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Comparing nursing medication rounds before and after implementation of automated dispensing cabinets: A time and motion study

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ABSTRACT

Nursing medication administration is an integral, albeit time consuming component of a nursing shift. Automated dispensing cabinets (ADCs) are a medicines management solution designed to improve both efficiency and patient safety. This study aimed to evaluate the time taken to undertake a medication round including the number of locations visited to retrieve medicines, across four different clinical specialties within one hospital. Studies to date have investigated the effect of ADCs on nursing medication rounds centred around one clinical specialty, in hospitals with varying levels of digital maturity. This study adds to the existing body of evidence by investigating multiple clinical specialties where EPMA in use throughout the study period. In this study, prior to ADC implementation nurses retrieved required medicines from shelves in the medication room, mobile medication carts, and patients' own drug (POD) lockers. Post-ADC implementation, medicines were retrieved exclusively from the ADC and POD lockers only. Nurses were observed on each ward completing medication rounds, using the data collection tool designed for this study. Pre-implementation data was collected between February and June 2023, and post-implementation data collected between July and September 2023. There was a statistically significant reduction in the time required for medicines retrieval on the surgical ward only, post-ADC implementation. The time taken to retrieve each medication went from a mean of 98.1 s to 47.2 s ($p = 0.0255$). When comparing all four specialties as a whole, there was a reduction in the mean time required to issue each medicine preversus post-ADC implementation, from 83.3 s to 62.6 s respectively, however this difference was not shown to be statistically significant. The mean number of locations visited to obtain all required medicines for each patient reduced significantly from 1.73 to 1.04 ($p < 0.01$). There is potential for improved efficiency as nurses become more familiar with new workflows. It may be of benefit to repeat this study to ascertain whether time savings have been further improved.

1. Introduction

Medication administration rounds have become more time consuming with polypharmacy recognised as a significant, complex and growing issue affecting many patients.[1] Efficiency is essential to ensure patients receive medications on time whilst ensuring nurses have sufficient time to undertake other clinical duties. With an increasing evidence base that links more direct clinical nursing time per patient-day with better patient outcomes, the need for additional ways to improve efficiency has never been more critical.[2–4] This combined with a global shortage of healthcare workers projected to reach 10 million by 2030, a growing demand for healthcare services and ongoing financial pressures to deliver more within existing budget constraints proves to be a continual challenge.[5] The automation of processes within the hospital settings to improve efficiency and patient safety is becoming increasingly common. Automated dispensing cabinets (ADCs) are one form of technology being adopted across inpatient clinical areas to optimise medication management at the point of care and expedite medication administration workflows to release nursing time to care.

More streamlined access to medications is vital for effective and timely treatment of patients in hospitals, especially for critical medications including but not limited to antimicrobials, anticonvulsants, anticoagulants, antidotes, antiparkinsons agents, antipsychotics, corticosteroids, cytotoxics, hypoglycemic agents and immunosuppressants.[6] Often the indication dictates the criticality as is the case with sepsis where rapid access to antimicrobials has been demonstrated to

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have a direct correlation with patient outcomes. It is well documented that risk of mortality increases exponentially when initiation of antimicrobials is delayed, with one study finding a 7.6 % decrease in survival for every hour that initiation is delayed.[7]

ADCs provide an electronic medicines management solution whereby medicines can be securely stored and obtained near the point of care by clinical staff, whilst enabling automated drug distribution via central pharmacy. The decision to implement ADCs within a hospital system typically involves pharmacy departments, with many factors to consider prior to implementation, including staffing resources and existing technology infrastructure. With successful implementation, expected benefits include patient safety, nursing, pharmacy and financial efficiencies. Guiding light technology reduces medicine selection errors. Non-alphabetical organisation of shelves reduces the risk of selecting the wrong strength of the correct medicine, and allows for separation of look alike, sound alike medicines.[8,9] ADCs are securely locked and only provide access to staff with the correct permissions which also supports reducing the risk of drug diversion. Stock levels are tracked in real time, with the ability to automatically send orders to the central pharmacy for stock replenishment, thus reducing the risk of stock-outs.[10] Expiration dates are also stored by ADCs with the ability to alert staff, reducing the risk of expired medicines being administered to patients.[8]

In addition, ADCs allow for streamlining of the medication administration process; a benefit of ADCs that is widely described in the literature but often without specifics as to how it is achieved. The evidence base published on the impact of ADCs on the nursing time required for medication retrieval or medication round is limited and often restricted to a single clinical area of study.[1,11,12] Cottney evaluated the impact of an ADC implemented on a single mental health unit reporting a reduction in time required to administer each dose; estimating that ADCs may release up to 66 min of nursing time every day per ward that can be redirected to other patient care activities.[1] This study was undertaken in a mental health hospital where nurses administering medication generally remain in one location while the patients come to them to receive their dose. This contrasts with typical medication rounds in acute hospital settings which involve nurses going to the patient's bedside. With distinct differences in workflow, it cannot be assumed that results can be generalised. Roman et al. implemented an ADC in an Australian emergency department reporting mixed results on time taken to retrieve medicines based on the type of medicine prescribed.[11] This study was undertaken outside of the UK where the healthcare system is different and therefore results may not be directly transferable to the National Health Service (NHS). Franklin et al. reported medication rounds became faster after the implementation of an ADC, electronic prescribing and medicines administration (EPMA) and barcode medicines administration (BCMA) on a surgical ward, but also noted an increase in nursing time spent on other medication related activities outside the medication round.[12] Hospitals in the UK are at varying stages of delivering full closed loop medication administration/management. Results from this study may not be applicable to hospitals where only EPMA is in use; the ability to assess the level of benefit of each technology in isolation is difficult.

The above has highlighted the gaps in literature and the need for further research in the field. With the planned introduction of ADCs at a large London teaching hospital, this study aimed to assess the impact of ADCs on nursing efficiencies. This was assessed by evaluating the time taken to undertake a medication round including the number of locations visited to retrieve medicines. Medication rounds were observed for multiple clinical specialties in a hospital setting where an EPMA solution was well established, and ADCs were newly implemented.

2. Methods

2.1. Study setting

This study was conducted at the main site of a large London teaching hospital in the United Kingdom with 1041 beds. A descriptive quantitative time in motion model was utilised to observe and record time spent on the medication administration process pre-and post-ADC implementation. This study was considered a service evaluation by the hospital pharmacy research and audit group who deemed ethics approval to not be necessary, as the observations would not involve any patient interaction, the recording of any patient details or alter any course of treatment. This aligned with guidance from the NHS Health Research Authority.[13]

2.2. Intervention

Prior to ADC implementation, each inpatient ward area had a clinical medication room which stocked all drug lines on an agreed stock list. Mobile medication carts had commonly used oral medications decanted from the clinical medication room by nurses and were wheeled from patient to patient as part of medication administration rounds along with a mobile computer. Medication preparation and administration occurred for one patient at a time. The EPMA software was consulted to determine due medications. Nurses would administer medicines available in individual bedside lockers where patients own drugs (POD), or medicines dispensed and labelled from the inpatient pharmacy for individual patient use was stored. Any due medicines not in bedside lockers would be obtained from the medication cart if available and administered at this stage. For any other outstanding medicine doses, the nurse would be required to retrieve these from either the clinical medication room or from another medication cart before returning to the patient to administer the medicines. Intravenous medicines and controlled drugs (CD) were exclusively stored within the clinical medication room; CDs within a secure wall mounted safe.[14]

Forty-five ADCs were implemented on inpatient ward areas at the hospital between February and July 2023. As part of implementation, ADCs were configured to store drug lines from the respective stock lists. ADCs were predominantly installed behind swipe accessed doors within clinical medication rooms. Ward stock CD medications were relocated from secure wall mounted safes to individual secure locked bins within the ADC. ADC remote queuing software was interfaced with the EPMA solution to enable nurses to send medication requests to the ADC from the bedside where medications were not available from POD lockers. Medication carts were removed from inpatient wards as part of post-ADC implementation workflows.

After ADC implementation, nurses continued to undertake medication rounds with a mobile computer on wheels, with medication preparation and administration continued to be for one patient at a time. The EPMA solution continued to be consulted to confirm due medications. Nurses would administer medicines available in individual bedside lockers where patients own drugs (POD), or medicines dispensed and labelled from pharmacy for individual patient use was stored. ADC remote queuing software was then utilised at the bedside, to request all remaining medicines from the ADC. The nurse would then retrieve and prepare any outstanding medication doses from the ADC by selecting doses queued at the ADC interface within the clinical medication room before returning to the patient to administer the medicines.

2.3. Study wards and participants

From the list of inpatient wards where an ADC had been deployed at the site, one ward per specialty was selected at random for inclusion in this study. An eligible ward was defined as a clinical area where an ADC had been implemented for at least three months and post-ADC data collection could be completed before the implementation of a new

hospital-wide EPMA solution in October 2023. A total of five wards were selected; one haematology ward, one liver ward, one surgical ward (providing an acute trauma service) and two medical wards (one acute medicine and one gerontology ward).

For each ward included, one medication round was observed pre-ADC implementation, and one observed post-ADC implementation. Post-implementation, the reviewers allowed at least three months post implementation as a washout period to ensure the nurses were familiar with the new workflows. Ward nurses advised which drug round typically had the most drugs administered. This guided the timing of observations. The time of the observed drug round was not consistent for all wards in the study, however for each ward, the post-implementation round was always observed at the same time of day as the pre-implementation round. Based on nursing workload, the observer would either observe the same nurse for the entire round while they completed medicines administration for each of their patients or observe multiple nurses.

2.4. Data collection and analysis

A standardised data collection tool was developed for use. The tool was then piloted by observing a nursing medication drug round to collect the predefined information fields. The pilot identified the need for an additional 'observations comments' field to capture any qualitative descriptions that do arise as part of the data capture process. Pre-ADC implementation data was collected between February and June 2023, with post-ADC data collection between July and September 2023. Data was entered directly into an electronic tool within Microsoft Excel to capture findings from observations. No patient identifiable information was recorded. The recorded elements of the medication round were:

- Date, time and ward
- Number of stock medicines retrieved
- Time taken to retrieve medicines
- Number of locations the nurse needed to visit to obtain all required medicines
- Any other pertinent information or findings observed were to be recorded in the comments section

The issuing and administration of CDs was considered a different workflow and therefore excluded from data collection. As each round started at the patient's bedside, visits to POD lockers were excluded from the location count. The primary outcomes were the time taken to retrieve medicines and the number of locations visited to retrieve all stock medicines, pre- and post-ADC implementation. Verbal consent was obtained from nursing participants ahead of observations.

Statistical analysis was conducted using RStudio version (2023. 12.0 + 396).[15] A Mann-Whitney *U* test was conducted to determine whether there was a difference in overall mean nursing time required for medicines retrieval pre-and post-ADCs across all inpatient wards involved in the study. The Mann-Whitney test was also applied to individual clinical specialties to determine whether there was a significant difference between specialties. The Mann-Whitney *U* test was chosen as it is suitable for assessing significance between groups of data, when the data is found to be non-parametric.

3. Results

There were 87 patients for whom a medication round was observed, 37 pre-ADC and 50 post-ADC implementation. The time taken to retrieve medicines for patients was observed and recorded for 126 medications pre-ADC and 138 medications post-ADC. The mean time taken to retrieve one medicine across all clinical specialties was reduced from 83.3 s to 62.6 s with ADC implementation. The Mann-Whitney *U* test comparing overall pre- and post-ADC time required for nurses to retrieve medicines across all medication rounds in all clinical specialties indicates that there is no statistical difference, W = 1087.5, *p*-value = 0.164. These results are presented in Table 1 below.

The mean number of medicines per patient decreased in the post-intervention group for all specialties except for hepatology.

Fig. 1 shows a boxplot of the distribution of nursing time to retrieve medicines for all observations within individual specialties included in this study. The Mann-Whitney *U* test for haematology, liver and medicine shows that there was no statistical difference in the time it took nurses to retrieve medication pre- and post-ADC. Surgery was an exception where results indicate there could be a reduction in the time associated with medicines retrieval post-ADC implementation, *p*-value comparing the times for nursing medication retrieval pre- and post-ADC on the surgical ward is <0.05.

There was also a notable reduction in the overall mean number of locations a nurse had to visit to retrieve all the required medicines, from 1.73 to 1.04 locations per patient. A Mann-Whitney *U* test demonstrated this to be a statistically significant reduction, W = 1270, $p \leq 0.01$. Pre-ADC it was observed that nurses often had to visit additional medication carts and the clinical medication room more than once to locate the required medicines. Post-ADC, nurses retrieved all required medicines almost exclusively from the ADC.

As part of the observations and recorded comments, it was noted that there was a high incidence of interruptions during medication rounds. For the total 87 patients for whom a drug round was observed, 65 interruptions were recorded in total, 34 pre-ADC and 31 post-ADC. For each patient, the number of interruptions ranged from zero to four, in both the pre- and post-ADC observations. Example sources and reasons captured as part of observation notes have been summarised and shared in Table 2.

4. Discussion

Although results from this study indicate a reduction in the mean time for medicines retrieval post-ADC implementation, this finding was not found to be statistically significant across all specialties. This was likely attributed to by a small data yield, with influence from outlier results. Anecdotally, nursing medication rounds appear to speed up when ADCs are used correctly and when nurses accurately follow the new workflows, however as demonstrated by these results, this is yet to translate into a significant time saving.

This study is unique in that it looked to assess whether there was an overall statistical difference in nursing time required to retrieve medicines, across multiple different clinical specialties, to confirm if benefits described in available literature can be applied broadly to different inpatient areas. Whilst our sample size was small, our data has shown that the only clinical specialty to show a significant reduction in time required for stock medicines retrieval was the surgical ward which provided an acute trauma service. These findings align with Franklin et al. who also described a reduction in nursing time required to complete medication rounds on a surgical ward, after the implementation of an ADC.[12] There are a few possibilities which could have attributed to this; trauma patients are typically younger, with fewer comorbidities and prescribed medicines.[16] It was also observed that the range of medicines prescribed, and stored within the ADC, is not as wide in surgery as other clinical specialties in the hospital. Nurses may consequently be more familiar with the location of medicines within ADCs and thus be able to issue them more quickly in comparison to the other wards included in the study, as they are less reliant on the guiding light to locate each medicine. Nursing experience and workload may also contribute to medication round efficiency. A significant reduction in the number of locations visited to obtain all required medication was also noted as a benefit in this study. Prior to implementation, nurses often had to visit multiple medication carts to find what they needed; restricting the number of locations where stocked medicines were kept post implementation was shown to improve this. However, it is acknowledged that in the post-intervention period, for all but one

Table 1
Mean time required to retrieve a medicine pre- and post-ADC implementation by clinical specialty.

Clinical Specialty	Intervention	Time of observed medication round	Number of medicines retrieved	Mean number of medicines per patient	Mean time to retrieve a medicine (seconds)	p-value (calculated from Mann-Whitney *U* test)
Haematology	Pre	1800	34	4.9	64	0.3148
	Post	1800	30	3	97.9*	
Liver	Pre	1200	16	1.8	113.6*	0.6812
	Post	1200	19	1.9	68.4*	
Medicine (acute medicine and gerontology wards combined)	Pre	0800	47	4.3	57.43	0.3483
	Post	0800	64	4	50.48	
Surgery (trauma)	Pre	1200	29	2.9	98.1	0.0255
	Post	1200	25	1.8	47.2	
Overall	Pre	N/A	126	3.4	83.3	0.164
	Post	N/A	138	2.8	62.6	

* These means have been impacted by outlier data points as shown in Fig. 1.

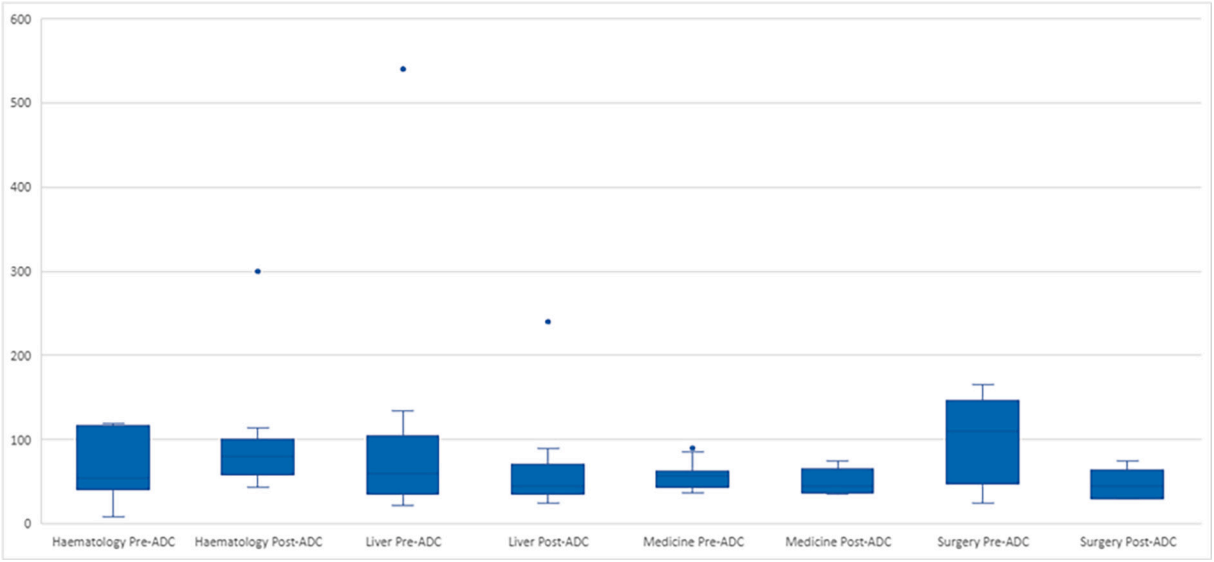

Fig. 1. Box plot showing the distribution of nursing time required to retrieve a medicine in seconds by specialty, pre vs post-ADC implementation. Outlier data points can be seen for haematology post-ADC, liver pre-ADC and liver post-ADC.

Table 2
Most common sources of interruption during the medication round, with examples for each.

Source of interruption	Example
Patient	Patient requested a specific drink which the nurse had to obtain from the kitchen
Nursing staff	A nursing colleague requested a second check of an intravenous medication
Other healthcare professional	Palliative care physician requested a patient update
Hardware issues	Medication cart drawer became stuck
Miscellaneous	A builder asked the nurse a question regarding renovation works required

specialty, the mean number of medicines per patient also reduced.

The findings have implications for hospitals planning to introduce ADCs within clinical inpatient areas. Our data shows that nursing efficiency gains vary between different clinical specialties. That said, there are published studies that have highlighted that ADCs support greater access to medications for nursing staff by reducing stock-outs and improving the timeliness of administration of some medications.[17,18] The discontinuation of medication carts secondary to ADC implementation translates to fewer locations requiring medicines management i.e. restocking and expiry date checking which was a task solely undertaken by nursing staff. Results published in 2015 found that since the introduction of ADCs that expired drugs were virtually eliminated leading to associated cost savings.[19] It is probable that the risk of unintentionally administering expired medicines to patients is also reduced, a patient safety benefit that can be assumed but of unknown clinical significance.

Technologies need to be used as intended to be effective. The importance of integrating EPMA and ADC solutions should not be underestimated to support full realisation of intended benefits. The successful introduction of ADC not only requires education, support and training to instill confidence in the system but also sustained efforts to ensure full engagement with the processes in the long term. With the second observation period being three months after ADC deployment, nurses may still have been in the adaptation period, familiarising themselves with the new technology and associated workflows. Research has shown that it may take over a year to become familiar with new healthcare technologies.[20,21] Restrictions on the data collection window timeframe may not have allowed nurses sufficient time to gain proficiency in the new workflows, a noted limitation of this study. Additionally, there is the consideration of nurses' digital literacy prior to implementation. No demographic details were recorded; however, it is possible that if a cohort of the observed nursing staff had below average digital literacy, this could have been a barrier to maximal efficiency savings with the system.[22] In time, with improved familiarity with the newly adopted workflow, further time savings for nurses are possible.

Ideally, the nursing medication administration process should

involve the preparation, administration and documentation in a linear process without interruptions. Studies have shown that interruptions or distractions in this process are thought to be a prominent factor in as many as 49 % of medication errors.[23] The high number of recorded interruptions during nursing medication rounds in this study is an incidental finding, so it was impossible to delineate the findings between the pre and post-intervention data. In theory post-implementation as nurses are obtaining medicines from the ADC within clinical medication rooms, it could be conceivable that fewer interruptions occur. In practice this was not observed to be the case. Strategies aimed at reducing unnecessary interruptions during medicines administration indicate that educational communications, creation of quiet zones, use of checklist and 'do not disturb' vests may reduce the incidence of interruptions but may not be widely accepted by nursing staff.[24] Identifying the most appropriate solutions to support minimising associated risks locally should be considered as the next steps.

4.1. Strengths & limitations

The strengths of this study are that we collected data across a range of specialties using robust methods, and that these same methods were used to evaluate two different time periods pre- and post-ADC introduction within the same organisation thereby strengthening existing literature in the field. We also used the same observer to collect the required data limiting measurement bias.

Several limitations have been identified for this study. Firstly, the observation period was short therefore only a few clinical specialties were eligible for inclusion, impacting the sample size available and potentially the proficiency of nurses in the post intervention group. Secondly, practice variability exists with medication administration rounds between different specialties and inter-person variability exists between nursing staff even within the same specialty, which may have introduced bias of unknown significance. Factors influencing this variability include the degree of complexity of patients being cared for, staff to patient ratios, and staffing experience levels. We acknowledge that excluding CDs from the observation may be another source of bias, as issuing and administering CDs are a common feature of nursing medication rounds which may limit the usefulness of these findings. We did not seek to capture nursing demographic information and were unable to extend the data collection period due to the implementation of a new hospital-wide change in EPMA system in early October 2023. Direct observations are time-consuming and collecting a larger data set was therefore challenging within the given time window and with the allocated resource available. More research in the field with larger observation sample size and even wider range of specialties, e.g. paediatrics, cardiology, renal should be considered to further substantiate findings from this study. Thirdly, it is widely accepted that observational studies of this kind are subject to the Hawthorne effect where nurses may make greater efforts and act more carefully or efficiently whilst being observed, potentially introducing bias.[25] That said, the observation method was the same pre- and post-ADC implementation and therefore the presence of an observer should have had minimal impact on our study findings.

4.2. Implications for pharmacy practice

As evidence of the specific benefits of ADCs and how these are achieved is limited, the findings of this study should be considered by hospitals contemplating implementation. Any potential benefits of ADCs in improving the efficiency of a medication round depends on where they are implemented, how they are used and how external factors can negatively impact the process. Frequently, hospital teams are required to implement technology within allocated financial envelopes and are required to make decisions on which locations to prioritise, often with little to no guidance. This decision should be based on where the most benefit can be gained.

Results from this study should help guide decision making for other NHS hospitals looking to implement ADCs in clinical areas. With a multitude of ADC benefits described in international literature, it is important that organisations define and assess the goals for ADC implementation locally ahead of deployment. Pharmacy departments are frequently approached to lead on the implementation of ADCs in practice. This often includes advice on the evidence base, where to implement and how.

Clinical areas where locating medicines poses challenges, or where common medications are routinely prescribed would, according to this study, benefit from the implementation of an ADC. Specifically, this study has identified surgery as a clinical area that should be considered for prioritisation if supporting nursing efficiencies is one of the intended goals of ADC implementation. Reducing the number of locations in which ward stock medications are stored should positively impact pharmacy workload, by reducing the number of locations pharmacy staff are responsible for inventory management. Additionally this should also reduce the risk of wastage due to stock expiry. The central pharmacy may receive fewer duplicate and hence unnecessary medication requests, as nurses have fewer places to look to locate stock, making medicines easier to find. These benefits should ultimately translate to financial savings for pharmacy departments.

In addition, effective training is essential if adherence to newly adopted workflows, including technical proficiency, is to be achieved. Patients and staff should keep interruptions to a minimum while nurses are conducting medication rounds in order to prevent medication errors and optimise efficiencies. It is also known that varying hospital processes, staffing resources, medicines distribution models and IT infrastructure have the ability to influence the outcome of benefits realised. Where nursing staff are the intended primary end users, this study also explicitly adds to available UK literature to strengthen the evidence base indicating a reduction in mean time required to retrieve medicines, equipping pharmacy teams with knowledge of new workflows and associated benefits to better enable them to educate nursing teams to create a cohesive environment ready and willing to embrace change.

5. Conclusions

The introduction of an ADC resulted in significant efficiency savings for nursing staff conducting medication rounds on a surgical unit. Results varied across the other clinical specialties, none of which showed a statistically significant change. ADC implementation significantly reduced the number of locations a nurse was required to visit to obtain required medications as part of the medication round. Continued familiarity with the system is likely to increase nursing proficiency with the use of ADCs over time and therefore it would be beneficial to repeat this study in future, with inclusion of a wider range of clinical specialties for more far-reaching results. Healthcare facilities considering ADC implementation should consider existing IT infrastructure and the potential for interoperability. ADCs are likely to demonstrate the greatest efficiency savings in clinical locations where locating medicines poses a particular challenge and for specialties where patients tend to be prescribed fewer medicines.

CRediT authorship contribution statement

Emma Jeffrey: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Áine Walsh:** Writing – review & editing, Supervision, Conceptualization. **Joseph Hague:** Writing – review & editing. **Kit Lai:** Writing – review & editing, Visualization, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal

relationships which may be considered as potential competing interests: Nil.

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