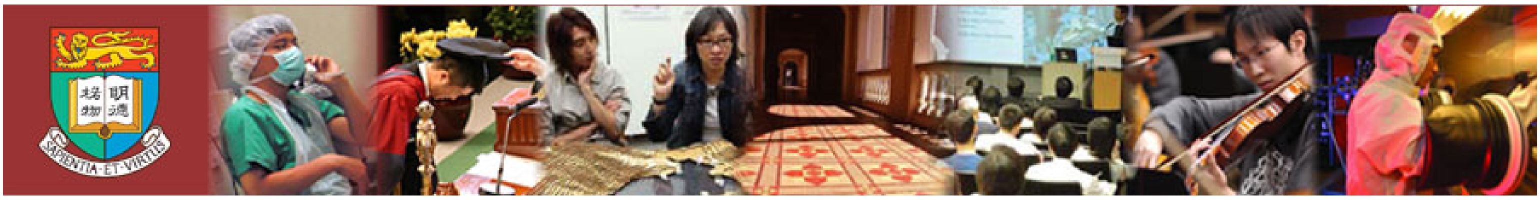

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Author(s)	Samaranayake, NR; Cheung, STD; Cheung, K; Lai, K; Chui, WCM; Cheung, BMY
Citation	International Journal of Medical Informatics, 2014, v. 83 n. 6, p. 450-458
Issued Date	2014
URL	http://hdl.handle.net/10722/200718
Rights	NOTICE: this is the author’s version of a work that was accepted for publication in International Journal of Medical Informatics. Changes resulting from the publishing process, such as peer review, editing, corrections, structural formatting, and other quality control mechanisms may not be reflected in this document. Changes may have been made to this work since it was submitted for publication. A definitive version was subsequently published in International Journal of Medical Informatics, 2014, v. 83 n. 6, p. 450-458. DOI: 10.1016/j.ijmedinf.2014.03.001

Title: Implementing a bar-code assisted medication administration system: Effects on the dispensing process and user perceptions

Nithushi R Samaranayake,[a] B.Sc (Pharmacy)

Shung-Tack D Cheung STD,[b] B(Pharm), MSc

Karen Cheng,[c] B(Health Science in Nursing), MSc (Healthcare in Nursing)

Kithelia Lai ,[c] B.Bus, M(Nursing)

William C Chui,[b] B(Pharm), MSc, MRPharmS (UK)

Bernard M Cheung,[a] PhD, FRCP

[a] Department of Medicine, Faculty of Medicine, The University of Hong Kong, Hong Kong

[b] Department of Pharmacy, Queen Mary Hospital, Hong Kong

[c] Central Nursing Department, Queen Mary Hospital, Hong Kong

Correspondence

Prof. Bernard MY Cheung,

Department of Medicine, Queen Mary Hospital,

102, Pokfulam Road, Hong Kong.

Telephone:+852 22554347

Fax:+852 28186474

E-mail:mycheung@hku.hk

Key words: Bar-code assisted medication administration (BCMA); stand-alone BCMA system; direct observation; attitudes; dispensing; drug administration

Word count : 3678

No of tables : 4

No of figures : 1

ABSTRACT

Purpose: We assessed the effects of a bar-code assisted medication administration system used without the support of computerised prescribing (stand-alone BCMA), on the dispensing process and its users.

Methods: The stand-alone BCMA system was implemented in one ward of a teaching hospital. The number of dispensing steps, dispensing time and potential dispensing errors (PDEs) were directly observed one month before and eight months after the intervention. Attitudes of pharmacy and nursing staff were assessed using a questionnaire (Likert scale) and interviews.

Results: Among 1291 and 471 drug items observed before and after the introduction of the technology respectively, the number of dispensing steps increased from 5 to 8 and time (standard deviation) to dispense one drug item by one staff personnel increased from 0.8 (0.9) to 1.5 (0.12) minutes. Among 2828 and 471 drug items observed before and after the intervention respectively, the number of PDEs increased significantly (*P<0.001*). 'Procedural errors' and 'missing drug items' were the frequently observed PDEs in the after study. 'Perceived usefulness' of the technology decreased among users who participated for both before and after questionnaires surveys (*N=11; P=0.008; power=0.76*). Among the interviewees, pharmacy staff felt that the system offered less benefit to the dispensing process (9/16). Nursing staff perceived the system as useful in improving the accuracy of drug administration (7/10).

Conclusion: Implementing a stand-alone BCMA system may slow down and complicate the dispensing process. Nursing staff believe the stand-alone BCMA system could improve the drug administration process but pharmacy staff believe the technology would be more helpful if supported by computerised prescribing. However, periodical assessments are needed to

identify weaknesses in the process after implementation, and all users should be educated on the benefits of using this technology.

[Word count = 284]

INTRODUCTION

Drug administration is the final step in the medication use process and errors that occur at this stage may directly harm the patient [1-3]. Therefore an additional defence, such as bar-code assisted medication administration (BCMA), is needed to intercept drug administration errors and to improve patient safety [4, 5]. BCMA systems have been shown to reduce drug administration errors when used as a closed-loop system, where prescribing, dispensing and drug administration processes are electronically linked [4, 5]. Computerised prescribing is a pre-requisite for a closed-loop BCMA system but many hospitals do not have this facility [6].

Hospitals that do not have computerised prescribing may use a system known as the stand-alone BCMA system [7]. This works by feeding the information on hand-written prescriptions to the computer, and generating and attaching bar-coded dispensing labels to each drug dispensed by the pharmacy. Therefore, implementing a stand-alone BCMA system requires considerable coordination between the pharmacy and the ward.

Staff are known to resist new technologies, and changes to work flow and their roles [8]. If users do not operate the technology correctly, technology-related errors may occur (9) and the envisioned benefits of the technology may not be achieved. Simple and easy-to-use systems that are perceived as useful may be more readily accepted [10, 11], which means that the application of technological innovations are greatly reliant on user attitudes. The closed-loop BCMA system has been studied in detail and implementation issues and workarounds have been reported [12, 13, 14]. Koppel et al, found that most of these workarounds were due to unexpected problems that were encountered by nurses when using the technology [12]. While some have shown that implementing a closed-loop BCMA system did not increase the time nurses spent on medication administration activities [15], others reported that nurse's perception on time efficiency reduced with this intervention [16]. Therefore the system design and the practicality of its usage are vital aspects to test before and after implementing technological innovations. Stand-alone BCMA systems have not been studied as much as closed-loop systems [4, 5, 12]. Bargren et al reported how a stand-alone BCMA system affected the drug administration process but its effects on the dispensing process and users have not been explored yet [7].

Our aim was to study a stand-alone BCMA system as it was introduced to a medical ward in a university hospital in terms of its effect on the dispensing process, pharmacy staff and nursing staff. More specifically, we aimed to study the timing and changes to the dispensing steps, identify socio-technical (human factor related) and technical issues introduced by the system to the dispensing process, assess changes in potential dispensing error (PDE) rates, and assess the attitudes of pharmacy and nursing staff after the introduction of the technology.

METHODS

The study setting

A stand-alone BCMA system was initiated in one medical ward (12 beds; 8-9 nurses) in a tertiary-care hospital in Hong Kong. The hospital had a separate pharmacy that dispensed drugs to in-patients. Most of the drugs were dispensed on a batch refill method, where drugs for each patient were dispensed daily. Some drug items were dispensed to refill ward stocks. Prescribing information on hand-written pre-formatted prescriptions were transferred to computers, 2D bar-coded dispensing labels were printed (at one dedicated printer) and attached onto each drug item dispensed by the pharmacy. Drugs that were dispensed by an Automated Dispensing Machine (ADM) were directly dispensed, with a 2D bar-code printed on the packaging. At the bedside, the nurse matched the bar-codes on drug containers/packs with that of the patient's bar-coded wrist band and the prescription in the computer system, to confirm the accuracy of the drug administration process. We included new prescriptions as well as refill prescriptions in the study. A 'drug item' was defined as a chemical substance that is used in the treatment, cure, prevention, or diagnosis of disease or used to otherwise enhance physical or mental well-being of a patient. For example if 'Paracetamol 500 mg every 6 hourly' was prescribed, it was counted as one drug item. Both oral and parenteral drug items were included but were not analysed separately due to unavoidable practical issues. Although drug items that required simple re-constitutions were included, bulk sterile drug items that needed preparation in the pharmacy were not included in the study.

All pharmacy and nursing staff who were involved in the project had a brief training session prior to the implementation. Drugs to other wards (except the study ward) were dispensed manually (without the help of the technology). 16 pharmacy staff members were involved in the project during the study period and included pharmacists and dispensers.

An uncontrolled before and after study design was used. We used a mixed method approach that included direct observation, structured questionnaire and interviews to study the effects of the stand-alone BCMA system on pharmacy staff and the dispensing process. Nursing staff were interviewed to assess their views. Ethical approval was obtained from the Institutional Review Board of the study hospital.

Direct observation study

We directly observed the number of dispensing steps, dispensing timing and potential dispensing errors (PDEs) in the pharmacy, before and after implementing the stand-alone

BCMA system. We also observed technical and socio-technical issues encountered by pharmacy staff when using the technology.

The dispensing process was timed one month before and eight months after implementation. The time taken by one staff member to complete the dispensing process of one drug item was measured in minutes. The pre-implementation timing study included drug items dispensed to all wards while the post-implementation timing study included drug items dispensed to the study ward only.

Workflow changes and, socio-technical and technical issues encountered by pharmacy staff when using the new system were directly observed eight months after the implementation using a pre-specified data collection format. Issues related to using the system were recorded under four main areas; technical problems, infrastructural problems, extra steps needed, and assistance needed from others. The research pharmacist who was involved in the observation was aware of the purpose of the study and used an un-disguised and non-interventional approach to observe the dispensing process. Informed consent was obtained from all staff members before shadowing them. The observations were carried out on 26 randomly selected weekday mornings during a period of two months.

The final step of the dispensing process, when a senior dispenser cross-checks the prepared drugs (ready to be dispensed) against the hand-written prescription, was observed by the research pharmacist and errors (potential dispensing errors, PDEs) detected at this stage were recorded before and after the intervention. PDEs detected in the post-implementation study were further categorised as ‘target PDEs’ (errors not related to the stand-alone BCMA system) and ‘unanticipated PDEs’ (errors that occurred as a result of using the stand-alone

BCMA system). In the before study, PDEs were observed on 36 observation days, which included 26 common observation days where the performance of the new technology and near misses were observed simultaneously, and 10 observation days where near-misses were assessed exclusively. Therefore the number of drug items observed to assess near-misses was greater than the number of drug items observed to assess other aspects of the 2D bar-code technology in the before study. An identical number of drug items were observed to assess the performance of the technology and near misses in the after study, because the two respective observations were conducted simultaneously. Chi square (two-tailed) was used to compare the number of PDEs observed in the before and after study.

The observations were done by one research pharmacist in order to avoid inter-observer variability.

Questionnaire survey

An interviewee administered questionnaire was used to assess the attitudes of pharmacy staff on using the stand-alone BCMA system, one month before and eight months after implementing the technology. The reliability of a previously validated questionnaire [17] was confirmed in the present context. 21 items that explained five constructs (‘Attitude of output and intention to use’, ‘perceived usefulness’, ‘perceived ease of use’, ‘job relevance’ and ‘external influences’) were retained. 19 of 21 items in the instrument had item-construct correlations of ≥0.3 [18]. The Cronbach’s alpha for each construct was ≥0.70 and the overall Cronbach’s alpha for the pre and post-implementation survey responses were 0.79 and 0.92 respectively. A five-point Likert scale was used for rating, in which a score of 1 indicated “strongly agree” and a score of 5 indicated “strongly disagree”. Mean scores of responses (for each construct) given by participants who took part in both the before and after questionnaire surveys (paired participants) were compared using Wilcoxon Signed Rank test. Responses of participants who took part in either one of the surveys (un-paired participants) were compared using Mann-Whitney U test. Bonferroni correction was made to control for type I error and $P<0.01$ was considered statistically significant. The minimum sample size needed to observe one unit change in the means of a given construct, assuming a standard deviation of 0.50, alpha of 0.05, and a power of 0.80, for paired and un-paired comparisons were 6 and 8 participants per group respectively.

Interview study

Interviews were conducted among pharmacy and nursing staff using a pre-determined interview guide and field notes were recorded [19] on site. A code list (a list of words that explained the main aspects discussed by interviewees) was developed after 5 iterative readings of the interview transcripts [19]. Using this code list, one independent reviewer and the research pharmacist coded a sub-set of three transcripts. The codes were compared and modified until both reached 90% agreement, defined as the 'fraction of phrases that were coded in an identical manner by both reviewers' [18, 19]. The research pharmacist then coded the remaining transcripts using the finalised code list.

RESULTS

Direct observation study

We observed 1291 and 471 drug items before and after the implementation of the stand-alone BCMA system. The number of dispensing steps increased from 5 to 8 steps (Figure 1) and the dispensing time (standard deviation) to dispense one drug item by one staff personnel increased from 0.8 (0.9) minutes to 1.5 (0.12) minutes after the implementation. We did not observe any deviations in the steps in the dispensing process, which were compulsory (Web only Table I). The staff involvement in each step did not change before and after incorporating the 2D bar-code technology but two major changes in task responsibilities were observed in the after study. Firstly, the job responsibility of dispensing staff increased because they were required to enter more specific drug related information into the system. Secondly, pharmacists were required to double-check the accuracy of data entry (made by dispensers) and to stop data entry errors at this point.

Among the dispensing steps that required the use of the technology, technical issues occurred and extra steps were needed when printing bar-coded labels (12 of 26 times the label printer was operated) and when using the ADM (7 of 18 times the ADM was used) (Web only table II). The directly related causes for these issues were 'unfamiliarity of the system', 'lack of knowledge', 'slips and lapses' and 'technical faults of the system'. Descriptions of these issues are detailed in Web only Table III.

We observed 2828 and 471 drug items to identify PDEs in the before and after studies respectively. There was a significant increase in the proportion of PDEs ($P<0.001$) after implementing the bar-coding system (Table I). A post-hoc power calculation comparing the total number of PDEs (taking into account the differences in sample sizes of the pre and post-implementation studies) showed a 95% power for this increase. 73.3% of the total PDEs in the post-implementation study were unanticipated. 'Procedural errors' and 'missing drug items' were examples of unanticipated PDEs (Web only table IV).

Questionnaire study

A total number of 21 pharmacy staff responded to the survey (11 paired participants, 5 pre-intervention only and 5 post-intervention only participants). The demographic characteristics of both paired and un-paired participants are shown in Table II. The mean and median scores of each questionnaire item and the comparison of mean scores before and after implementation are shown in Table III. The mean score of the item 'perceived usefulness' increased among both groups but was statistically significant only among the paired participants (*P=0.008; power=0.76*) after correcting for type 1 error. The mean scores of 'job relevance' showed an increasing trend among both groups after the system was implemented but was not statistically significant after correcting for type I error.

Interview study

16 pharmacy staff (12 completed both the interview and the questionnaire) and 10 nursing staff were interviewed. The views expressed by pharmacy and nursing staff were related to three key areas; efficiency, safety, and issues related to using the stand-alone BCMA system. Some of their views are shown in Table IV.

Perceptions of pharmacy staff

Most pharmacy staff believed that the dispensing process was slower after implementing the BCMA system (N=14). Participants attributed these time delays to increased number of steps in the dispensing process, the need to enter more prescribing information at the point of data entry and printing labels. Their responses are shown in Table IV (Comments 1-3).

Most participants thought that work was made more difficult or complicated after implementing the technology than before (N=8). Issues mentioned by participants were mainly related to hardware and software deficiencies, and technical defects. The dispensing process using the bar-code system was only partially automated because some steps were carried out manually. Participants perceived this set-up as a 'complicated system' and difficult to use (N=8). Some participants viewed that the absence of computerised prescribing was a barrier for prompt updating of patient profiles when prescribing changes were made (N=3). Most of the technical defects highlighted by pharmacy staff were related to label printing (N=7) and the use of the automated dispensing machine (N=4) (Comments 4-8 of Table IV).

Most pharmacy staff believed that the new system improved the safety in the drug administration process and benefited the nursing staff and patients (N=8). Their perceptions on the usefulness of the stand-alone BCMA system to reduce dispensing errors were mixed. Some participants reasoned that dispensing errors reduced as a result of more thorough checking (N=5) while others thought the new system did not benefit the dispensing process without the support of computerised prescribing (N=8). Some of their comments (Comments 9-10) are shown in Table IV.

Perceptions of nursing staff

Nursing staff commonly believed that the drug administration process was slower when using the stand-alone BCMA system (N=9). Some also believed that the work load had increased (N=4), and the process was more difficult and complicated when using the new system (N=3). In fact, some nurses claimed that they had to do more work because they checked the administration process manually and also used the 2D bar-code system (N=3) (Comments 11-12 of Table IV).

Issues that were highlighted by nurses focused on three main areas, current system deficiencies, infrastructural and process related drawbacks and technical defects. Some nursing staff thought that the system was too inflexible to the timing of drug administration

(N=3) and when re-using remaining drugs from previous days (N=2) (Comment 13 of Table IV). User-unfriendly computer screens, inability to detect the nature of the error once warned by the system, delays in updating patient profiles, and difficulties in administering emergency medication, were some of the other issues that were explained by the nursing staff (Comments 14 and 15 of Table IV).

Nursing staff also referred to infrastructural and staff deficiencies that caused difficulties when using the system (N=6). Main concerns included, the hassle of transporting equipment around, slow transmittance at work stations and coordination with the pharmacy department (Comments 16-19 of Table IV).

Most nurses believed that a stand-alone BCMA system could improve patient safety and was useful to check the accuracy of the drug administration process (N=8) (Comments 20-23 of Table IV). However, a few emphasised weaknesses in the system that may overlook drug administration errors (N=2) such as verifying only the bar-code on the label and not the contents of the drug container (Comments 24-25 of Table IV).

DISCUSSION

To our knowledge this is the first study to assess the effects of a stand-alone BCMA system on the dispensing process. We found that implementing this system increased the number of dispensing steps and dispensing time. Pharmacy staff encountered socio-technical (human factor related) and technical issues when using the system. The safety of the dispensing process decreased due to the introduction of unanticipated dispensing errors after implementing the new technology. The 'perceived usefulness' of the stand-alone system decreased among pharmacy staff, who believed the technology would be more helpful if supported by computerised prescribing. Nursing staff believed that the stand-alone BCMA system, although increased the workload, was useful in reducing drug administration errors. However, they acknowledged that technical, infrastructural and system related problems were encountered.

There are some important implications to our study. A stand-alone BCMA system is a safety measure that may be adopted by hospitals when using hand-written prescriptions [7]. However, work flow changes and unanticipated dispensing errors may occur in the pharmacy as a result of this initiative. Incorporating safety systems are associated with increased work and time [7, 20] even in processes indirectly related to the technology. Moreover, users may get frustrated due to the unexpected issues they have to face. If they find ways around difficult procedures, errors may occur and the envisioned benefits of the technology will be lost [9, 12, 13, 14,18-25]. As users are known to readily accept health technologies they think are useful and relevant to their job [10, 11], one important step to motivate users to adopt a new system is to explain the improvement in patient safety resulting from their extra effort [19]. Another is to conduct periodical post-implementation assessments of processes and user attitudes to identify areas of difficulty that need further improvements.

Most issues observed in this study have also been reported with closed-loop systems and hence may be anticipated by others who plan to adopt this technology. Similar to the stand-alone system, Holden et al. reported that nurses perception on time efficiency decreased when using a closed-loop BCMA system [16]. Difficulties in using bar-code scanners such as malfunctioning scanners, failing batteries, unreadable bar-codes and uncertainty of wireless connectivity [24, 26], logistic difficulties in carrying bar-coding equipment around to each patient, clinically insignificant error messages [27, 28], and the difficulty of administering emergency medication were common to both closed-loop and stand-alone systems. Unlike in stand-alone systems, updating changes in prescriptions is faster in closed-loop systems, but Van Onzenoort et al found that delays in responses from computerised systems [26] were still common. A particular danger in a stand-alone system is the possibility of affixing the wrong bar-coded dispensing labels to the drug container. Although a closed-loop system is less prone to such errors, the wrong bar-code label may still be attached if in-house re-packaging is done [29]. Therefore, all users of BCMA technology should be warned against over-reliance on the technology and should be advised to continue self-vigilance at all times.

Limitations and strengths

There are some limitations to this study. Firstly, we must acknowledge that the stand-alone BCMA systems used in different hospitals may differ according to the vendor and the hospital setting. However, most findings of this study are generalisable as they have also been reported with closed-loop systems and will be useful to the majority of hospital administrators. Secondly, the sample size differed in the before and after studies because the pilot implementation took place in one ward only. There was a limitation when comparing prescriptions of all wards (pre-implementation) against prescriptions of the study ward (post-implementation) when timing the dispensing process and when assessing the number of PDEs. This was unavoidable as the study design we used was an uncontrolled before and after study. However, we believe that the comparison was valid because the study ward treated patients across all specialties. Besides, one of our main messages is that the number of PDEs increased as a result of new errors related to the 2D bar-code technology, and the limitation in the study design would have minimal affects on this finding. Although, the number of PDEs related to the bar-code technology increased significantly, some of these errors may have been due to unfamiliarity of the system. Our study did not assess if these errors would decrease when users get more familiar with the system or when the system has been better improved. Therefore these findings should be tentative. The closed-loop BCMA system has been shown to reduce drug administration errors but there are no published studies of the impact of stand-alone systems on error rates. We believe that this would be important information to confirm the value of a stand-alone BCMA system and should be addressed in future studies. Lastly, the number of participants included in the questionnaire survey was relatively small, but we have already tried to survey all staff exposed to the new system.

Our study also has several merits. We used three methods; direct observation, questionnaire and interviews to study the effect of the stand-alone BCMA system. Results from quantitative and qualitative methods were found to be complementary, thus increasing the reliability of our findings. The post-implementation study was conducted eight months after the intervention allowing users to familiarise with the intervention. PDEs were detected using a direct observation method which is more accurate than reviewing medication charts or incident reports [30]. The research pharmacist was familiar with the study participants and conducted non-interventional observations on 26 days over a two-month period so that the Hawthorn effect was minimised.

In conclusion, implementing a stand-alone BCMA system increases the number of dispensing steps and dispensing time. Pharmacy staff believe the technology would be more helpful if supported by computerised prescribing and nursing staff believe it is useful to reduce drug administration errors. However, technical, infrastructural and system related issues are encountered when operating the system. Hospital managers should plan ahead in anticipation of these effects when introducing a stand-alone BCMA system to hospitals. Users need to be educated that the increase in the time and complexity of work associated with a stand-alone BCMA system is worthwhile in order to improve patient safety.

Authors' contributions

Conception and design of study: NRS, STDC, KC, KL, CMWC, BMYC. Analysis and interpretation of data: NRS. Drafting of the paper: NRS. Critical revision of paper for important intellectual content: NRS, STDC, KC, KL, CMWC, BMYC. Final approval of the paper: BMYC

Acknowledgments

The authors wish to thank all the staff members in the Department of Pharmacy and the study ward, Queen Mary Hospital, Hong Kong for their support in carrying out this research.

Funding

BMY Cheung received support from the Faculty Research Fund, Li Ka Shing Faculty of Medicine, University of Hong Kong. N Samaranayake holds a Postgraduate Scholarship and a University Postgraduate Fellowship from the University of Hong Kong. N Samaranayake also holds the Wong Ching Yee Medical Scholarship for 2012.

Conflicts of interest statement

Nothing to disclose

SUMMARY TABLE

What was already known on the topic

- Closed-loop bar-code assisted medication administration (BCMA) systems are useful to reduce drug administration errors
- BCMA systems without the support of computerised prescribing (stand-alone BCMA systems), may be used in hospitals that use hand-written prescriptions
- Stand-alone BCMA systems cause considerable workflow changes to the drug administration process

What this study added to our knowledge

- A stand-alone BCMA system increases the length and time of the dispensing process and may introduced unanticipated dispensing errors
- Pharmacy staff believe the technology would be more helpful if supported by computerised prescribing
- Nursing staff perceive that the stand-alone BCMA system is useful to reduce drug administration errors but they also believe that the system slows down the drug administration process and technical, infrastructural and system-related issues are encountered when using the technology
- Hospital managers should note that a stand-alone BCMA system may affect the dispensing process in addition to the drug administration process and therefore should plan ahead to minimise these effects

REFERENCES

1. Leape LL, Bates DW, Cullen DJ, et al., Systems analysis of adverse drug events, JAMA. 274 (1995) 35-43.
2. Bates DW, Cullen DJ, Laird N, et al., ADE Prevention Study Group. Incidence of adverse drug events and potential adverse drug events. Implications for prevention, JAMA. 274 (1995) 29-34.
3. Samaranayake NR, Cheung STD, Chui WCM, et al., The pattern of the discovery of medication errors in a tertiary hospital in Hong Kong, Int. J. Clin. Pharm. Published Online First: 20 February 2013. doi 10.1007/s11096-013-9757-0.
4. Paoletti R, Suess T, Lesko M, et al., Using bar-code technology and medication observation methodology for safer medication administration, Am. J. Health. Syst. Pharm. 64 (2007) 536-43.
5. Poon E, Keohane C, Yoon C, et al., Effect of bar-code technology on the safety of medication administration, N. Engl. J. Med. 362 (2010) 1698-707.
6. Whyte M. Computerised versus handwritten records, Paediatric. Nursing. 17 (2005) 15-8.
7. Bargren M, Der-Fa L, An evaluation process for an electronic bar code medication administration information system in an acute care unit, Urol. Nurs. 29 (2009) 355-91.
8. Karsh BT, Holden RJ, Alper SJ, et al., A human factors engineering paradigm for patient safety: designing to support the performance of the healthcare professional, Qual. Saf. Health. Care. 15 (2006) i59-i65.
9. Samaranayake NR, Cheung STD, Chui WCM, et al., Technology-related medication errors in a tertiary hospital: A 5-year analysis of reported medication incidents, Int. J. Med. Inform. 12 (2012) 828-33.

10. Zhang H, Cosila M, Archer N, Factors of adoption of mobile information technology by homecare nurses: A Technology Acceptance Model 2 approach, Comput. Inform. Nurs. 28 (2010) 49-56.
11. de Veer AJE, Francke AL, Attitudes of nursing staff towards electronic patient records: A questionnaire survey, Int. J. Nurs. Stud. 47 (2010) 846-54.
12. Koppel R, Wetterneck T, Telles JL, et al., Workarounds to barcode medication administration systems: Their occurrences, causes, and threats to patient safety, J. Am. Med. Inform. Assoc. 15 (2008) 408-23.
13. Sana Daya Marini SH, Impact of BCMA on medication errors and patient safety: A summary, Stud. Health. Technol. Inform. 146 (2009) 439-44.
14. Harrison MI, Koppel R, Bar-Lev S, Unintended consequences of information technologies in health care - An anteractive sociotechnical analysis, J. Am. Med. Inform. Assoc. 14 (2007) 542-9.
15. Poon EG, Keohane C, Featherstone E, et al., Impact of barcode medication administration technology on how nurses spend their time on clinical care, AMIA Annual Symposium Proceedings. 2006, 1065
16. Holden RJ, Brown RL, Alper SJ, et al., That's nice, but what does IT do? Evaluating the impact of bar coded medication administration by measuring changes in the process of care, Int J Ind Ergon. 41 (2011), 370-9.
17. Samaranayake N, Cheung D, Chui W, et al. editors., Development and validation of a survey instrument to assess attitudes of health professionals on using 2-D bar-code technology: an extension of the technical acceptance model, The 44th APACPH Conference; 2012 Oct 14-17; Colombo, Sri Lanka.
18. Hurley AC, Bane A, Fotakis S, et al., Nurses' satisfaction with medication administration point-of-care technology, J. Nurs. Adm. 37 (2007) 343-9.

19. Nanji KC, Cina J, Patel N, et al., Overcoming barriers to the implementation of a pharmacy bar code scanning system for medication dispensing: A case study, J. Am. Med. Infor.m Assoc. 16 (2009) 645 -50.
20. Franklin BD, O'Grady K, Donyai P, et al., The impact of a closed-loop electronic prescribing and administration system on prescribing errors, administration errors and staff time: a before-and-after study, Qual. Saf. Health. Care.. 16 (2007) 279-84.
21. Redwood S, Rajakumar A, Hodson J, et al., Does the implementation of an electronic prescribing system create unintended medication errors? A study of the sociotechnical context through the analysis of reported medication incidents, BMC. Med. Inform. And. Decis. Mak. 11 (2011) 29.
22. Walsh KE, Adams WG, Bauchner H, et al., Medication errors related to computerized order entry for children, Pediatrics. 118 (2006) 1872-9.
23. Koppel R, Cohen A, Abaluck B, et al., Role of computerized physician order entry systems in facilitating medication errors, JAMA. 293 (2005) 1197-1203.
24. Patterson ES, Rogers ML, Chapman RJ, et al., Compliance with intended use of bar code medication administration in acute and long-term care: An observational study, Hum. Factors. 48 (2006) 15-22.
25. Patterson ES, Cook RI, Render ML, et al., Improving patient safety by identifying side effects from introducing bar coding in medication administration, J. Am. Med. Inform. Assoc. 9 (2002) 540-53.
26. Van Onzenoort H, Van De Plas A, Kessel A, et al., Factors influencing bar-code verification by nurses during medication administration in a Dutch hospital, Am J Health Syst Pharm.65 (2008) 644-8.
27. Mims E, Tucker C, Carlson R, et al., Quality-monitoring program for bar-code-assisted medication administration, Am J Health Sys Pharm. 66 (2009) 1125-31.

28. Fitzhenry F, Doran J, Lobo B, et al., Medication-error alerts for warfarin orders detected by a bar-code-assisted medication administration system, Am J Health-Sys Pharm. 68 (2011) 434-41.

29. Cina J, Fanikos J, Mitton P, et al., Medication errors in a pharmacy-based bar-code-repackaging center, *Am J Health Sys Pharm.* 63 (2006), 165.

30. Flynn FA, Barker KN, Pepper GA, et al., Comparison of methods for detecting medication errors in 36 hospitals and skilled-nursing facilities, Am. J. Health. Syst. Pharm. 59 (2002) 436-46.

Table I: Comparison of potential dispensing errors (PDEs) detected before and after implementing the stand-alone bar-code assisted medication administration system

Description	Period of study	
	Before	After
Number of prescriptions observed	1363	212
Number of drug items observed	2828	471
Overall PDEs, N (%)	12 (0.4%)	15 (3.20%)
Target PDEs, N (%)	-	4 (0.85%)
Unanticipated PDEs, N (%)	-	11 (2.34%)

*The 'number of drugs observed' was used as the denominator for calculating percentages.

PDEs, potential dispensing errors

Table II: Demographic characteristics of pharmacy staff who participated in the questionnaire survey

Variable	Paired participants	Unpaired participants	
	Pre and Post (n = 11)	Pre only (n = 5)	Post only (n = 5)
Gender, %			
Male	54.5	80.0	20.0
Female	45.5	20.0	80.0
Age category, %			
21 – 30	9.1	20.0	60.0
31 – 40	54.5	60.0	40.0
41 – 50	36.4	20.0	-
Highest education level, %			
Additional training	18.2	80.0	75.0
Graduate	63.6	20.0	25.0
Postgraduate	18.2	-	-
Current employment status, %			
Pharmacist	27.3	-	-
Senior dispenser	18.2	20.0	-
Dispenser	45.5	80.0	75.0
Other	9.1	-	25.0
Total number of years of experience in the profession, %			
0 – 5 years	-	-	40.0
6 – 10 years	9.1	20.0	20.0
11 – 15 years	45.5	60.0	20.0
16 – 20 years	18.2	20.0	20.0
Above 20 years	27.3	-	-

Table III: Comparisons of survey mean scores of the 5 constructs before and after the intervention

Paired t tests (n = 11 participants paired by the summed scores of each construct)					
Construct	**Pre-median (SD)**	**Post-median (SD)**	**Pre-mean (SD)**	**Post-mean (SD)**	***P value****
Attitude of output and intention to use	2.83 (0.44)	3.00 (0.71)	2.70 (0.44)	3.06 (0.71)	0.102
Perceived usefulness	3.00 (0.36)	4.00 (0.88)	3.07 (0.36)	3.84 (0.88)	0.008
Perceived ease of use	3.00 (0.39)	3.75 (0.78)	3.25 (0.39)	3.64 (0.78)	0.125
Job relevance	3.00 (0.69)	3.00 (0.88)	2.82 (0.69)	3.45 (0.89)	0.031
External influences	2.67 (0.54)	3.00 (0.85)	2.46 (0.54)	2.97 (0.85)	0.121
Student t tests (n = 5 pre and n = 5 post unpaired participants)					
Construct	**Pre-median (SD)**	**Post-median (SD)**	**Pre-mean (SD)**	**Post-mean (SD)**	***P value****
Attitude of output and intention to use	2.67 (0.38)	3.17 (0.67)	2.80 (0.38)	3.13 (0.67)	0.346
Perceived usefulness	3.00 (0.58)	4.00 (0.54)	2.92 (0.58)	3.88 (0.54)	0.031
Perceived ease of use	3.00 (0.37)	3.50 (0.57)	3.05 (0.37)	3.30 (0.57)	0.390
Job relevance	2.00 (0.43)	3.67 (0.44)	2.27 (0.43)	3.47 (0.45)	0.013
External influences	2.67 (0.38)	3.33 (0.30)	2.53 (0.38)	3.13 (0.30)	0.032

SD, standard deviation

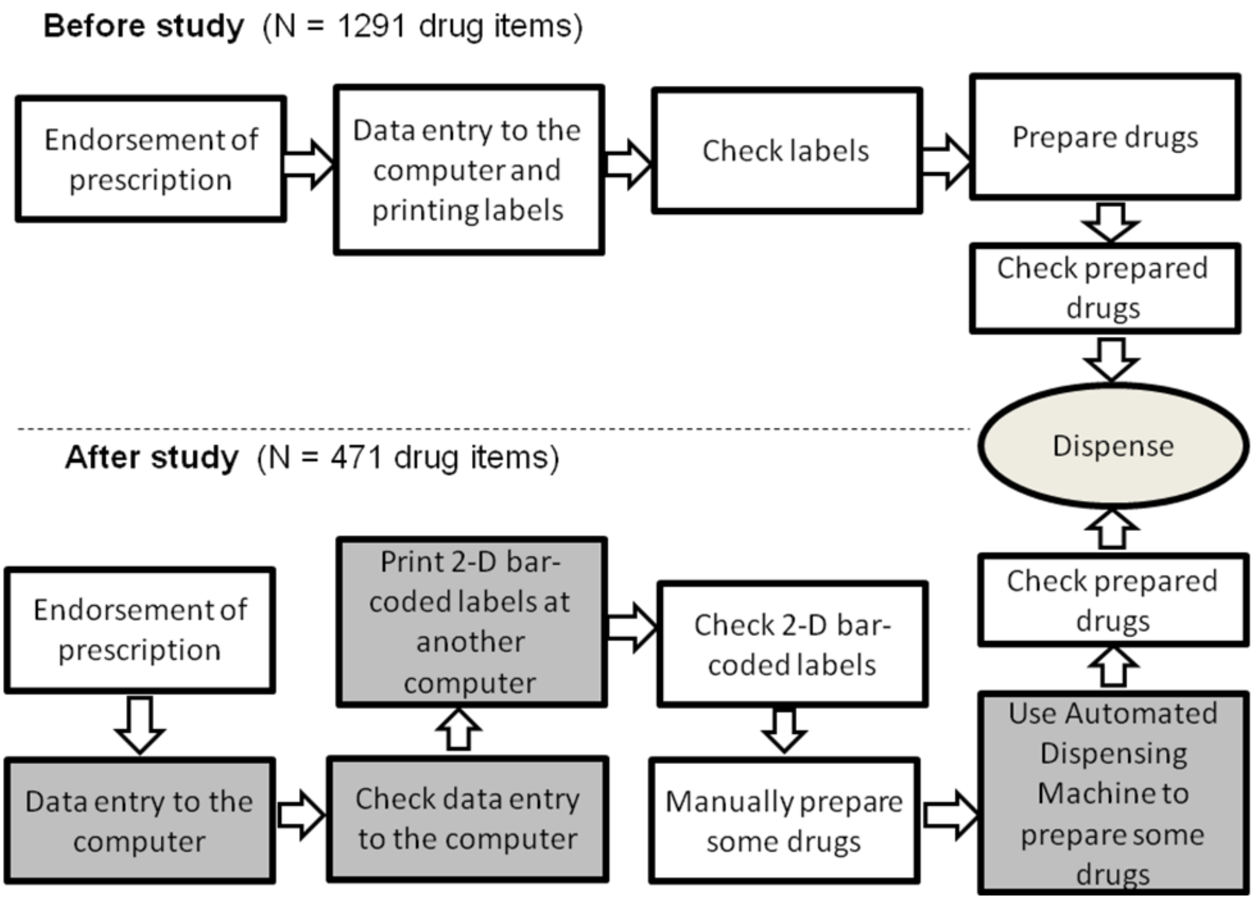
*Comparisons are between pre and post-implementation means; $P<0.01$ is considered significant due to the bonferroni correction

Table IV: Examples of perceptions of pharmacy and nursing staff who were interviewed

Comment	**Staff type-ID code**	**Examples of perceptions on using the stand-alone BCMA system**
Pharmacy staff		**Efficiency**
Comment 1	Pharmacy staff - G	"Need to input more data such as frequency, duration, need to check them and verify….takes more time to input data."
Comment 2	Pharmacy staff - J	"….more time consuming because you have to verify the label, print the label etc. I need to stick the label carefully; otherwise the bar-code scanner cannot read it."
Comment 3	Pharmacy staff - L	"…Work load is a bit larger, because I need to pick the label at another computer…"
		Issues related to using the system
Comment 4	Pharmacy staff - B	"…not a closed-loop system. Therefore can't get hold of changes in the patient profiles quickly. Have to wait for the doctor's updated prescription to come down to the pharmacy for changes to be made…"
Comment 5	Pharmacy staff - K	"…sometimes there is a problem with the printing quality of the labels …they need to be re-printed"
Comment 6	Pharmacy staff - B	"..The ADM [automated dispensing machine], ..over the last six months, we needed maintenance at least 3-4 times.."
Comment 7	Pharmacy staff - G	"..Machine does not work sometimes…takes time to find the problem.."
Comment 8	Pharmacy staff - H	"..Increases a lot of work load..when the system is out of order there is a disruption to work.."
		Safety
Comment 9	Pharmacy staff - D	"…From the patients view..yes, better timing of drug administrations. No benefit in terms of dispensing because it does not improve efficiency, work load and accuracy. 'Not really [reduce dispensing errors], we need a scanner to scan the details of the drugs that we dispense. There is still room for error because the bar-coding system is not really connected to the dispensing process…."
Comment 10	Pharmacy staff - E	"..Yes [reduce drug administration error], more information is provided to the ward. Dispensing errors are also reduced because the prescription is verified by the pharmacist."
Nursing staff		**Efficiency**
Comment 11	Nursing staff – R	"Has made daily work much harder and time consuming".
Comment 12	Nursing staff – T	"…we have to coordinate with the pharmacy as well."
		Issues related to using the system
Comment 13	Nursing staff – Q	"..It is hard to match the times of the 2D bar-code system....so we need to withhold some drug administration…sometimes the 2D bar-code system

		won’t work because of the double door system…”
Comment 14	Nursing staff– U	“Sometimes there are drug bottles with contents remaining, but we cannot save it for next time because the system is not flexible......the drug name, dose, frequency are not shown in the same screen… pharmacy is not close to us..”
Comment 15	Nursing staff- U	“… Sometime the doctor changes the dosage but it takes time to update the new dosage in the system…when you need to give a drug very fast the system is too slow…”
Comment 16	Nursing staff- V	“…We need to bring all the equipment to check records,.....not easy..”
Comment 17	Nursing staff – W	“…Sometimes we need to use the scanner 2-3 times before it senses it..”
Comment 18	Nursing staff – Z	“..The ID on the patient’s wrist band wares off if the patient is there for a long time..”
Comment 19	Nursing staff - U	“…Loading is very slow because it has to go through many fire walls…”
		Safety
Comment 20	Nursing staff- Q	“..2D bar-coding is a good thing. It is a good thing for patient safety…”
Comment 21	Nursing staff- S	“..Can ensure increased rate of accuracy….reduce wrong patient with wrong drug..”
Comment 22	Nursing staff- T	“..We pay attention to drug safety even manually..but bar-code may help. In the middle of the night the 2D bar-coding system is helpful because there is only one nurse and no one to help..”
Comment 23	Nursing staff- V	“..Can check if it complies to the 3-checks and 5-rights", “Yes, definitely [improves patient safety]”
Comment 24	Nursing staff - W	“…We check the bar-code on the label but this does not verify that the actual drug inside the plastic pack is the right drug…”
Comment 25	Nursing staff - Z	“….It will double confirm whether it is the right drug and right patient…but if the strength is not correct it will not be detected”.

Figure 1: Dispensing steps before and after implementing the stand-alone bar-code assisted medication administration system



= Indicates an additional step or a step that needed additional input by pharmacy staff

Note: The second step in the after study required the entry of additional prescribing information by dispensers and hence was considerably different from the before study