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The impact of automation on workload and dispensing errors in a hospital pharmacy

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Keywords
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Abstract

Objectives To determine the effect of installing an original-pack automated dispensing system (ADS) on dispensary workload and prevented dispensing incidents in a hospital pharmacy.

Methods Data on dispensary workload and prevented dispensing incidents, defined as dispensing errors detected and reported before medication had left the pharmacy, were collected over 6 weeks at a National Health Service hospital in Wales before and after the installation of an ADS. Workload was measured by non-participant observation using the event recording technique. Prevented dispensing incidents were self-reported by pharmacy staff on standardised forms. Median workloads (measured as items dispensed/person/hour) were compared using Mann–Whitney U tests and rate of prevented dispensing incidents were compared using Chi-square test. Spearman's rank correlation was used to examine the association between workload and prevented dispensing incidents. A P value of ≤ 0.05 was considered statistically significant.

Key findings Median dispensary workload was significantly lower pre-automation (9.20 items/person/h) compared to post-automation (13.17 items/person/h, $P < 0.001$). Rate of prevented dispensing incidents was significantly lower post-automation (0.28%) than pre-automation (0.64%, $P < 0.0001$) but there was no difference ($P = 0.277$) between the types of dispensing incidents. A positive association existed between workload and prevented dispensing incidents both pre- ($\rho = 0.13$, $P = 0.015$) and post-automation ($\rho = 0.23$, $P < 0.001$). Dispensing incidents were found to occur during prolonged periods of moderate workload or after a busy period.

Conclusion Study findings suggest that automation improves dispensing efficiency and reduces the rate of prevented dispensing incidents. It is proposed that prevented dispensing incidents frequently occurred during periods of high workload due to involuntary automaticity. Prevented dispensing incidents occurring after a busy period were attributed to staff experiencing fatigue after-effects.

Introduction

The prevention of medication errors is a fundamental requirement of pharmaceutical care and pharmacists are encouraged to review data on dispensing errors such that causes can be identified and addressed.[1,2] Dispensing errors are defined as deviations from a written prescription occurring during the dispensing process of selecting and assembling medication (drug/content errors), generating and affixing of dispensing labels (labelling errors) and issue of the dispensed products to patients (issue errors).[3] Dispensing errors are sub-divided into unprevented and prevented dispensing incidents. Unprevented dispensing incidents (errors) are dispensing errors detected and reported after medication

Table 1 Types of automated dispensing system

Type of automated dispensing system	Description
Repackaging systems	Medication is removed from the manufacturer's original packs and assembled into unit dose packs or blister cards.
Ward-based automated dispensers	These systems are electronic storage devices comprising a cabinet and/or trolley. Medication is stored within computerised patient- or product-specific drawers in the cabinet. When a patient's details are entered into the system's computer, the appropriate drawer opens, enabling administration of the medication.
Pharmacy-based original-pack dispensers	Medication is stored on a specially designed shelf within the automated dispensing system. During label generation the pharmacy labelling software transmits a signal to the robot software such that picking devices within the automated system select the required medication from the shelf. The medication is transferred to the delivery station by conveyor belt or chute. Some automated systems have labelling devices, which affix the corresponding dispensing labels to the medication.

has left the pharmacy, which may or may not lead to patient harm.[3–6] Prevented dispensing incidents (near-misses) are dispensing errors detected during dispensing before the medication has left the pharmacy.[3,4,6,7] Limited research has been conducted into the incidence, nature and causes of dispensing errors. Research has shown that there is a wide variation in the rate of unprevented dispensing incidents (UK community pharmacy, 0.04–3.32%; US community pharmacy, 0.08–24%; UK hospital pharmacy, 0.008–0.02%; US hospital pharmacy, 0.06–18%) and prevented dispensing incidents (UK community pharmacy, 0.22–0.48%; US community pharmacy, 1.28%; UK hospital pharmacy, 0.11–2.7%; US hospital pharmacy, 0.75%).[3] Variations in the rates of unprevented and prevented incidents may be attributable to differences in research methods and definitions used. However, prevented dispensing incidents (0.13%) have been shown to occur significantly more frequently than unprevented dispensing incidents (0.016%; $P = 0.04$).[7] Nevertheless, the most common types of unprevented and prevented dispensing incidents reported involve supply of the wrong drug, strength and quantity of medication and labelling dispensed medication with the wrong directions.[3,7]

Various factors have been reported as contributing to dispensing errors including look-alike/sound-alike drugs, interruptions, complex prescriptions and occupational stressors.[6–11] High workload, low staffing and staff stress have been implicated as causes of dispensing errors.[7–11] The majority of research has relied on the subjective reporting of causative factors by pharmacy staff. However, Guernsey and colleagues demonstrated a positive relationship between workload, measured using the surrogate marker of items dispensed, and potentially serious unprevented dispensing incidents.[12]

Automation has been advocated as a key strategy for improving dispensary efficiency, working conditions, maximising storage capacity and minimising dispensing errors.[13–15] Various types of automated dispensing systems (ADSs) exist (Table 1). Within the UK, original-pack ADSs are becoming increasingly commonplace within hospital pharmacy. Fitzpatrick and colleagues reported that the installation of an original-pack ADS in a hospital pharmacy increased dispensary workload (items dispensed) by 19% and reduced prevented dispensing incidents by 16%.[16] In contrast, Franklin and colleagues reported that the installation of an original-pack ADS at two hospitals significantly reduced the rate of prevented dispensing incidents but had no significant effect on workload in terms of outpatient prescription turnaround times.[17] However, both these studies employed surrogate markers to measure workload.

In 1997, governing power for health and social care in Wales was devolved from the UK Government to the Welsh Assembly Government. In 2002, the Welsh Assembly Government published *Remedies for Success. A Strategy for Pharmacy in Wales*, advocating the re-design of pharmacy services, harnessing of new technologies and optimisation of existing resources.[15] Consequently funding was secured from the Welsh Assembly Government enabling the phased implementation of original-pack ADSs in hospitals across Wales. Currently all acute National Health Service (NHS) hospitals in Wales have an original-pack ADS. This phased programme of automation provided an opportunity for an examination of the impact of automation on dispensary efficiency and safety. This study aimed to explore the effect of ADSs on dispensary workload and prevented dispensing incidents in one hospital pharmacy.

Method

Study design

A longitudinal case study methodology (single case, embedded design) was adopted for this study.[18] This study design allowed the establishment of association between workload and prevented dispensing incidents pre- and post-automation, while retaining the holistic and meaningful characteristics of real-life practice within the hospital pharmacy.

Table 2 Details of the participating hospital

	Hospital characteristics
Type	Teaching hospital
Bed number	600
Specialties	General medicine, general surgery, emergency medicine, critical care, cardiology, elderly, obstetrics, gynaecology, paediatrics, neonatal medicine, genitourinary medicine, renal, psychiatry, oncology and haematology
Type of pharmacy	Single centralised pharmacy
Number of pharmacy staff	100
Pharmacy staffing complement	Pharmacists, pre-registration pharmacy graduates, technicians, student technicians and assistant technical officers
Pharmacy services	Dispensing, ward pharmacy clinical services, pre-operative assessment clinics, medicines information, quality control, sterile and non-sterile production
Dispensary services	Supply of non-stock medication to each hospital department, ward, outpatient clinic and casualty in accordance with inpatient, outpatient and discharge prescriptions
Pharmacy labelling software	EDS
Opening hours	Seven days a week Monday to Friday 8.45 am–5.15 pm Saturday 9 am–12 pm Sunday 10 am–12 pm

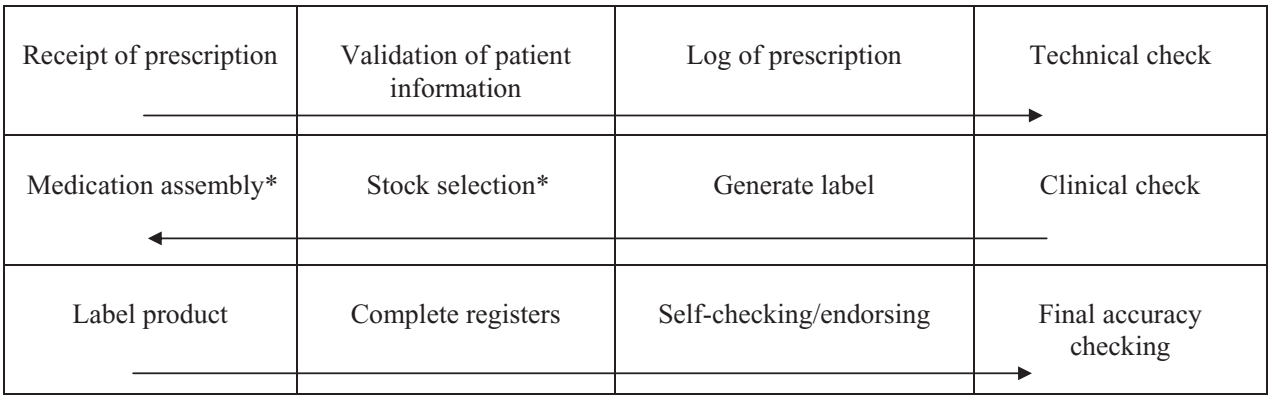

Figure 1 The dispensing process at the participating hospital pre- and post-automation. Asterisk indicates stages in the dispensing process undertaken by an automated dispensing system.

Study setting

The research was undertaken in a large district general NHS hospital within a University Local Health Board Trust which serves a population of approximately 130 000. Details of the participating hospital are outlined in Table 2.

The hospital is supported by a single, centralised pharmacy department. Pre-automation the pharmacy department was located at the far end of the hospital away from the wards and clinics. Figure 1 summarises the dispensing process used by the pharmacy department both pre- and post-automation.[11] Technicians and accredited checking technicians (ACTs) were responsible for receiving the prescription, validating patient information, logging prescription receipt by the pharmacy, performing a technical/legal check of prescriptions, generating labels, selecting stock, assembling medication, labelling medication, completing registers, self-checking and endorsing prescriptions. All prescriptions were clinically checked by a pharmacist. Pharmacists or ACTs would perform a final accuracy check of the dispensed medicines. Pre-automation the dispensing process had been modernised such that an electronic tracking system was employed to log prescription processing and the EDS computer software was used to generate dispensing labels. However, pharmacy staff were required to select drugs manually from dispensary shelves, assemble medication, affix dispensing labels to the assembled products and complete controlled drug or private prescription registers.

In January 2008 a new, purpose-built pharmacy department was opened at the hospital. This new pharmacy department was located closer to the wards. An original-pack ADS (ARX RowaSpeedcase) was installed in the dispensary. The ADS was loaded automatically and comprised two medication storage units. The ADS computer software was linked with the EDS pharmacy labelling software such that label generation signalled the ADS to select the required medication from the storage unit and convey the selected medication to the dispenser's computer terminal. Differences to work processing in

the dispensary following the installation of the ADS were determined during a focus group (Box 1). The changes to work processing included the separation of inpatient prescriptions into individual patient-specific trays and the supply of original manufacturers' packs of medication. However, the ADS could only accommodate medication packs of certain shape, size and weight. Therefore, not all medication was issued from the ADS. Medication dispensed manually post-automation were dressings and some bottles of liquid medicines that were not packaged in an outer box.

Box 1 Methods and findings of the focus group

Aim
- Establish the differences in the dispensing process pre- and post-automation

Method
- Four focus groups were undertaken with pharmacy staff (group 1: four accredited checking technicians, group 2: six accredited checking technicians, group 3: 17 pharmacists, group 4: four technicians) on 22 October 2009
- Audio-recordings were transcribed verbatim and analysed to determine the differences in the dispensing process pre- and post-automation.

Results
- Changes that happened post-automation:
- Separation of inpatient prescriptions, delivered to pharmacy in the ward bag, into individual patient trays
  ACT 4: 'Whereas before we used to pick up the bag. Once the bag used to go through team A [legal and clinical checking], the bag would go for dispensing so the person would pick up the blue bag [ward bag]. Whereas now. . . .'
  ACT 3: 'Take out the contents [of the bag], separate into individual trays.' (Focus group 1)
  Technician 2: 'Divided into boxes isn't it. Into trays. Each prescription and every item that comes down [to pharmacy] goes into an individual box.' (Focus group 3)
- Supply of manufacturers' original packs of medication during dispensing
  ACT 9: 'Plus we give out full boxes now. Whereas before we used to give what they ask for. We are now giving the full box. . . .'
  ACT 10: 'Before the robot we were splitting [original packs]. Now the robot gives you full packs. We give a full pack out.' (Focus group 2)
- Designated member of staff for dispensing outpatient prescriptions
  ACT 4: 'What we do now is have a designated person for outpatients, whereas before if there were outpatients anyone would do the outpatients.' (Focus group 1)

ACT, accredited checking technician.

Study participants

All members of pharmacy staff that were involved in the dispensing of medication for patients were eligible to participate in the study. Forty-five members of staff (pharmacists, $n = 16$; ACTs, $n = 7$; technicians, $n = 16$; pre-registration pharmacists, $n = 2$; student technicians, $n = 4$) were eligible pre-automation. Since the ADS had been installed a number of staff had retired, left the department or were on maternity leave. At the time of post-automation data collection, some of these posts remained vacant. Consequently, only 32 members of staff were eligible post-automation (pharmacists, $n = 16$; ACTs, $n = 9$; technicians, $n = 5$; pre-registration pharmacists, $n = 1$; student technicians, $n = 1$). Thirty-one of the staff recruited post-automation had also participated in the pre-automation stage of data collection. The only exception was the pre-registration pharmacist who had not been in post during pre-automation data collection. Pharmacy staff excluded from the study were those not involved in dispensing and those only involved in the manufacture of extemporaneous and/or aseptically dispensed medication. In accordance with the UK Department of Health Research Governance Framework, pharmacy staff were fully informed about the research and written informed consent was obtained from eligible staff participating in the study.[19]

Pilot study

A pilot study was undertaken for 2 weeks at the hospital both pre- (23 April–6 May 2007) and post-automation (11–24 May 2009). During the pilot the researcher confirmed the dispensing process used at the hospital through non-participant observation as described by James and colleagues.[11] The dispensing process was found to be identical pre- and post-automation, as outlined in Figure 1. The data-collection procedure for workload measurement and reporting of prevented dispensing incidents was subsequently piloted and were found to be feasible.

Data collection

Duration of data collection

A sample size calculation was undertaken to determine the duration of data collection required to demonstrate statistically significant differences in the mean workload for incident and incident-free periods. The sample size was calculated based on the assumption that, both pre- and post-automation, incident-free periods would occur when workload was low and incidents would happen when workload was high. Based on previous measurements of dispensary workload undertaken by Hiom and colleagues it was proposed that the incident-free periods would arise when the

Table 3 Quantification of the Hawthorne effect: median workload (items/person/hour) and interquartile range determined pre- and post-automation using the Welsh benchmarking event recording techniques during the initial 2 weeks and remaining 4 weeks of data collection

	Median workload measured using event recording (items/person/hour) and interquartile range	
	Pre-automation	Post-automation
Workload initial 2 weeks	9.08 (4.65–11.99)	12.38 (8–16.16)
Workload remaining 4 weeks	9.09 (5.87–11.86)	12.71 (6.89–16.93)
P value	0.551	0.901

To determine the influence of the Hawthorne effect, workload measurements for the Welsh benchmarking event recording for the initial 2 weeks of data collection and the remaining 4 weeks of data collection both pre- and post-automation were compared using a Mann–Whitney U test. With no statistical difference between the workload for the initial 2 weeks and remaining 4 weeks of data collection, the full 6 weeks of data collection, both pre- and post-automation, were analysed.

workload was 0–5 items/person/h whereas incidents would occur when workload was 6–15 items/person/h.[20] It was calculated by means of a two-sample *t* test that, accepting a type I probability of 0.05 and a type II error probability of 0.1, data should be collected over a period of 28 days to demonstrate a statistically significant difference of 3.38 items/person/h in workload. It was anticipated that the presence of the observer would influence pharmacy staff behaviour (Hawthorne effect). Based on research by Savage it was agreed that 2 weeks' data collection would be assigned to accommodate for the Hawthorne effect.[21] Therefore data on dispensary workload and prevented dispensing incidents was collected each working day (Table 2) for a period of 6 weeks (pre-automation: 8 May–18 June 2007; post-automation: 25 May–5 July 2009) with the initial 2 weeks allowing for the Hawthorne effect. To determine the influence of the Hawthorne effect the median workload for the first 2 weeks of data collection was compared with the remaining 4 weeks of data collection as described in Table 3. With no statistically significant difference between the two data sets the full 6 weeks of data were analysed. It is noted that a time period of 2 years had elapsed between the pre-automation and post-automation data collection. This timeframe was to allow the installation and embedding of the ADS. Therefore, post-automation data collection took place when all technical issues associated with installation of the ADS had been resolved and the dispensing system was stable. Also, pre- and post-automation data collection were undertaken at the same time of the year to minimise the impact of confounding variables such as seasonal affect on bed occupancy and staff.

Data-collection procedure

Dispensary workload was determined by the researcher (KLJ) by non-participant observation using the Welsh benchmarking event recording method as previously described by James and colleagues.[22] Using the dispensary rota, the observer recorded, on a standardised observation schedule, staff time allocated to dispensary duties each hour of the working day. During observation the observer recorded on the observation schedule how much time was spent by non-scheduled staff undertaking dispensary duties, defined by the inclusion criteria (Table 4).[22] The observer also recorded the time spent by scheduled staff away from the dispensary or engaged in duties defined in the exclusion criteria (Table 4). The total staff time allocated for dispensing duties was adjusted to account for time spent by scheduled staff away from dispensing and the additional time spent by non-scheduled staff engaged in dispensary duties. Details of the number of items dispensed were obtained from the pharmacy computer system and by manually counting prescriptions.

Prevented dispensing incidents

It is hospital procedure that all dispensed medicines are checked by a qualified pharmacist or accredited checking technician before the medication is issued to a patient. In this study, participants were required to self-report details of all prevented dispensing incidents defined by the inclusion criteria (Table 4) using the anonymous, standardised UK Dispensing Error Analysis Scheme dispensing error recording forms.[3,5] A form was completed for each dispensed item which could contain more than one dispensing error type, such as wrong strength on label (label error) and wrong strength dispensed (drug/content error). Each dispensing error form was reviewed for completeness of reporting by the researcher prior to analysis.

Research governance

Ethical approval was obtained from North East Wales Research Ethics Committee (REC: 09/WNo03/12). In addition, NHS Research and Development approval was obtained from the participating hospital and the researcher held an honorary contract at the hospital. Investigating the professional behaviour of healthcare staff is complicated by the legal and ethical issues surrounding observer intervention in the event of an error. To minimise observer bias yet preserve

Table 4 Inclusion and exclusion criteria for study

Inclusion criteria for the study were:

- For the Welsh benchmarking event recording technique:
  - dispensing of inpatient, outpatient, discharge prescriptions, patient's own drugs, monitored dosage systems, controlled drugs, clozapine, cytotoxics, emergency cupboard items,
  - if less than 15 min duration: ordering/dispensing internal order, patient counselling, pharmacy sales, private prescriptions, medicines information queries and training.
- Prevented dispensing incidents, defined as dispensing errors detected during the dispensing process before the medication had left the pharmacy, up to and including the point at which the medication was handed to the patient, that were reported to the UK DEAS by participating hospitals.
- A dispensing error was defined as a deviation from a written prescription/medication order, including pharmacists; written endorsements, occurring during the dispensing process of selecting and assembling medication (drug/content errors), generating and affixing of dispensing labels (labelling errors) and issue of dispensed products to patients (issue errors) which involve the following dispensing error types.

Drug/content errors	Labelling errors	Issue errors
• Wrong drug dispensed	• Wrong drug/drug details on label	• Failure to supply drug
• Wrong strength dispensed	• Wrong strength on label	• Drug supplied which was cancelled/not prescribed
• Wrong form dispensed	• Wrong form on label	• Incorrect bag label
• Wrong strength and form dispensed	• Wrong warnings or directions on label	• Drugs incorrectly bagged
• Expired stock dispensed	• Completely wrong label on bottle	• Sent to wrong ward
• Wrong quantity dispensed	• Wrong patient name on label	• Issued to wrong patient
• Drug not dispensed	• Wrong ward/cost centre on label	• Other issue error
• Wrong strength POD supplied	• Missing/wrong expiry on label	
• Expired POD supplied	• Failure to relabel POD	
• Wrong quantity of POD supplied	• Other incorrect or incomplete information on label	
• POD not supplied	• Wrong strength on POD relabel	
• Other drug error	• Wrong warnings/directions on POD relabel	
	• Other label error	

- Prevented dispensing incidents associated with individually dispensed items issued in accordance with ward controlled drug requisition, inpatient medication chart/order/requisition, outpatient/clinic/accident and emergency prescription and discharge prescription dispensed in the dispensary.
- Issue data defined as the total number of medication items dispensed individually in accordance with ward controlled drug requisitions, inpatient, outpatient and discharge prescriptions.

Exclusion criteria for the study were:

- For the Welsh benchmarking event recording technique:
  - dispensing of stock requests through dispensary, emergency boxes, stock replenishment, ward stock boxes, clinical trials, extemporaneous dispensing, vaccine distribution, returns, family planning orders for outside hospitals,
  - if greater than 15 min duration: ordering/dispensing internal order, patient counselling, pharmacy sales, private prescriptions, medicines information queries and training.
- Unprevented dispensing incidents, defined as dispensing errors detected after the medication has left the pharmacy, which could have or did lead to patient harm, that were reported to the UK DEAS by participating hospitals.
  - Prevented dispensing incidents, reported to the UK DEAS by participating hospitals, involving dispensing error types and/or associated with individually dispensed items which are not included in above inclusion criteria.
  - Errors arising during screening of prescription for legal validity, screening of prescription for clinical safety (clinical check), reconstitution or preparation of extemporaneous products, reconstitution or preparation of aseptic products, completion of controlled drug documentation, completion of private prescription or other regulatory documentation, transcription of information from one prescription/medication order to another and/or supply of stock medication to wards or other clinical areas.
  - Issue data on stock items supplied to wards or other clinical areas.

POD, patient's own drug; UK DEAS, UK Dispensing Error Analysis Scheme.

patient safety the researcher would only intervene in the dispensing process if she witnessed an error, act or omission that remained undetected despite every opportunity to correct the error.

Data analysis

Workload measurement

Data on dispensary workload measured using the event recording technique were entered into a Microsoft Excel spreadsheet for analysis. Data collected using the event recording technique on total staff time scheduled for dispensary activities were corrected for unscheduled deviations in staff activities as described by James and colleagues.[22] Histograms were constructed to determine the normality of data on dispensary workload.[2,23] It was determined that data on dispensary workload was not normally distributed. The median workload (items/person/hour) and interquartile range (IQR) was subsequently ascertained for the entire data-collection period pre- and post-automation. A Mann–Whitney U test was used to examine the relationship between dispensary workload pre- and post-automation.[23,24] Statistical significance was taken as $P \leq 0.05$.

Prevented dispensing incidents

Data on the prevented dispensing incidents were coded and entered into SPSS (version 13) for analysis. The rate of prevented dispensing incidents was calculated as:

$$\text{Rate of prevented dispensing incidents} = \frac{\text{Number of prevented incidents containing one or more error types}}{\text{Total number of medication items dispensed}} \times 100$$

To determine the normality of data, histograms were constructed of the frequency (y axis) for each determined rate of prevented dispensing incidents (x axis). It was determined that the data on the rate of prevented dispensing incidents were not normally distributed. A Chi-square test was used to compare the rate of prevented dispensing incidents pre- and post-automation.[23,24] Fisher's exact test was used to compare categorical data on the types of dispensing errors reported as prevented dispensing incidents pre- and post-automation as it allows the comparison of two categorical variables.[23,24] A $P \leq 0.05$ was considered statistically significant.

Dispensary workload and prevented dispensing incidents

Data on dispensary workload and prevented dispensing incidents (incidents/person/hour), corrected for staffing level and hour of working day, were entered into SPSS to enable correlation analysis. For both pre- and post-automation data sets Spearman's rank correlation was calculated to determine the association between dispensary workload and prevented dispensing incidents.[23,24] In addition, the median dispensary workload, number of prevented dispensing incidents and staffing levels were determined for each hour of the working day and presented as line graphs. The median workload and rate of prevented dispensing incidents were determined for each day of the week. A Kruskal–Wallis H test was undertaken to determine the impact that day of the week had on dispensary workload and prevented dispensing incidents.[23,24] The level of statistical significance was set at $P \leq 0.05$.

Results

Influence of automation on dispensary workload

Post-automation the median dispensary workload was significantly greater (13.17 items/person/h, IQR = 9.74–17.58) than pre-automation (9.20 items/person/h, IQR = 6.15–11.90; U = 29302, $P < 0.001$).

Influence of automation on prevented dispensing incidents

During the 6-week data-collection period pre-automation, 36 719 items were dispensed and 235 prevented dispensing incidents were reported involving 279 different dispensing error types. In contrast, during the 6 weeks of data collection post-automation, 52 808 items were dispensed and 147 prevented dispensing incidents were reported, which involved 184 different dispensing error types. The rate of prevented dispensing incidents was significantly lower post-automation (0.28%) than pre-automation (0.64%; $\chi^2 = 66.67$, $P < 0.0001$). Prevented dispensing incidents were categorised as labelling errors (pre-automation: 61%, $n = 143$; post-automation: 59%, $n = 86$), drug errors (pre-automation: 21.6%, $n = 51$; post-automation: 17%, $n = 25$), issue errors (pre-automation: 0; post-automation: 0), combined drug and label errors (pre-automation: 14%, $n = 33$; post-automation: 18%, $n = 27$), combined label and issue error (pre-automation: 1%, $n = 2$; post-automation: 1%, $n = 2$), combined drug, label and issue errors (pre-automation: 0.4%, $n = 1$; post-automation: 0%, $n = 0$) and combined drug and issue errors (pre-automation: 2%, $n = 5$; post-automation: 5%, $n = 7$). There was no statistically significant difference in the categories of error types reported pre- and post-automation by the participating hospital ($P = 0.277$). The most common dispensing error types reported as prevented dispensing incidents both pre- and post-automation are shown in Table 5.

Table 5 Dispensing error types reported as prevented dispensing incidents pre- (n = 279) and post-automation (n = 184)

	Number of prevented incidents (%)	
Dispensing error type	Pre-automation	Post-automation
Drug/content error		
Wrong strength dispensed	22 (8)	10 (5)
Wrong drug dispensed	13 (5)	7 (4)
Wrong dosage form dispensed	9 (3)	9 (5)
Wrong quantity dispensed	21 (8)	16 (7)
Expired/deteriorated drug dispensed	6 (2)	4 (2)
Drug not dispensed	7 (3)	7 (4)
Wrong strength and form dispensed	4 (1)	1 (0.5)
Wrong strength POD dispensed	0 (0)	0
Expired POD dispensed	2 (1)	0
Wrong quantity of POD dispensed	1 (0.4)	0
POD not supplied	1 (0.4)	0
Other	6 (2)	2 (1)
Total drug/content error	92	56
Labelling error		
Wrong directions/warnings on label	57 (20)	47 (26)
Wrong strength on label	15 (5)	10 (5)
Wrong drug details on label	13 (5)	8 (4)
Wrong patient name on label	42 (15)	30 (16)
Completely wrong label on bottle	2 (1)	2 (1)
Missing/wrong expiry date on label	11 (4)	2 (1)
Wrong ward/cost centre on label	2 (1)	3 (1.5)
Wrong strength on POD relabel	1 (0.4)	1 (0.5)
Wrong warnings/direction on POD relabel	3 (1)	1 (0.5)
Completely wrong relabel	0 (0)	1 (0.5)
Wrong patient name on relabel	1 (0.4)	0
Other labelling error	31 (11)	16 (9)
Total labelling errors	178	121
Issue error		
Failure to supply drug	4 (1)	7 (4)
Incorrect bag label	1 (0.4)	0
Issued to wrong patient	3 (1)	0
Drug supplied cancelled/not prescribed	1 (0.4)	0
Total issue errors	9	7
Grand total	279 (100)	184 (100)

POD, patient's own drug.

Relationship between workload and prevented dispensing incidents pre- and post-automation

Pre-automation

Correlation analysis revealed a positive linear association between dispensary workload and prevented dispensing incidents ($\rho = 0.13$, $P = 0.015$). The relationships between the time of day, dispensary workload, staffing levels and prevented dispensing incidents are shown in Figure 2. Throughout the working day, staffing levels were relatively constant at 11 to 16 staff. The staffing level was highest between 4 and 5 pm. In contrast, dispensary workload varied during the day but was usually between 7 and 11 items/person/h. Dispensary workload was at its highest (11 items/person/h) between 11 am and 12 pm. The occurrence of prevented dispensing incidents also varied during the day. However, there appeared to be a diurnal pattern with the highest number of prevented dispensing incidents occurring at 11 am–12 pm and 2–3 pm when both dispensary workload and staffing levels were high, at 9–11 items/person/h and 16 staff respectively. Day of the week had no significant impact on dispensary workload ($P = 0.122$) or the occurrence of prevented dispensing incidents ($P = 0.907$) (Table 6).

Post-automation

Post-automation there was a positive linear association between workload and prevented dispensing incidents ($\rho = 0.23$, $P < 0.001$). Figure 3 outlines the relationship between the time of day, dispensary workload, staffing levels and prevented dispensing incidents. Similar to pre-automation, staffing level was relatively constant between 10 and 15 people throughout the working day. The maximum staffing level was observed at 4–5 pm, with the minimum staffing level between 1 and 2 pm. Dispensary workload was relatively constant at between 10 and 15 items/person/h. The maximum workload of 22 items/person/h was observed at 11 am–12 pm and the minimum workload occurred at 5–6 pm. The rate of prevented dispensing incidents was highest between 9 and 10 am when workload and staffing level was high. Day of the week had a significant effect on dispensary workload ($P = 0.011$) with dispensary workload lowest on a Saturday (Table 6). However, the day of the week had no effect on the occurrence of prevented dispensing incidents ($P = 0.132$) (Table 6).

Discussion

Main findings

The study revealed that post-automation dispensary workload increased significantly by 43% (from 9.20 items/person/h pre-automation, 13.17 items/person/h post-automation) and the rate of prevented dispensing incidents decreased significantly by 56% (from 0.64% pre-automation to 0.28% post-automation). Both pre- and post-automation there was a significant positive association between dispensary workload and the occurrence of prevented dispensing

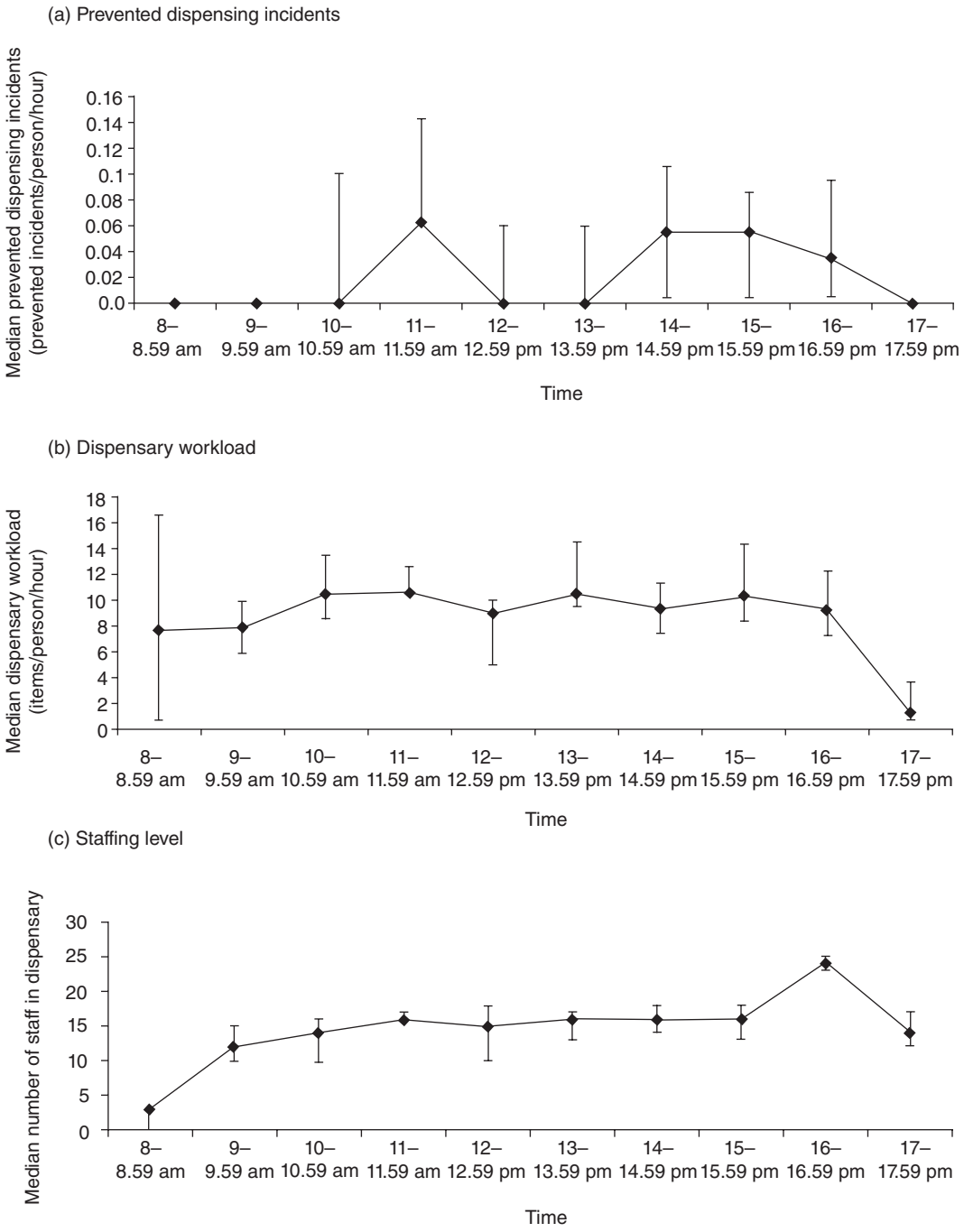

Figure 2 Pre-automation relationship between time of day and (a) prevented dispensing incidents, (b) dispensary workload and (c) staffing level. Error bars represent the interquartile range for data (n = 363).

incidents. Prevented dispensing incidents were found to occur most frequently in the morning and mid-afternoon either after a prolonged period of moderate workload or following a busy period.

Limitations

A major limitation of this study was that workload assessment was undertaken by non-participant observation. The validity and reliability of such observational studies can be

Table 6 Median workload and rate of prevented dispensing incidents for each day of the week pre- and post-automation

	Pre-automation		Post-automation	
	Median workload (items/person/hour) and interquartile range	Rate of prevented dispensing incidents, % (number of incidents/number of items dispensed)	Median workload (items/person/hour) and interquartile range	Rate of prevented dispensing incidents, % (number of incidents/number of items dispensed)
Monday	9.47 (6.75–11.91)	0.5 (30/5464)	14.63 (9.37–19.97)	0.4 (36/8797)
Tuesday	9.17 (6.10–11.89)	0.7 (46/6783)	14.76 (11.25–18.64)	0.2 (27/11860)
Wednesday	9.14 (7.29–11.30)	0.4 (36/6737)	14.5 (11.82–18.30)	0.3 (31/10637)
Thursday	9.53 (5.96–12.53)	0.7 (44/6679)	11.05 (8.13–17.69)	0.2 (14/7954)
Friday	10.28 (7.52–12.79)	0.5 (43/7960)	13.88 (11.69–17.29)	0.3 (25/9737)
Saturday	8.36 (3.25–12.92)	1.1 (19/1760)	9.90 (5.66–12.68)	0.3 (7/2109)
Sunday	6.77 (2.53–10.74)	1.3 (17/1336)	12.08 (4.35–14.41)	0.4 (7/1714)

compromised by observer bias and the Hawthorne effect. However, this study was carefully designed to minimise these effects by using a trained observer to collect data, clearly defining activities to be observed and allowing a period of time for pharmacy staff to become accustomed to the presence of the observer in the dispensary. A further limitation of the study was that it relied on staff self-reporting details of prevented dispensing incidents and so incidents could not be reported unless staff were aware an error had occurred. Even though the hospital operated a fair blame, open reporting culture, pharmacy staff may not have reported prevented dispensing incidents for fear of being disciplined or vilified. Also, staff may not report the incident if the error or drug involved is considered harmless.[25] Therefore, prevented dispensing incidents may be under-reported.

Impact of automation on dispensary workload and prevented dispensing incidents

This study found that automation improved dispensing efficiency and reduced the rate of prevented dispensing incidents. Following the installation of an original-pack ADS at the participating hospital, the median dispensary workload, as determined using the Welsh benchmarking event recording technique, increased significantly by 43% from 9.20 items/person/h pre-automation to 13.17 items/person/h post-automation. This is consistent with previous research which demonstrated that an original-pack ADS increased workload (measured as items dispensed) by 19%.[16] In contrast, Franklin and colleagues reported that the installation of an original-pack ADS had no significant effect on outpatient prescription turnaround times.[17]

Automation significantly reduced the rate of prevented dispensing incidents by 56% from 0.64% pre-automation to 0.28% post-automation. This is consistent with previous research in UK hospitals which has shown that the installation of an original-pack ADS significantly decreased the occurrence of prevented dispensing incidents by 16–60%.[16,17,26] There was no statistically significant difference between the dispensing error types reported pre- and post-automation. However, similar to previous research automation was associated with fewer drug errors and more labelling errors.[16,17,26]

The study findings revealed that both pre- and post-automation there was a positive association between dispensary workload and the number of prevented dispensing incidents. This is consistent with previous research undertaken in an outpatient pharmacy in a US hospital which showed that a linear relationship existed between the number of prescriptions dispensed and potentially serious unprevented dispensing incidents ($R^2 = 0.78$, $P < 0.001$).[12] Excessive workload pressures have also been shown to increase the risk of errors in other healthcare settings and aviation.[27–29] However, it is interesting to note that pre-automation there were no prevented dispensing incidents between 1 and 2 pm when workload was at a peak of 11 items/person/h.. This finding may be attributed to several factors. The workload may be so high that staff didn't have the time to stop and report the prevented dispensing incidents. Alternatively, staff may have failed to detect dispensing errors during busy periods, resulting in the errors being issued to patients (unprevented dispensing incidents), potentially causing patient harm. In addition, at a higher workload staff may be less distracted and more focused on the task in hand, resulting in fewer prevented dispensing incidents. This study did not evaluate the impact of mental workload on dispensing incidents. Pre-automation errors may have arisen from mental stressors. However, automation may have reduced errors associated with mental workload and stressors. Further work is needed to explore and validate these proposed explanations.

In previous research, inadequate staffing has been subjectively reported by pharmacy staff as contributing to dispens-

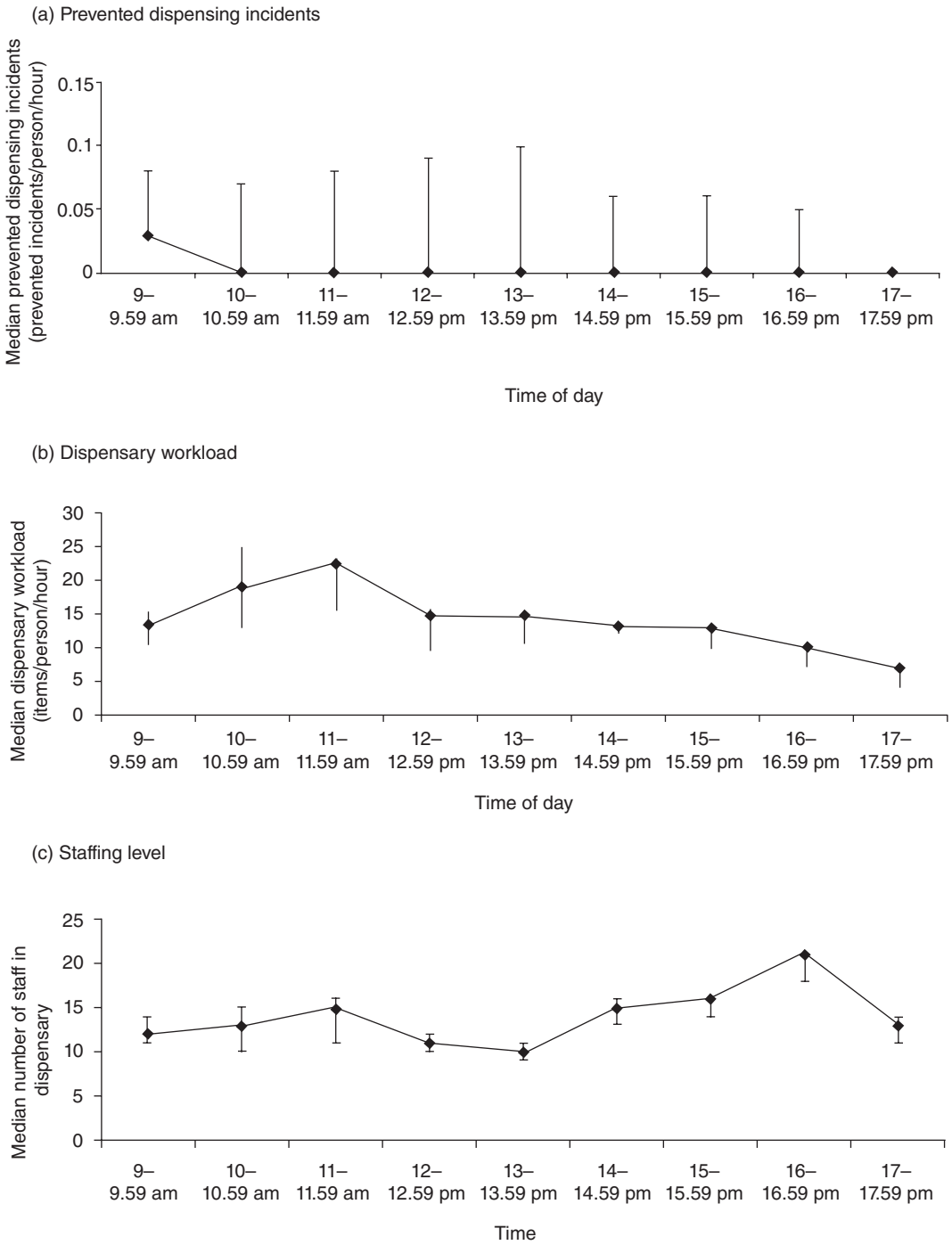

Figure 3 Post-automation relationship between time of day and (a) prevented dispensing incidents, (b) dispensary workload and (c) staffing level. Error bars represent the interquartile range (n = 341).

ing errors.[3,8–11,30] Both pre- and post-automation the staffing levels were relatively constant throughout the working day. Further work is needed to provide conclusive evidence of the impact of staffing levels on prevented dispensing incidents. Furthermore, this study did not investigate dispensary staffing skill mix and the effect on workload and prevented dispensing incidents. Research in critical care has reported that the composition of nursing and medical staff, including supervision from senior staff, significantly reduced the occurrence of patient safety incidents.[27] Although the day of the

week had no significant impact on the occurrence of prevented dispensing incidents, inadequate staff skill mix may be problematic at weekends when pharmacy staff specialising in technical and manufacturing services may be required to work in the dispensary. Therefore, pharmacy managers should ensure that, when scheduling staff for work on weekends and public holidays, there is adequate skill mix and supervision from senior staff.

Pre-automation there was a diurnal pattern to the occurrence of prevented dispensing incidents with the maximum number of incidents occurring mid-morning and afternoon. A similar relationship has been reported between doctors working hours and prescribing errors, with errors peaking after 2 and 7 h of work during their shift.[28] Corradini and Cacciari report that errors in the aviation industry occur during periods of low workload or prolonged moderate workload, or in periods of high workload and in transition phases form high to low workload.[29] Analysis of workload and prevented dispensing incidents revealed that dispensing incidents most commonly occurred in the morning, between 11 and 12 pm pre-automation and 9–10 am post-automation; and between 2 and 3pm (pre-automation) when workload was high and staff would be having their tea or lunch break. The occurrence of prevented dispensing incidents in the morning, both pre- and post-automation, may be attributed to involuntary automaticity whereby staff follow dispensing procedures in a ritualised manner without conscious control or attention to the task resulting in errors.[31] Involuntary automaticity is reportedly more likely to occur when workload is high, and when staff are stressed and fatigued.[31] A peak in the occurrence of prevented dispensing incidents was also observed pre-automation between 2 and 3 pm when the dispensary workload was lower than the workload at 1–2 pm. During this transition from a busy, stressful period to a period of lower workload, staff concentration may have been impaired, a phenomenon termed fatigue after-effect.[32] To minimise errors resulting from prolonged task performance and mental fatigue, research in nursing, aviation and the transport industry has recommended that staff activities should be varied and regular short breaks scheduled.[33,34] At this hospital, dispensary staff activities were rotated every 1.5 h and a 15 min break was scheduled for mid-morning and mid-afternoon. Research has shown that even micro-breaks of 15–30 s can minimise errors arising during the prolonged performance of computer tasks.[35–37] This suggests that to minimise computer selection and labelling errors pharmacy staff could take micro-breaks when using computers for a prolonged period of time. The impact of task rotation and breaks on prevented dispensing incidents warrants further work.

Conclusion

This study demonstrated that post-automation dispensary workload significantly increased by 43% and the rate of prevented dispensing incidents decreased by 56%. Post-automation there were fewer drug errors and more labelling errors. It is recognised that automation has the potential to eliminate all drug content errors as staff are no longer required to select drugs from shelves. However, the irony of automation is that while humans still have to enter drug data into the pharmacy computer system there is still the potential of the incorrect drug being labelled and supplied. Both pre and post-automation dispensing incidents were found to occur during prolonged periods of high workload when pharmacy staff would experience involuntary automaticity and become more complacent and less vigilant. Pre-automation prevented dispensing incidents also occurred after a busy period when staff were experiencing fatigue after-effects. Therefore, regardless of whether a hospital operates a manual or automated dispensing system pharmacy staff activities should be rotated at timely intervals to break the monotony of dispensing.

Declarations

Conflict of interest

The author(s) declare(s) that they have no conflict if interest to disclose.

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Author contributions

All authors state they had complete access to the study data that support the publication.

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