IJPP
International Journal of
Pharmacy Practice

IJPP 2008, 16: 375–379

Received October 10, 2007
Accepted August 7, 2008
DOI 10.1211/ijpp.16.6.0006
ISSN 0961-7671

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Acknowledgments: The research was funded by MDG Medical and the Department of Health's Patient Safety Research Programme. The authors would like to acknowledge the help of Kara O'Grady, Parastou Donyai, Karen Gordon, Veronika Wirtz, Sylvia Birch and Monsey Chan for their assistance with data collection. The Centre for Medication Safety and Service Quality is affiliated with the Centre for Patient Safety and Service Quality at Imperial College Healthcare NHS Trust which is funded by the National Institute of Health Research. An abstract presenting preliminary results from this work was presented at the British Pharmaceutical Conference, Manchester, September 2005.

Conflicts of interest: The research was partly funded by MDG Medical, the company that developed ServeRx, under an unrestricted grant. AJ was paid a consultancy fee by MDG Medical to visit the USA to demonstrate ServeRx to a potential future customer. The paper is an accurate representation of the study results. The funders had no role in study design; collection, analysis and interpretation of data; writing of the report; or the decision to publish the paper. The authors' work was independent of the funders.

The impact of an electronic prescribing and administration system on the safety and quality of medication administration

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Abstract

Objective To assess the effect of an electronic prescribing and administration system on the safety and quality of medication administration in a UK hospital.
Setting Surgical ward in a teaching hospital.
Method Data were collected before and after introducing a closed-loop system comprising electronic prescribing, automated dispensing, barcode patient identification and electronic medication administration records (ServeRx, MDG Medical). We observed medication administration during drug rounds and assessed medication administration error (MAE) rates for ward-stock and non-ward-stock drugs, accuracy of medication administration documentation, timeliness of administration, administration of medication from unlocked areas and supervision of patients taking oral medication by nursing staff.
Key findings Pre- and post-intervention MAE rates were 6.4 and 2.3% respectively for ward-stock drugs (95% confidence interval for the difference (CI) –5.8 to –2.4%), and 14.6 and 13.7% for non-ward-stock drugs (CI –6.5 to 4.7%). Excluding omissions due to unavailability, pre- and post-intervention MAE rates were 6.2 and 2.2% respectively for ward-stock drugs (CI –5.7 to –2.3%), and 9.2 and 3.5% for non-ward-stock drugs (CI –9.3 to –2.1%). Pre-intervention, 2086 doses (96.3%) were documented correctly and 1557 (95.9%) post-intervention (CI –1.6 to 0.8%). There were five clinically significant documentation discrepancies pre-intervention (0.2%), and 33 (2.0%) afterwards (CI 1.1 to 2.5%). Timeliness of administration improved post-intervention ($P < 0.001$; Chi-square test), as did administration of medication from unlocked areas (CI 4.7 to 7.3%) and supervision of patients taking oral medication (CI 17 to 23%).
Conclusion Reductions in MAEs, excluding omissions due to unavailability, occurred for both ward-stock and non-ward-stock drugs. The system also improved timeliness and security of drug administration. However, there was an increase in potentially significant documentation discrepancies.

Introduction

Electronic prescribing and ward-based automated dispensing are often cited as being important ways to reduce medication errors in hospital inpatients.[1–3] However, the majority of published data focus on electronic prescribing alone, and originate from the USA,[4–8] where systems of prescribing, dispensing and administration are very different to those elsewhere.[9,10] Previous studies also focus on prescribing errors,[4,7,8] or include all types of medication error without differentiating between prescribing and administration.[5,6] The introduction of electronic systems may necessitate significant changes to the way in which medication is administered, yet little is known about their effect on the quality and safety of medication administration. Only three previous studies have explored this issue. Two UK studies used observation to identify medication administration errors (MAEs). One reported a significant reduction in MAEs following the introduction of electronic prescribing and electronic medication administration records (eMARs) on an orthopaedic ward, but was published only as an abstract.[11] The other suggested no difference in MAE rates between a hospital using electronic prescribing (and paper medication administration records) and a different hospital using paper-based prescribing.[12] The third study described medication incidents reported before and after introducing eMARs in a US hospital;[13] however, the use of incident reports is known to grossly underestimate the incidence of MAEs.[14–16] No studies have explored other issues relating to the safety and quality of

medication administration, such as the accuracy of documentation and the timeliness of administration. There are also very few data on the impact of electronic prescribing combined with ward-based automated dispensing.[17,18]

We have piloted a closed-loop electronic prescribing, automated dispensing, barcode patient identification and eMAR system on a UK hospital ward. The key aspects of its quantitative[19] and qualitative[20] evaluation have been published elsewhere; we demonstrated significant reductions in both prescribing errors and MAEs. We also showed a significant increase in the confirmation of patient identity before medication administration. These benefits were accompanied by increases in staff time requirements for medical, pharmacy and nursing staff. The present paper presents in more detail the impact of the system on the safety and quality of medication administration.

Our objectives were to explore the impact of the system on MAEs for both ward-stock and non-ward-stock drugs, timeliness of medication administration, accuracy of documentation, administration of medication from unlocked areas and supervision of patients taking oral medication by nursing staff.

Methods

Setting

We studied a 28-bed general surgery ward in a London teaching hospital. Scheduled drug rounds took place four times each day with one round serving half of the ward; there were therefore eight rounds each day. Pre-intervention, systems for prescribing, supply and administration were typical of those in the UK.[9,10] Medication orders were written by doctors onto formatted paper drug charts which were also used by nursing staff to document administration,[21] and medication was stored in two drug trolleys plus stock cupboards. Commonly used medication was kept as ward stock. The ward received a ward pharmacy service, with a daily visit from the ward pharmacist on weekdays and a short visit on Saturdays. The pharmacist checked that all medication orders were clear, legal and clinically appropriate as well as supplying any non-stock medication required. Any non-stock medication urgently required could also be obtained from the pharmacy by nursing staff.

The intervention was a closed-loop system incorporating electronic prescribing, ward-based automated dispensing, barcode patient identification prior to drug administration, and eMARs (ServeRx version 1.13, MDG Medical, Tel Aviv, Israel). Only intravenous fluids and oral anticoagulants remained on handwritten paper charts; the majority of medications were stored in the automated cabinet. The ward pharmacy service remained largely as before. The system is described in more detail elsewhere;[19] it went live in June 2003. The study was approved by the local research ethics committee.

Study design

We used a before-and-after design. Pre-intervention data were collected in spring 2003, about 3 months pre-intervention. Post-intervention data were collected about 1 year post-intervention, in summer 2004. The same ward pharmacist was responsible for the study ward throughout. All data were collected by observation of medication administration.

Definitions

Opportunity for error

The denominator used to calculate the MAE rate was the number of opportunities for error (OE). An OE was any dose of medication that the researcher observed being administered (or omitted) and could classify as being either correct or incorrect. 'Administration' was taken to include leaving a dose at a patient's bedside for subsequent self-administration. Doses given in between scheduled drug rounds were not considered OE as they could not be observed; this included the majority of controlled drugs. Dietary supplements prescribed by dieticians were excluded. Each intravenous dose potentially comprised two OE, one relating to its preparation and one to its administration. Doses administered by any other route were associated with only one OE.

MAE

An MAE was defined as any dose of medication administered (or omitted) that deviated from the patient's current medication orders.[19] This definition includes omission of doses due to unavailability of the required medication on the ward. Administration of medication in relation to food was not assessed, and failure to follow hospital procedures was not in itself considered an MAE. Errors prevented by the observer or the patient were included as MAEs; those prevented by other health care professionals were not. Timing and documentation were excluded as MAEs but were assessed separately.

Documentation discrepancies

Documentation discrepancies occurred where the details recorded by the nurse concerning whether or not a dose was given, and reasons for any non-administered doses, were different to those observed by the researcher.

Potentially significant documentation discrepancies

These were documentation discrepancies where the action documented, in terms of the drug being given or not given, was the opposite of that actually observed. These therefore excluded documentation of the incorrect reason for non-administration.

Data collection

The primary outcome measure in our main study[19] was the MAE rate, and the sample size was based on being able to identify a reduction in MAE rate from 5 to 2.5%. This required 906 OE in each phase of the study, which was estimated to require observation of 56 drug rounds.[22] During each phase of the study, four pharmacist researchers between them aimed to observe 56 drug rounds. Approximately equal numbers of drug rounds were observed for each side of the ward, time of day and day of the week.

During each observed drug round, the researcher accompanied nurses preparing and administering medication, and compared the medication given with that prescribed, using established methods.[23,24] Intravenous medication was generally

administered before or after the main drug round, but was observed wherever possible. Researchers recorded details of each dose administered or omitted, whether or not it was an OE, and whether or not an MAE occurred. The researchers combined quantitative data collection with field notes that were written up in detail immediately after the observation. The principal investigator (BDF) gave all researchers training in the methods and definitions before data collection began.

The observers were advised to intervene tactfully if they were in a position to prevent an error that could result in patient harm. Such cases were included as MAEs; previous work has shown that neither observation nor routine intervention affects MAE rates.[23]

The following were also recorded, but were not considered MAEs: (1) the accuracy of documentation of medication administration; (2) timeliness of drug administration; (3) whether the nurse supervised the patient taking each oral dose, or whether the dose was left at their bedside for subsequent self-administration and (4) whether doses were administered from unlocked areas such as the patient's bedside table. Closed but unlocked storage cupboards at the nurses' station were not considered to be unlocked areas for the purposes of this study.

Data analysis

Separate MAE rates were calculated for ward-stock and non-ward-stock medication, both including and excluding omissions due to unavailability of medication on the ward. The 95% confidence intervals for differences between proportions (CI) were calculated where appropriate.[22] The Chi-square test was used to test for differences in categorical data where there were more than two categories. We also calculated the positive predictive value of a dose being documented as given, and a dose being documented as omitted, using the following equation.

$$\text{Positive predictive value} = \text{true positives}/(\text{true positives} + \text{false positives}) \times 100\%$$

Results

The drug rounds and OE observed

Pre-intervention, 56 drug rounds and 2336 doses were observed. Of these doses, 692 (30%) were not considered OE. This was because doses were self-administered (n = 160), refused by the patient (n = 97), not given for clinical reasons (n = 39) or not observed in sufficient detail to determine whether or not an MAE had occurred (n = 396). There were therefore 1644 OE, as presented previously.[19]

Post-intervention, 55 rounds and 1678 doses were observed. Of these, 500 (30%) were not OE as they were self-administered (n = 27), refused (n = 101), not given for clinical reasons (n = 64) or not observed in sufficient detail (n = 308). There were 1178 OE.[19]

There was no difference between pre- and post-intervention periods in terms of side of ward ($P = 0.92$; Chi-square test), time of day ($P = 0.92$) or day of week ($P = 0.98$) on which drug rounds were observed. The majority of OE both pre- and post-intervention were oral; fewer intravenous doses were observed post-intervention (171 pre-intervention and 39 post-intervention).[19]

MAEs

As reported previously, 141 MAEs were identified pre-intervention (8.6% of OE) and 53 post-intervention (4.4%). The difference was statistically significant. Types of MAE and examples are given elsewhere.[19]

There were no differences in MAE rates on different days of the week, either pre- or post-intervention. In terms of time of day, there was no statistically significant difference pre-intervention ($P = 0.51$; Chi-square test), although there was a trend towards a higher error rate during the 12 noon drug round. However, there was a significant difference post-intervention ($P = 0.02$), with the highest error rate observed at 12 noon.

Table 1 presents MAE rates according to whether or not drugs were ward stock on the study ward. The pre- and post-intervention difference in MAE rates was significant for ward-stock drugs if all types of MAE were included (CI –5.8 to –2.4%), but not for non-ward-stock drugs (CI –6.5 to 4.7%). However, if one excludes omissions due to unavailability, predictably much higher for non-ward-stock medication, the difference is significant for both ward stock (CI –5.7 to –2.3%), and non-ward stock (CI –9.3 to –2.1%).

Timeliness of administration

Table 2 summarises the time within which prescribed doses were administered. Administration was more timely post-intervention ($P < 0.001$; Chi-square test).

Table 1 MAE rates for ward-stock and non-ward-stock drugs

Difference between time for which prescribed and time administered	Pre-intervention	Post-intervention
OE		
OE relating to ward-stock drugs (% of all OE)	1199 (73%)	952 (81%)
OE relating to non-ward-stock drugs (% of all OE)	445 (27%)	226 (19%)
MAEs		
MAEs identified in ward-stock drugs (% of stock OE)	77 (6.4%)	22 (2.3%)
MAEs identified in non-ward-stock drugs (% of non-stock OE)	65 (14.6%)	31 (13.7%)
MAEs identified in ward-stock drugs, excluding omissions due to unavailability (% of stock OE)	74 (6.2%)	21 (2.2%)
MAEs identified in non-ward-stock drugs, excluding omissions due to unavailability (% of non-stock OE)	41 (9.2%)	8 (3.5%)

Table 2 Timeliness of medication administration

Difference between time for which prescribed and time administered	Pre-intervention	Post-intervention
<1 hour	1719 (79%)	1475 (89%)
1–2 hours	422 (19%)	203 (11%)
>2 hours	47 (2%)	0 (0%)
Total	2188 (100%)	1678 (100%)

Quality of documentation

Pre-intervention, 2167 doses could be assessed for the quality of documentation, of which 1963 (91%) were given, and 204 (9%) omitted. Post-intervention, 1623 doses were assessed, of which 1406 (87%) were given and 217 (13%) omitted. Overall, 2086 doses (96.3%) were documented correctly pre-intervention, and 1557 (95.9%) post-intervention. The difference of –0.4% is not statistically significant (CI –1.6 to 0.8%). There were five potentially significant documentation discrepancies pre-intervention (0.2%), and 33 (2.0%) post-intervention; these mainly concerned doses that were initially documented as being unavailable since they were not in the automated dispensing system, but subsequently located and given. The difference of 1.8% is significant (CI 1.1 to 2.5%).

Pre-intervention, the positive predictive value of a dose being documented as given (either by the nurse or by the patient) was 99.7%. Post-intervention, it was 99.1%. The difference of –0.6% just fails to reach clinical significance (CI –1.2 to 0.0%). Pre-intervention, the positive predictive value of a dose being documented as omitted (because the drug was unavailable, omitted for a clinical reason, documented as not given without giving any reason or left blank) was 91.3% (CI 87.6 to 95%). Post-intervention, it was 89.5% (CI 85.5 to 93.5%). The difference of –1.8% is not significant (CI –7.3 to 3.7%).

Administration from unlocked areas

Pre-intervention, we assessed 2188 doses, of which 132 were self-administered by the patient from unlocked areas. A further 47 doses were administered by nursing staff from unlocked areas, giving a total of 179 doses (8.2% of all doses) administered from unlocked areas. Post-intervention, we assessed 1678 doses, of which 36 were self-administered by the patient from unlocked areas. A further four were administered by nurses from unlocked areas, giving a total of 40 doses (2.4%). The difference of –5.8% pre- and post-intervention is statistically significant (CI –7.3 to –4.7%).

Supervision of patients taking oral medication

Pre-intervention, this could be assessed for 1031 doses, for which administration was supervised for only 45 (4.4%). Post-intervention, we assessed 1009 doses, for which administration was supervised for 243 (24.1%). The difference of 20% is statistically significant (CI 17 to 23%).

Discussion

Our previous paper demonstrated a reduction in MAEs and a dramatic improvement in checking of patient identity prior to administration;[19] here we have also demonstrated an improvement in the timeliness of drug administration, a reduction in administration of doses from unlocked areas and an increase in nursing staff supervising patients taking oral doses of medication according to hospital policy. These findings suggest that such electronic systems can have a wide range of benefits.

However, there was no difference in the overall accuracy of documentation, and an increase in potentially significant documentation discrepancies. These generally arose where a drug was not available in the automated cabinet and was therefore recorded as missing at the point of preparation, but then located at the patient's bedside or elsewhere and given during the drug round without subsequently amending the eMAR.

Limitations

There are limitations associated with all before-and-after studies, as other factors may have influenced the results obtained. However, we are not aware of any other significant changes during the study period, and results are consistent with being due to the intervention studied. The study also took place at one point in time on one ward; generalisability to other wards, other hospitals or to different stages of the system's implementation is therefore unknown.

Comparison with previous work

Previous studies suggest either no difference[12] or a reduction[11] in MAEs with automation; however, differences in methods and study designs limit the comparisons that can be made. Other studies have also shown that computerisation can increase new types of error,[25] highlighting the need to evaluate such systems.

A previous UK study has assessed the positive predictive value of paper drug charts for identifying omitted doses; a value of 64% was reported.[26] We identified higher values in the present study.

We identified higher MAE rates at the midday drug round; this phenomenon has been reported in a previous UK study[27] and we suspect is due to more frequent interruptions and distractions during the middle of the day.

Implications and interpretation

This is the first study to explore the effects of an electronic prescribing and administration system on both the quality and safety of medication administration. While the system had many benefits, there was an increase in potentially significant documentation discrepancies. Redesigning the system to allow easier amendment of administration records at the point of administration may improve documentation accuracy.

We identified much higher MAE rates for non-ward-stock drugs when compared with stock drugs; this is mainly due to an

increase in omissions due to unavailability for non-ward-stock drugs, as might be expected. This occurred both pre- and post-intervention. However, there was also a trend towards higher rates for other types of MAE for non-ward-stock drugs, particularly pre-intervention; further studies should explore this in more detail. It may be that MAEs are more likely with drugs with which nursing staff are unfamiliar. Reductions in MAE rates, excluding omissions due to unavailability, occurred for both ward-stock and non-ward-stock drugs. There was little impact on omissions due to unavailability.

The improvement in the timeliness of drug administration is likely to be for two reasons. First, the system audibly prompts when doses are due, making it less likely that doses are inadvertently forgotten and then given late. Second, using the electronic system, nursing staff prepared oral medication and placed it in the electronic trolley in advance; they then took the trolley from patient to patient administering medication. The patient-to-patient drug round was therefore much faster post-intervention,[19] resulting in more doses being given within an hour of the time for which they were prescribed.

The electronic storage system resulted in safer medication storage, with fewer doses being administered from unlocked areas. There is no obvious reason why the system would result in nursing staff observing a higher percentage of oral doses being taken, as per hospital policy. It may be that introducing the new system resulted in an increased focus on policies for medication administration on the study ward.

Conclusion

A system incorporating electronic prescribing, ward-based automated dispensing and eMARs led to an improvement in the timeliness of drug administration, a reduction in administration of doses from unlocked areas and an increase in nursing staff observation of patients taking oral doses of medication. There was no difference in the overall accuracy of documentation, but potentially significant documentation discrepancies increased. Redesigning the system to allow easier amendment of administration records at the point of administration may improve documentation accuracy. Future studies should explore the impact of electronic systems on a wider range of outcome measures than prescribing errors alone.

References

1 Committee on Quality of Health Care in America IoM. To err is human: building a safer health system, 1st edn. Washington DC: National Academy Press; 2000.
2 Kaushal R, Bates DW. Information technology and medication safety: what is the benefit? Qual Saf Health Care 2002;11:261–5.
3 Bates DW. Using information technology to reduce rates of medication errors in hospitals. Br Med J 2000;320:788–91.
4 Overhage JM, Tierney WM, Zhou XH, McDonald CJ. A randomized trial of "corollary orders" to prevent errors of omission. J Am Med Inform Assoc 1997;4:364–75.
5 Bates DW, Leape LL, Cullen DJ et al. Effect of computerized physician order entry and a team intervention on prevention of serious medication errors. JAMA 1998;280:1311–16.
6 Bates DW, Teich JM, Lee J et al. The impact of computerized physician order entry on medication error prevention. J Am Med Inform Assoc 1999;6:313–21.
7 Potts A, Barr FE, Gregory DF, Wright L, Patel NR. Computerized physician order entry and medication errors in a pediatric critical care unit. Pediatrics 2004;113:59–63.
8 Chertow GM, Lee J, Kuperman GJ et al. Guided medication dosing for inpatients with renal insufficiency. JAMA 2001;286:2839–44.
9 Stebbing C, Jacklin A, Barber N, Bates DW. A comparison of the US and UK inpatient medication systems. Eur J Hosp Pharm Pract 2006;12(4):36–40.
10 Brock TP, Franklin BD. Differences in pharmacy terminology and practice between the United Kingdom and the United States. Am J Health-Syst Pharm 2007;64:1541–6.
11 Fowlie F, Bennie M, Jardine G, Bicknell S, Toner D, Caldwell M. Evaluation of an electronic prescribing and administration system in a British Hospital. Pharm J 2000;265:R16.
12 Cavell GF, Hughes DK. Does computerised prescribing improve the accuracy of drug administration? Pharm J 1997;259:782–4.
13 Wilson AL, Hill JJ, Wilson RG, Nipper K, Kwon IW. Computerized medication administration records decrease medication occurrences. Pharm Pract Manage Q 1997;17(1):17–29.
14 Barker KN, McConnell WE. The problems of detecting medication errors in hospitals. Am J Hosp Pharm 1962;19:360–9.
15 Hall KW, Ebbeling P, Brown B, Shwortz I. A retrospective-prospective study of medication errors: basis for an ongoing monitoring program. Can J Hosp Pharm 1985;38:141–3.
16 McNally KM, Sunderland VB. No-blame medication administration error reporting by nursing staff at a teaching hospital in Australia. Int J Pharm Pract 1998;6:67–71.
17 Oren E, Shaffer ER, Guglielmo BJ. Impact of emerging technologies on medication errors and adverse drug events. Am J Health-Syst Pharm 2003;60:1447–58.
18 Ridge KW. Evaluating performance in a hospital medicines supply system. PhD thesis, University of Manchester; 1998.
19 Franklin BD, O'Grady K, Donyai P, Jacklin A, Barber N. The impact of a closed-loop electronic prescribing and administration system on prescribing errors, administration errors and staff time: a before and after study. Qual Saf Health Care 2007;16:279–84.
20 Barber N, Cornford T, Klecun E. Qualitative evaluation of an electronic prescribing and administration system. Qual Saf Health Care 2005;16:271–8.
21 Dean BS, Allan EL, Barber ND, Barker KN. Comparison of medication errors in an American and a British hospital. Am J Health-Syst Pharm 1995;52:2543–9.
22 Gardner MJ, Altman DG. Statistics with confidence – confidence intervals and statistical guidelines. London: BMJ Publications; 1989.
23 Dean B, Barber N. Validity and reliability of observational methods for studying medication administration errors. Am J Health-Syst Pharm 2001;58:54–9.
24 Taxis K, Barber N. Ethnographic study of incidence and severity of intravenous drug errors. Br Med J 2003;326:684–7.
25 Koppel R, Metlay JP, Cohen A. Role of computerized physician order entry systems in facilitating medication errors. JAMA 2005;293:1197–1203.
26 Dean BS, Kanabar PB, Ashby N, Taxis K, Barber N. What can the drug chart tell us about medication administration? Hosp Pharm 1998;5:167–70.
27 Ho CYW, Dean BS, Barber ND. When do medication administration errors happen to hospital inpatients? Int J Pharm Pract 1997;5:91–6.