implementation.

We aimed to compare the ROI and evaluate quality improvement after implementation of a centralized automated-dispensing robot. We compared the ROI after 8 years of use with the initial estimated ROI and assessed quality improvement based on dispensing errors and user satisfaction.

Materials and Methods

Setting

The European Georges Pompidou Hospital (HEGP) is a teaching hospital in Paris, France with 714 beds and 106 day hospital places (43 clinical wards). The mean duration of hospitalization is 6.1 days. The hospital is equipped with a patient information system, integrating an electronic health record and a computerized physician order entry system (DxCare®, Medasys), and 50 automated medication cabinets (Omnicell® Inc.). The total number of referenced drugs managed in the pharmacy is 1700. Before implementation of the robot, the pharmacy team for the global medication dispensing process consisted of three pharmacy technicians, two pharmacy technician aides, three pharmacy residents and seven pharmacists.

Medication process

Each electronic medication prescription by a physician is reviewed by a pharmacist. Drugs are dispensed by pharmacy technicians. Before implementation of the robot, the technicians manually dispensed drugs via decentralized automated-dispensing cabinets or urgent global deliveries. After implementation, the technicians dispensed drugs using the robot. Cabinets are refilled twice a week per unit. Since 2008, a centralized automated-dispensing robot (Rowa® system from ARX®) was implemented in the pharmacy to store and deliver drugs.

Centralized automated-dispensing system

The centralized automated-dispensing system consists of tandem robots with a duplicate stock for a total approximate capacity of 22 000 boxes. In 2008, each robot included a specific refrigerated unit, a loading unit (ProLog system) to input drug boxes using barcodes, and a dispensing system. In 2013, the system was upgraded to improve the quality process. In contrast to the first robot, the new system integrated the capacity to read datamatrix available on each drug box. It was equipped with three specific scanners (ROWA VMAX). Due to the absence of a refrigerated unit, refrigerated drugs were removed.

The two systems, controlled by ARX® software, were interfaced with the drug stock management software Pharma® (Computer Engineering Company). Almost 95% of the drugs are stored in the robot. Some drugs are not stored in the robot, such as plasma-derived medicinal products and narcotics drugs, due to weight, large dimensions, lack of a barcode on the drug box, or classification.

Comparison of return on investment

ROI is commonly used to gauge an investment's profitability, because of its versatility and simplicity to calculate. An estimated ROI was initially calculated to justify the investment for the hospital financial department.

We assessed the ROI of robot implementation by annually comparing the true ROI to the estimated ROI, calculated after implementation in 2008 (initial estimated ROI) and its upgrade in 2013 (estimated ROI with upgrade). Since 2013, the initial estimated ROI and estimated ROI with upgrade were combined.

ROIs were calculated by deducting the costs of investment from the cost savings since implementation of the robot. The investment costs included buying and installation of the robot, annual maintenance and repairs, and upgrading of the robot. The cost savings were evaluated by the reduction of drug stocks and the decrease in pharmacy staff dedicated to global dispensing.

Quality improvement

Dispensing errors

We conducted a before and after study to evaluate the benefit of the centralized automated-dispensing robot on dispensing errors. Observations were performed by a pharmacist before robot implementation and after 2 years of use. Twenty prepared global deliveries were examined on five consecutive days. Before implementation, deliveries were manually prepared by pharmacy technicians, whereas they have been ordered from the robot by pharmacy technicians after implementation and manually completed for drugs stored outside the system. We evaluated the mean number and standard deviation (SD) of drug units per global delivery. The error rate was calculated as the number of dispensing errors divided by the total unit doses ordered, multiplied by 100.

User satisfaction

Every new system generally faces user reluctance. We thus aimed to assess acceptability of the robot. A survey questionnaire was administered to recurrent users, including pharmacy technicians and pharmacy residents working at the HEGP pharmacy. Senior pharmacists were not surveyed as they did not use the robot. We used the questionnaire developed by Palm *et al.* [7, 8]. It consists of six dimensions, evaluating compatibility, expectations, user support, ease of use, usefulness and user satisfaction. Each component is evaluated using a Likert scale, for which 1 = strongly disagree, 2 = disagree, 3 = somewhat disagree, 4 = neutral (neither disagree nor agree), 5 = somewhat agree, 6 = agree and 7 = strongly agree. We added an 'intention to continue using the robot' dimension, also evaluated by Palm *et al.*

Statistical analysis

The mean numbers of drug units per global delivery were compared using Student's *t*-test. Dispensing error rates were compared using the Chi-squared test. Descriptive statistics were used to summarize the information for the satisfaction dimension. Results were computed using aggregate variables for each dimension by the mean score and standard deviation (SD). The mean ages for pharmacy residents and pharmacy technicians were compared by Fisher's exact test. Other statistical analyses were performed using Welch's *t*-test. Analyses were performed using the statistical online software BiostaTGV (https://marne.u707.jussieu.fr/biostatgv).

Results

Comparison of return on investment

We estimated the yearly savings and investment costs from 2008 to 2016 (Fig. 1). The ROI was positive after 8 years of use (+$294 498). The total costs savings and investment costs were +$1 315 158 and −$1 020 660, respectively. Costs savings were divided between decreasing drug stocks (+$75 084), observed the first year after implementation of the robot, and cumulative reduction of pharmacy staff in the dispensing area (+$1 240 074), corresponding to a mean annual reduction of +$155 009. Before implementation of the robot, the pharmacy staff for medication dispensing consisted of three pharmacy technicians and two pharmacy technician aides. Since 2008, one pharmacy technician and 1.5 pharmacy technician aides were moved to other pharmaceutical activities, except in 2013 for the upgrade of the robot. Indeed, during this period, one pharmacy technician aide was necessary to compensate for the absence of the automatic dispensing system. The investment costs included purchase of the robot, technical and computer support, and the first year of maintenance (−$483 892), robot maintenance (−$226 985), robot repairs (−$30 784) and robot upgrade (−$276 000). No repairs have been necessary since the upgrade.

The comparison between the estimated and real ROI are presented in Fig. 2. In 2008, the estimated ROI for 8 years of use (corresponding

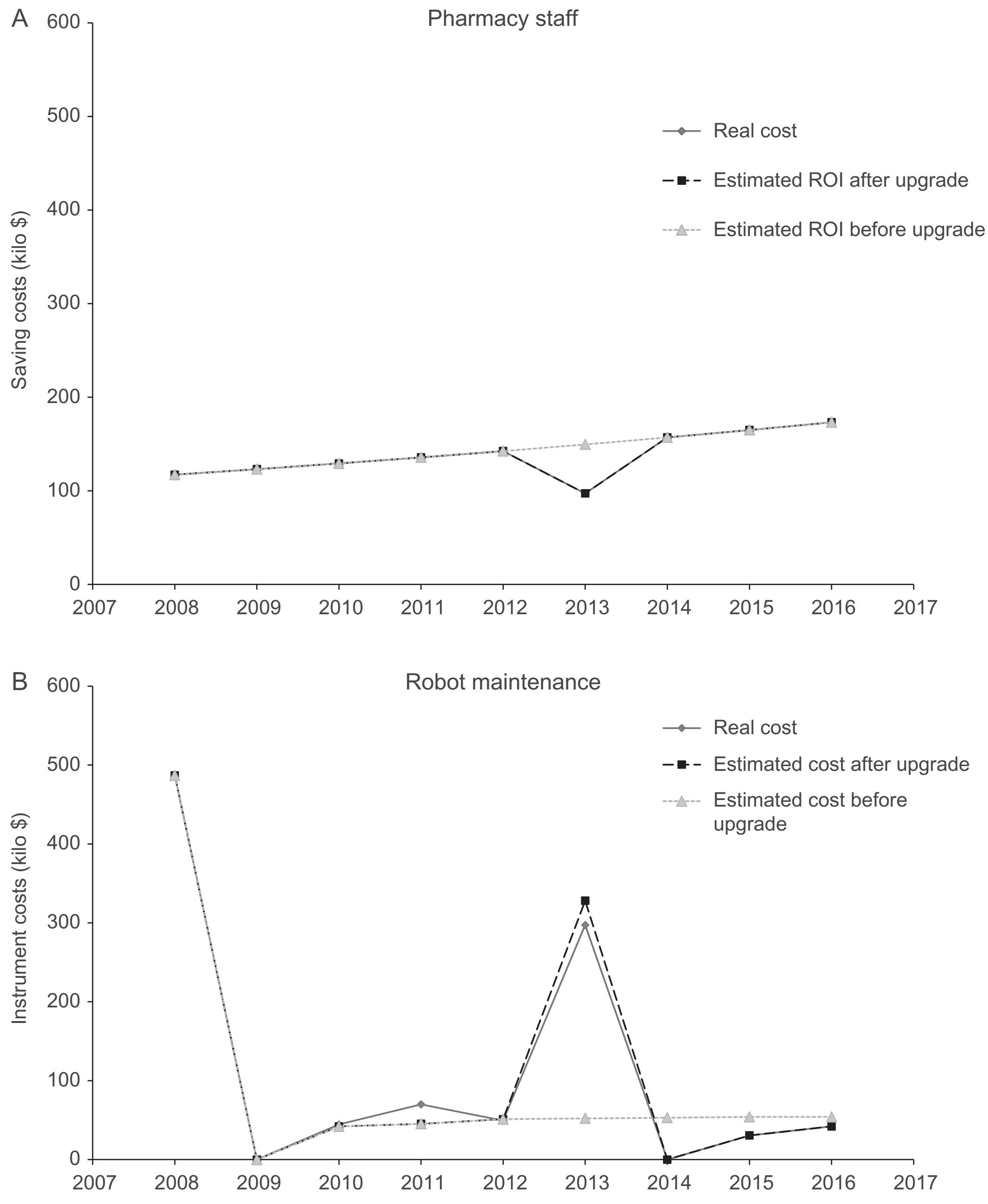

Figure 1 Real and estimated costs before and after upgrade divided between pharmacy staff (A) and those of the robot and maintenance (B) from 2008 to 2016.

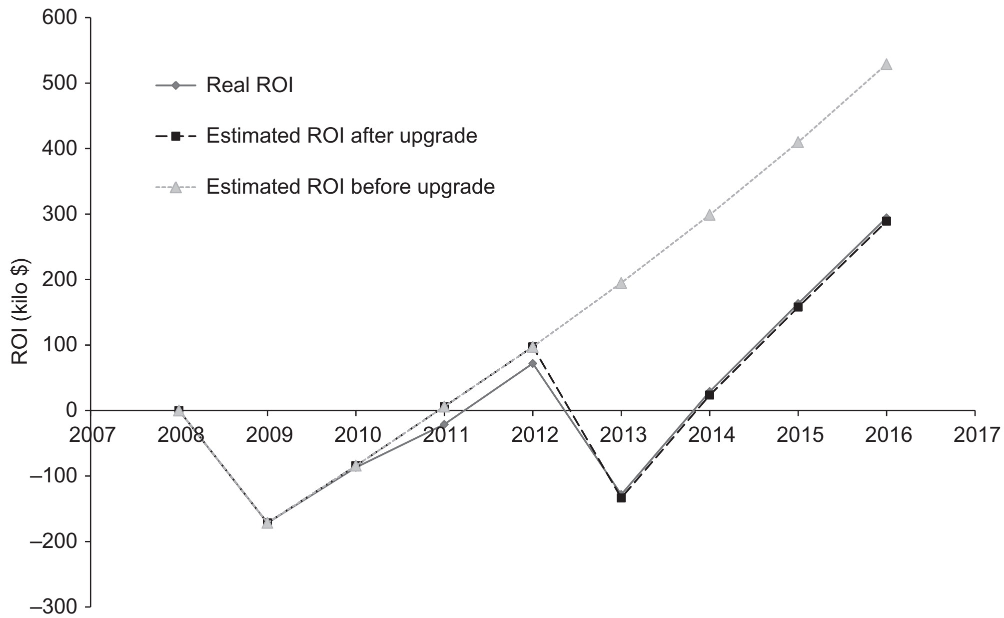

Figure 2 Real and estimated returns on investment (ROI) from 2008 to 2016 in a French hospital, before and after upgrade.

Table 1 Respondent demographic characteristics and perceptions for the six dimensions of the survey of robot use for pharmacy residents and pharmacy technicians.

	Residents	Technicians	Total	*P*-value
n	13	18	31	
Age—mean years (SD)	27.7 (1.3)	33.3 (8.3)	31.0 (6.9)	0.01
Experience with the robot—mean years (SD)	0.81 (0.48)	3.53 (3.60)	2.31 (2.99)	0.009
Women—*N* (%)	7 (53.8)	15 (83.3)	22 (71.0)	0.11

to 2016) was +$528 946 based on cost savings of +$1 367 496 and investment costs of −$838 550. However, the estimated ROI was reevaluated in 2013 due to the necessity of the robot upgrade. Until 2010, there was little difference between the estimated and real ROIs. In 2011, a major repair of the robot was needed following human misuse, explaining the 26.1% increase of the real ROI in 2012. The robot upgrade in 2013 altered the estimated ROI for 2016 to + $289 129. We observed no major deviations since 2013. In 2016, a positive difference between the real and new estimated ROI (+1.86%) was reported.

Quality improvement

Dispensing errors

The mean number of drug units per global delivery was 40.0 (SD: 28.6) before implementation and 32.8 (SD: 25.2) after 2 years of implementation. There was no significant difference ($P = 0.40$). Over the 40 global deliveries assessed, we controlled a total of 25 719 drug units. The error rate before implementation was 2.9% (419 errors/14 526 units), which decreased to 1.7% (194 errors/11 193 units) after. The error rates were significantly different ($P < 0.001$).

User satisfaction

We analyzed a total of 13 and 18 questionnaires from pharmacy residents and technicians (Table 1). The average age of the respondents was 31.0 ± 6.9 years and 22 (71.0%) were women ($P = 0.11$). The mean duration of experience with the robot was 2.31 ± 2.99 years ($P = 0.009$). Results of the aggregate variables for the six dimensions of the robot survey are presented in Table 2. The perception of experience with the robot did not differ significantly between pharmacy residents and technicians, except for user satisfaction ($P = 0.04$). No dimension scored below the average level on the scale of 1–7 points for either pharmacy residents or technicians. The lowest average perception was reported by pharmacy residents for expectations (4.7 1 ± 1.27) and by pharmacy technicians for support (4.71 ± 1.63). Overall, the highest average appreciation was obtained for the perceived ease of use (5.81 ± 0.96), followed by compatibility (5.63 ± 1.06) and user satisfaction (5.52 ± 1.20). The mean score was 4.8 ± 2.1 for the additional questions defining the 'intention to continue using the robot' dimension.

Discussion

After 8 years of using the robot (from 2008 to 2016), we recorded a ROI of +$294 498. The estimated ROI for 8 years of use was +$528 946 (+$1 367 496 of cost savings and −$838 550 of investment costs). We observed a 26.1% difference of ROI in 2012, due to major repairs. The payback period was consequently increased by almost 3 years. Following the upgrade of the robot in 2013, the estimated ROI was recalculated and there was little difference with the real ROI (+1.86%).

Moreover, there was an improvement in the medication dispensing process, with a significant reduction of 41% in medication error rates

Table 2 Perceptions of robot use for the six dimensions of the survey from Palm for pharmacy residents and pharmacy technicians—mean (SD)

Items from questionnaire developed by Palm [10, 11]	Residents	Technicians	Total	*P*-value
Compatibility	5.85 (0.93)	5.48 (1.06)	5.63 (1.02)	0.26
Support	5.37 (1.37)	4.75 (1.63)	5.01 (1.55)	0.09
Usefulness	5.52 (1.39)	5.43 (1.22)	5.47 (1.29)	0.76
Ease of use	6.16 (0.74)	5.61 (1.00)	5.81 (0.96)	0.12
User satisfaction	5.90 (1.12)	5.25 (1.20)	5.52 (1.20)	0.04
Expectations	4.71 (1.27)	4.85 (0.97)	4.79 (1.11)	0.73

following implementation of the robot. Following implementation, all pharmacy staff received training before using the robot. The perception of their experience with the robot did not differ significantly between pharmacy residents and technicians in the user satisfaction survey, despite that pharmacy residents had less experience with the robot. Indeed, due to the limited duration of the resident internship in pharmacy, the ease of robot use contributed to the increase in compliance of the staff and optimization of the quality process. This was underlined by the highest score of 5.81 (SD: 0.96) given by both types of users for this dimension.

We found that this pharmacy-based robot improved workflow efficiency and provided greater storage capacity, in accordance with the literature. Franklin *et al.* showed that the implementation of dispensing robots in the UK hospital pharmacies resulted in a 23% increase in storage capacity over traditional storage in one site and a 123% increase in another [9]. Robots ensure that drug resources are secure, organized, tracked and ready for use, leading to improved safety of the medication process [3, 9]. A significant reduction in dispensing errors, from 16% to 60%, has been observed in several studies [4, 9, 10]. This was confirmed in our study in which the reduction of dispensing errors was 41%. We did not evaluate the impact of the robot in the management of expiry dates and batch number in this study, but a substantial quality improvement would be expected. A centralized automated-dispensing system optimizes drug traceability. Information present in datamatrix, such as quantity, expiry dates and batch number are automatically recorded by uploading unit, which is crucial for batch number recall management. In addition to identifying the batch number concerned, the robot improved time savings and patient safety by increasing pharmacy staff reactivity.

Centralized automated-dispensing systems also help pharmacy staff to reduce or eliminate labor-intensive tasks by automating the management of drugs and supplies where they are needed. We found there to be a significant reduction in drug delivery times after implementation of the robot (data not shown). Franklin *et al.* found a significant reduction in median picking time [9]. Finally, robots induce departmental reorganization, with a net reduction of pharmacy technicians for the global dispensing process and their reassignment to the unit-dose dispensing process [11–13]. In our hospital, one pharmacy technician and 1.5 pharmacy technician aides were moved to more value-added activities, such as unit-dose dispensing activities and the delivery of chemotherapy drugs to units.

This is the first study to compare ROI following the implementation of a centralized automated-dispensing system. However, this study has some limitations. It was monocentric, not allowing generalization of the data for all centers. The calculation of the ROI may have been underestimated, as the cost savings did not include the management of expired drugs and the effect of the reduction of drug stocks after the first year of implementation of the robot.

Despite their benefits, these technologies are not all-inclusive. Centralized automated-dispensing robots and automated-dispensing cabinets in the wards must be associated with barcode medication administration (BCMA) systems at the patient bedside [14] to complete drug traceability and ensure patient safety during the medication process.

The ROI after 8 years of use was positive, despite the initial and upgrade costs, but was close to the estimated ROI recalculated following the robot upgrade. Economic projections should be calculated with caution because of technological and regulatory changes that can lead to premature obsolescence of the system. In our experience, such systems are worthwhile investments, leading to a ROI within a few years. Over the last decades, centralized automated-dispensing systems have largely contributed to improve the quality and safety of the medication process. In addition to optimizing drug stock management, such systems result in greater efficiency of the global dispensing process by significantly reducing dispensing errors and improving time savings, with good compliance of pharmacy staff and redeployment of some members to value-added activities.

Acknowledgements

We thank Anne Pont, Béatrice Dejean and Nathalie Valin for their help during this study.

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