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RESEARCH PAPER

A 'time and motion' evaluation of automated dispensing machines in the emergency department

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Summary
Background: There has been limited assessment of the impact that automated medication dispensing machines have on the medication administration process, particularly in Australian emergency departments. The aim of this study is to examine the change in medication retrieval times, number of medications retrieved and staff perceptions before and after the installation of automated dispensing machines in an Australian emergency and trauma centre.
Methods: A time and motion method recorded the time taken and number of medications retrieved from the medication room by emergency department staff, before and after the installation of two automated dispensing machines. Surveys were administered to staff members to elicit the perceived impact on clinical practice, utilising 5-point Likert scales.
Results: A total of 954 medication retrievals (1030 medications) were recorded in the pre-implementation period and 842 (991 medications) in the post-implementation period. The mean time taken to retrieve any medication was significantly longer in the post-implementation period (+5.7 s; $p < 0.01$). For schedules 2, 3, 4 or unscheduled medications, the mean time increased by 26.9 s ($p < 0.01$), but decreased by 36.1 s ($p < 0.01$) for schedule 8 or 11 medications. The mean number of medications per retrieval increased slightly in the post implementation

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period (+0.10; $p < 0.01$). Staff perceptions were that automated dispensing machines improve knowledge of medications on imprest ($p = 0.03$) and reduced medication retrieval time ($p < 0.01$). *Conclusions:* This study found that the medication retrieval process was slower with automated dispensing machines for Schedules 2, 3, 4 and unscheduled medications, but quicker for Schedule 8 and 11 medications in an Australian emergency and trauma centre. Although retrieving medications took slightly longer overall, staff believed automated dispensing machines save time.

What is known

- Automated dispensing machines (ADM) securely store medications, restrict access, and enable accurate recording and tracking of medication usage in clinical environments.
- ADMs have been integrated with electronic prescribing systems as part of standard practice in the majority of hospitals in North America.
- In this setting, reported benefits include a reduction in nursing time spent retrieving and administering medications.
- ADMs are relatively uncommon in Australian hospitals and benefits reported in North America may not be applicable given few Australian hospitals have electronic medication management systems.

What this paper adds?

- This study quantifies the impact of ADMs in an Australian emergency and trauma centre without an electronic prescribing system.
- The average time to retrieve schedule 8 or 11 medications decreased with ADMs, but increased for schedules 2—4 or unscheduled medications and overall.
- The average number of medications per retrieval increased slightly with ADMs for schedules 2—4 or unscheduled medications and overall.
- Staff perceptions were that ADMs improve knowledge of medications on imprest and reduced medication retrieval time.

Introduction

Automated dispensing machines (ADM) have been implemented in many hospital settings in an effort to improve the safe and efficient retrieval of medications in clinical environments.[1] Medications stored within ADMs enable both accurate recording and tracking of medication usage and staff access. Systems such as the Care Fusion Pyxis Med Station® store medications within a secure computerised cabinet and restrict access with individual fingerprint login. This system has been shown to be successful in reducing stock holding, misappropriation of medication and improving financial reporting.[1—3] The technology also has the potential to identify, prevent and solve many drug-related problems with the information recorded.[2]

In North America, ADMs are common and have been integrated with electronic prescribing systems as part of standard practice in the majority of hospitals. Literature has been published over the past 20 years evaluating the benefits in this environment. Positive clinical outcomes include a reduction in the nursing time spent administering medications[3,4] a reduction in the rate of medication errors [5] and a large reduction in missed medication doses.[3—6] Despite these benefits, ADMs are still relatively uncommon within Australian hospitals and any benefits seen in North America may not be applicable due to the differences between health care systems,[7] particularly given relatively few hospitals have electronic medication management systems.[8] The only Australian study focused on pharmacy specific outcomes including pharmacist workload and prescription turn-around time associated with ADMs.[1]

The aim of this study was to assess the impact of ADMs on the medication administration process within an Australian emergency department (ED) setting without an electronic medication management system. Specifically, (i) to quantify the difference in the time taken to retrieve medications before and after implementation, (ii) to quantify the difference in the number of medications retrieved per medication room visit, and (iii) to assess the perceived impact on clinical practice by emergency staff members.

It is hypothesised that retrieval time for less restricted Schedule 2 (S2), Schedule 3 (S3), Schedule 4 (S4) and unscheduled medications will increase as they are relocated from an open shelf to a locked cabinet, and retrieval time for Schedule 8 (S8) and Schedule 11 (S11) medications will decrease with the elimination of manual record keeping and large volume stock counts.

Methods

Research ethics statement

This paper reports the findings of a research study that adhered to the National Statement on the Conduct of Human Research by the Australian National Health and Medical Research Council, and has been approved by the Alfred Health Human Research Ethics Committee (project number 220/12).

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Setting

The Alfred Hospital is a major adult referral hospital in metropolitan Melbourne, Victoria, Australia with an annual Emergency and Trauma Centre (E&TC) attendance of approximately 65,000 patients.

Two Care Fusion Pyxis Med Stations® were installed into the secure medication room of the E&TC in July 2012. Prior to their introduction, less restricted medications (S2, S3, S4 and unscheduled) were located on open shelves sorted in alphabetical order by generic name. More restricted medications (S8 and S11) were locked within a pin-code medication safe for which all transactions were manually recorded and stock counted. Following the installation of the ADMs, almost all medications were stored within the machines. A small number of high turnover medications with low risk of misuse remained accessible from an open shelf in the medication room.

A compulsory education and training programme was introduced in June 2012 for all nursing staff, one month prior to the installation of the ADMs. The programme included group tutorials and practical sessions demonstrating the operation of the ADMs. New staff commencing in the E&TC after the ADMs were installed undertook the same training programme on the first day of orientation.

The E&TC maintains a separate medication cupboard in the trauma and resuscitation area and a separate medication room in the short-stay area. These areas were not affected by the installation of the ADMs in the main ED medication room. The majority of the medication retrievals made from the main E&TC medication room are for 'non-life-threatening' conditions. The Alfred E&TC does not currently utilise electronic medication management systems, such as electronic prescribing.

Design

The time and motion method was used to record medication retrieval times before and after the ADMs were installed, consistent with previous studies.[3,4] An independent trained observer measured the time spent by any E&TC staff retrieving medications from the E&TC medication room for administration to patients during the observation periods. Timing of observations in the pre-implementation period began when staff entered the medication room and walked towards the medication shelf or safe and ended when the medication was in hand. In the post implementation period timing started when staff entered the medication room and walked towards the ADM and ended when the medication was in hand. The number of medications retrieved, the regulatory schedule and retrieval location (open shelf, locked medication safe or ADM) of each medication were recorded.

Observations were completed in three to six hour blocks during morning and evening shifts. Data was collected for approximately six weeks ending in June 2012 just prior to ADM implementation in July 2012 and for six weeks ending in April 2013 post ADM implementation. The post observation period was delayed by eight months to ensure that the new technology was fully embedded into practice prior to evaluation. Observations in which staff performed duties other than medication retrieval inside the medication room were excluded, such as reference checking and dose calculations.

A qualitative survey of E&TC staff was conducted pre and post ADM implementation to identify the perceived impact on practice. The extent of agreement with six statements was measured on a 5-point Likert scale. The scale allowed 5 different responses for each statement, ranging from strongly agree (one) to strongly disagree (five). The median response was compared pre and post ADM implementation (see Appendix 1).

Data analysis

Differences in mean medication retrieval time and the mean number of medications retrieved pre and post ADM implementation were assessed using student's *t*-tests, and where non-normal, the bias-corrected bootstrapped standard errors were used. Analyses by medication schedule excluded observations in which both S2, S3, S4 or unscheduled medications and S8 or S11 medications were retrieved as time could not be allocated individually. Wilcoxon Rank-Sum testing was used to assess difference between medians in the qualitative survey. Statistical significance was defined as $p < 0.05$. Analysis was conducted in STATA v11.

Results

Emergency staff attended the medication room on 954 occasions and retrieved 1030 medications in the pre-implementation period. Retrieval of multiple medications was relatively uncommon (6.7%) and very few included medications of both S2, S3, S4 or unscheduled and S8 or S11 (1.0%). In the post-implementation period, the medication room was attended on 842 occasions for 991 medications. Similarly, retrieval of multiple medications was uncommon (9.6%) with few including medications of both S2, S3, S4 or unscheduled and S8 or S11 (2.6%).

The average time to retrieve any medication was 30.3 s (SD: 47.4) in the pre-implementation period compared with 36.0 s (SD: 25.1) in the post-implementation period (+5.7 s; $p < 0.01$) (see Table 1). Retrieval of S2, S3, S4 or unscheduled medications was significantly slower in the post-implementation period (+18.4 s; $p < 0.01$). This was driven by a longer time to retrieve S2, S3, S4 or unscheduled medications stored within the ADM (+26.9 s; $p < 0.01$) rather than the low risk/high turnover medications that remained on open shelves (−6.8 s; $p < 0.01$). In contrast, retrieval of S8 or S11 medications was significantly quicker in the post-implementation period (−36.1 s; $p < 0.01$).

On average, 1.08 medications were retrieved per attendance in the pre-implementation period and 1.18 in the post-implementation period (+0.10; $p < 0.01$) (see Table 2). There was no change in the average number of medications retrieved per attendance for S8 or S11 medications, or S2, S3, S4 or unscheduled medications stored on open shelves. For S2, S3, S4 or unscheduled medications within the ADM, the average number of medications retrieved per attendance increased slightly in the post-implementation period (+0.12; $p < 0.01$).

The qualitative survey was completed by 78 emergency staff members in the pre-implementation period and 58

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Table 1 Average medication retrival time (seconds).

	Pre-implementation (SD)	Post-implemtation (SD)		Difference (95% CI)	*p*-Value
Any medication	30.3 (47.4) [*N* = 1030]		36.0 (25.1) [*N* = 991]	5.7 (2.2, 8.9)	<0.01
S2/S3/S4/U-S[a]	11.8 (15.9) [*N* = 793]	In Pyxis	38.7 (20.0) [*N* = 555]	26.9 (24.8, 28.8)	<0.01
		Not in Pyxis	5.0 (6.7) [*N* = 187]	−6.8 (−8.2, −5.4)	<0.01
		Combined	30.2 (22.9) [*N* = 742]	18.4 (16.2, 20.4)	<0.01
S8/S11[a]	93.5 (65.2) [*N* = 215]		57.4 (24.1) [*N* = 198]	−36.1 (26.8, 46.3)	<0.01

Abbreviations: SD = standard deviation; S2/S3/S4/S8 = Therapeutic Goods Administration Medication and Poisons Schedule 2 (Pharmacy Medicine)/Schedule 3 (Pharmacist Only Medicine)/Schedule 4 (Prescription Only Medicine)/Schedule 8 (Controlled Drug)/U-S (unscheduled); S11 = Drugs, Poisons and Controlled Substances Act 1981 (Vic) Schedule 11 (Drug of dependence).
[a] Analysis excluded imprest room attendances in which multiple medications of different schedules were retreived.

Table 2 Average number of medications retrieved per imprest room attendance.

	Pre-implementation (SD)	Post-implementation (SD)		Difference (95%CI)	*p*-Value
Any medication	1.08 (0.3) [*N* = 954]		1.18 (0.5) [*N* = 842]	0.10 (0.06, 0.14)	<0.01
S2/S3/S4/U-S[a]	1.08 (0.3) [*N* = 736]	In Pyxis	1.20 (0.6) [*N* = 462]	0.12 (0.06, 0.18)	<0.01
		Not in pyxis	1.09 (0.3) [*N* = 172]	0.01 (−0.04, 0.06)	0.34
		Combined	1.17 (0.5) [*N* = 634]	0.09 (0.04, 0.14)	<0.01
S8/S11[a]	1.03 (0.2) [*N* = 209]		1.06 (0.3) [*N* = 186]	0.036 (−0.01, 0.08)	0.13

Abbreviations: SD = standard deviation; S2/S3/S4/S8 = Therapeutic Goods Administration Medication and Poisons Schedule 2 (Pharmacy Medicine)/Schedule 3 (Pharmacist Only Medicine)/Schedule 4 (Prescription Only Medicine)/Schedule 8 (Controlled Drug)/U-S (unscheduled); S11 = Drugs, Poisons and Controlled Substances Act 1981 (Vic) Schedule 11 (Drug of dependence).
[a] Analysis excluded imprest room attendances in which multiple medications of different schedules were retreived.

Table 3 Likert scores pre- and post-implementation of pyxis.

	Pre implementation (*N* = 78)		Post implementation (*N* = 54)		*p*-Value
	Median	IQR[a]	Median	IQR[a]	
1. Easy to find imprest stock	2	2—2	2	2—3	0.11
2. Always adequate imprest stock	2	2—2	2	2—3	0.57
3. Knowledge of all imprest stock	4	2—4	3	2—4	0.03
4. Never wait to retrieve S8/S11s	3.50	2—4	2	2—4	0.96
5. Automated dispensing machines save time selecting imprest stock	3	3—4	2	2—4	<0.01
6. Automated dispensing machines improve selecting correct stock	2	2—3	2	1—2	0.08

[a] Score ranged from 1: Strongly Agree to 5: Strongly Disagree.

in the post-implementation period. Results indicated that knowledge of stock on imprest improved in the post-implementation survey ($p = 0.03$) and that ADMs save time selecting medications ($p < 0.01$) (see Table 3).

Discussion

Implementation of ADMs in this Australian E&TC improved the time taken to retrieve S8 and S11 medications, such as opioid analgesics, to be administered to patients. Legislation in Australia requires nursing staff to clearly document all activities related to these substances in a register including a count of all stock in the safe with each transaction. ADMs replace manual documentation with electronic documentation and reduce the quantity of stock to be counted with each transaction. The results are consistent with a similar study conducted in North America which reported that the retrieval of controlled medications usually stored in a locked safe is faster with ADMs: 107 s (SD: 106) without ADMs versus 48 s (SD: 23) with ADMs. [4]This finding is of particular significance in the ED environment, given (i) S8 and S11 medication orders contribute to a large proportion of total medications administered (approximately 20% in this study), and (ii) time to analgesia, including mostly opioid analgesia, is often a key performance indicator in EDs.[9,10]

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In contrast, retrieval of S2, S3, S4 and unscheduled medications, such as antibiotics, were significantly more time consuming with ADMs. There is no legal requirement that these drugs be recorded when taken from the medication room to be administered to a patient. It was therefore not unexpected that it would take staff longer to login to the ADM and enter patient information prior to retrieving the medication, compared to direct retrieval from an open shelf. Slower times may also be explained by queuing of staff given only one person can use an ADM at any time. Whilst the installation of two ADMs may have minimised the potential of queuing, some staff were observed waiting for access. In comparison, staff members were also observed returning to the medication room at a later time rather than waiting when all machines were in use. This suggests that nursing staff adjusted their behaviour with the aim of collecting medications as efficiently as possible, and is consistent with the finding that nursing staff retrieved significantly more S2, S3, S4 and unscheduled medications per attendance in the post-implementation period.

A key concern prior to the installation of the ADMs was the impact the new procedures would have on the staff. However, staff perceptions in the post implementation period were generally positive. The finding that staff believed ADMs had resulted in a reduction in medication retrieval times is of particular interest, given that medication retrieval times were slightly slower overall. This perception is likely attributable to the significant reduction in the time taken to retrieve S8 and S11 medications, which in relative terms is a very time consuming process. In addition, this finding may also be related to a potential reduction in time spent searching for medications not stored in the medication room. Given staff could search electronically for stock on ADMs and receive a definitive answer, less time may have been spent searching for medications without success. This is supported by the survey finding that knowledge of stock improved with ADMs.

The time taken to administer medications in the ED can have a significant impact on patient outcomes.[9,11,12] Early initiation of antibiotics has been associated with improved outcomes for patients with sepsis, febrile neutropenia, meningitis and open fractures.[13–17] Fittingly, the time to initiation of antibiotic therapy in the ED has been suggested as a key performance indicator for hospitals world-wide.[18] Therefore, new technologies including ADMs, which aim to improve the medication administration process will play an increasingly important role in patient care.

Although ADMs have also been demonstrated to reduce administration errors,[5] missed doses[1,3–6] and cost associated with improved accountability,[1–3] these outcomes were not measured in this study. The reduction in missed doses is related to the increase in number and range of medications that can be stored in ADMs. However, as the number of available medications did not change with the installation of the ADMs in this study, the number of missed doses was not investigated. In addition, five of the six studies that reported these outcomes were conducted in hospitals with electronic prescribing systems. The one study conducted without an electronic prescribing system cited available documentation of missed doses as a key limitation and did not measure administration errors.[1] As this study was similarly conducted in a hospital without an electronic prescribing system, inclusion of these outcomes was not considered to be feasible.

Limitations

A number of limitations need to be noted when interpreting the results. First, the 'time and motion' method is dependent on a trained observer to accurately record events within the medication room. To improve the accuracy of reporting, the observer underwent extensive training and piloted the data collection form prior to the first observation period. In addition, data was collected over long blocks of time (three to six hours) to improve consistency in data collection. Second, whilst E&TC staffing, casemix and presentations were consistent in the two time periods, there was a hospital-wide service redesign.[19] Although the redesign focused on improving efficiency in patient assessments, quality of care and patient disposition from hospital, this study was limited to the time staff spent selecting medications from the medication room. This task is unlikely to have been affected by the broader hospital service redesign.

Conclusion

This study found that the medication retrieval process was slightly slower overall with ADMs in an Australian emergency and trauma centre without electronic medication management systems. Although the retrieval of Schedule 8 and 11 medications was quicker with ADMs, it took longer to retrieve Schedule 2, 3, 4 and unscheduled medications. Whilst retrieval times are important, key performance indicators such as time to administration of first dose analgesics and antibiotics needs further evaluation. An assessment of ADMs integrated with electronic management systems is also warranted, given the inevitable push towards electronic prescribing within Australian practice. Nevertheless, these results are expected to be useful to senior medical staff and hospital administrators considering the installation of ADMs in a similar fast-paced environment such as the E&TC.

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Author contributions

CR, SP, DS and MD conceived and designed the study. MD secured funding. CR, CW and SP developed the study protocol and data collection form. CR and CW supervised the data collection. CR and SP analysed the data. CR, SP, CW, DS, and MD prepared and approved the manuscript.

Provenance and conflicts of interest

The authors declare no financial or other interest in the product or distributor of the product. This paper was not commissioned.

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Appendix 1.

Pre and post Pyxis qualitative survey statements
It is always easy to find imprest medications in the E&TC drug room.
There is always adequate stock of imprest medication in the E&TC drug room.
I always know whether the medication I am after is kept on imprest in the E&TC drug room.
I can always access an imprest S8/S11 from the safe when I need to; I never have to wait for someone else to complete their task.
An automated dispensing machine (like Pyxis) in the E&TC saves time in selecting a drug from imprest.
Having a Pyxis machine in the E&TC improves safety in selecting the correct medication.

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