A retrospective review of medication-related incidents at a major teaching hospital and the potential mitigation of these incidents with electronic prescribing and medicines administration

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Abstract

Objectives: To describe the frequency of the different types of medication-related incidents that caused patient harm, or adverse consequences, in a major teaching hospital and investigate whether the likelihood of these incidents occurring would have been reduced by electronic prescribing and medicines administration (EPMA).

Methods: A retrospective review of harmful incidents (n=387) was completed for medication-related reports at the hospital between 1 September 2020 and 31 August 2021. Frequencies of different types of incidents were collated. The potential for EPMA to have prevented these incidents was assessed by reviewing DATIX reports and additional information, including results of any investigations.

Results: The largest proportion of harmful medication incidents were administration related (n=215, 55.6%), followed by incidents classified as 'other' and 'prescribing'. Most incidents were classified as low harm (n = 321, 83.0%). EPMA could have reduced the likelihood of all incidents which caused harm by 18.6% (n=72) without configuration, and a further 7.5% (n=29) with configuration where configuration refers to adapting the software's functionality without supplier input or development. For 18.4% of the low-harm incidents (n=59) and 20.3% (n=13) of the moderate-harm incidents, EPMA could reduce the likelihood of the incident occurring without configuration. Medication errors most likely to be reduced by EPMA were due to illegibility, multiple drug charts or missing drug charts.

Conclusion: This study found that administration incidents were the most common type of medication-related incidents. Most of the incidents (n = 243, 62.8%) could not be mitigated by EPMA in any circumstance, even with connectivity between technologies. EPMA has the potential to prevent certain types of harmful medication-related incidents, and further improvements could be achieved with configuration and development.

Key Messages

What is already known on this topic:

One intervention shown to reduce medication errors is 'Electronic prescribing and medicines administration' (EPMA) systems.

What this study adds:

This study found that administration incidents were the most common type of medication-related incidents, most of the incidents were classified as low harm. More than half of the incidents could not be mitigated by any EPMA system even with further development, but EPMA could reduce the likelihood of a small number of low-harm and moderate-harm incidents.

How this study might affect research, practice, or policy:

EPMA could lead to a reduction of harmful incidents in hospitals, and further improvements can be achieved with targeted configuration and development. Recommendations provided by this study can be used by hospitals to target their optimisation of EPMA.

Introduction

Medicines are an integral part of healthcare but there is growing evidence of the importance of medicines safety and the need to prevent medication errors to improve patient safety. Medication related adverse events can be the result of people either experiencing adverse drug reactions (not usually preventable) or as a result of medication errors (usually preventable) [1,2]. Medication errors, which are commonly understood as errors throughout the process of prescribing, dispensing, administering or monitoring medicines, irrespective of whether this caused harm to a patient or not [3], occur frequently. Although medication error classification may differ between organisations, the principles of error reduction and clinical risk management still apply to the underlying risks [4].

The data collected by the National Reporting and Learning System in England indicates that medicines cause around 9% of total reported incidents in the NHS [5]. Across England it's estimated that 237 million medication errors occur each year, with 66 million having the potential to be clinically significant [6]. Current literature shows that around half of adverse drug events (ADEs) are preventable in the secondary care setting [7,8]. Given the consequences of ADEs there is a significant need for preventative strategies that systemically target medication errors to improve patient safety and reduce costs.

EPMA can be defined as the use of electronic systems to facilitate the communication of a prescription or medicine order to aid the choice, administration, and supply of a medicine. Electronic prescribing and medicines administration (EPMA) systems can overcome certain drawbacks of paper-based prescribing and has been shown to reduce medication errors. EPMA can eliminate errors due to poor handwriting and illegibility, a particular problem for paper-based prescribing [9] and can also reduce problems due to data loss. EPMA ensures legibility and completeness of a prescription and most systems have in-built clinical decision support functionalities that provide decision support for clinicians with recommended doses, routes and frequencies [10] to decrease the

likelihood of the clinician writing an incorrect prescription. Kwan [11] found that the use of clinical decision support systems increased the percentage of patients received the desired level of care by 5.8%.

At the time of the study, Nottingham University Hospitals (NUH) NHS Trust, a large teaching Hospital in the East Midlands, relied solely on a paper-based system, except for cancer patients receiving care via Chemocare (https://www.cis-healthcare.com/). The Trust acquired funding to implement a next generation EPMA system called Nervecentre (NerveCentre Software, Wokingham, UK) as the first part of a fully integrated electronic patient record. Nervecentre has a range of clinical decision support and safety features including the ability to build dose sentences, automatic interaction and allergy checking, and barcode scanning for positive patient and medication identification (https://nervecentresoftware.com/next-gen-epr-3/epma/).

This study investigated the different types of medication-related incidents at NUH from a non-anonymous incident reporting system (DATIX [12], to 1) describe the frequency of the different types of medication-related incidents that caused patient harm; 2) identify and classify whether the likelihood of these incidents occurring, and associated risk could have been reduced by EPMA, including clinical decision support. This research is important because it identifies a novel way of determining what impact the EPMA system could have on existing safety issues at the point of system selection and identifies significant areas or themes relating to medication safety that cannot be solely addressed by the implementation of an EPMA system.

Methods

Study Design

The study was a retrospective review of 3988 medication-related reports recorded by healthcare professionals at Nottingham University Hospitals NHS Trust through the

DATIX incident-reporting system. This reporting system provided the framework for classifying incidents in line with the requirements of the English National Reporting and Learning System (NRLS) [13]. The reports represent the records of inpatients at the hospital between 1st September 2020 and 31st August 2021. The study was approved by the Clinical Effectiveness Department at the Trust and ethical committee approval was not required.

Data Sources/Measurement

Data from DATIX included only medication-related incidents that were submitted and classified by the reporter as medication related. Repeat entries were excluded and data were anonymised. The incidents were classified into categories by the healthcare professional that reported the incident. The DATIX categories refer to the stage in the medication process where the incident occurred; these categories included: Administration, Discharge, Pharmacy, Prescribing and there is also a category for Other incidents. The incidents were then further categorised into more specific subcategories (see Supplementary File 1).

The data extracted from each DATIX entry included the degree of harm to the patient, and category and subcategory of the type of incident. The degree of harm was selected by the healthcare professional reporting the incident and (except for no-harm incidents) was confirmed or updated by a second person (an incident investigator within the Trust). Staff are expected to assess harm in accordance with the incident reporting policy at the Trust [14]. The policy defines each degree of harm and gives a non-exhaustive list of examples.

The levels of harm were:

1. None: any unexpected or unintended event that resulted in no harm and no additional treatment being required.
2. Low: any unexpected or unintended event that required extra observation or minor treatment and caused minimal harm.

3. Moderate: any unexpected or unintended event that required further additional treatment or an intervention of some kind and caused temporary or short-term harm.
4. Severe: any unexpected or unintended event that caused permanent or long-term harm.
5. Catastrophic (Death): any unexpected or unintended event that may have caused death.

Selection of Records

Prior to the in-depth review of the data, any medication-related incidents identified in the outpatient setting were excluded, as shown in Figure 1. From this point, all incidents that were rated as no harm (3269) were removed from the review so only incidents with a harm rating of low, moderate, severe, or catastrophic were reviewed (see Figure 2). During the in-depth review, further exclusions were applied, as shown in Figure 2.

Insert Figure 1

Insert Figure 2

Some DATIX reports involved more than one incident per report. This brought the total number of incidents to 387. This was the total number of incidents reviewed in-depth.

Method for Assessing the Potential for EPMA to have Prevented Incidents

MC and KH (trained in the process of reviewing incident reports) reviewed each report by reading the original entry and any additional information, including results of any investigations. They assessed to what extent EPMA (Nervecentre) could have reduced the likelihood of each incident using the mutually exclusive outcomes shown below. The classification of these outcomes took account of whether:

A. EPMA (Nervecentre) would reduce the likelihood of this incident occurring without configuration.

B. EPMA (Nervecentre) could reduce the likelihood of this incident occurring with some configuration.

C. EPMA could reduce the likelihood of this incident occurring with development.

D. EPMA could not reduce the likelihood of this incident occurring in any circumstances.

Any uncertainties or disagreements on outcome classification were brought to the team for discussion. Incidents that were classified as being avoidable with the use of the EPMA system (those classified as 1 or 2 above) were further run through EPMA test scripts to determine whether the medication error scenarios were correctly categorised and triggered an intervention by the EPMA system. The most common themes tested were barcode scanning, duplicated administration, and drug-drug interaction. For example, barcode scanning involved using an iPad or phone to scan codes for both the patient and the drug before being able to administer it. Alerts were displayed if the incorrect patient or drug was scanned, which would reduce the likelihood of incidents involving the wrong patient and/or drug at administration.

Data Processing and Analysis

The reports on the DATIX system between 01/09/2020 and 31/08/2021 were downloaded and stored in a Microsoft Excel spreadsheet, including the categorisation of incidents. All reports available within the period were used (no missing data), however, not all reports fitted the scope of the review (see figure 1 and 2). Each incident was reviewed by reading all the information provided on the report and the potential impact of EPMA was recorded on a Microsoft Excel Spreadsheet using the 4-point classification system shown above. Microsoft Excel was also used to process the data and analyse the results. Pivot tables were used to generate frequencies for each category and subcategory and to obtain the frequencies of associated harm with each category. Pivot tables were also used to obtain EPMA outcomes in relation to the category and degree of harm. Descriptive statistics were determined and are reported.

Results

Of the 387 incidents reviewed, over half (55.6%, 215 incidents) were administration related. Within this category, the largest subcategory (17.3%, 67 incidents) was 'non-administration / dose omitted or significantly delayed', which was often due to poor communication, human error (e.g., forgetting to give drug), distractions and low staff numbers. Incidents classified as 'Other' accounted for 26.4% (102 incidents) of the total number of incidents. New adverse drug reaction contributed the most to this category with 44 incidents (43.1%) The frequency of incidents within each category and sub-category are shown in Table 1.

Most incidents reviewed were classified as low harm (83%, 321 incidents), with the remaining classified as moderate harm (16.5%, 64 incidents) apart from two incidents (one severe and one catastrophic). In relation to administration incidents, 89.8% (n=193) were low harm and 10.2% (n=22) were moderate harm. The category 'Other' consisted of all four categories of harm: 65.7% low harm (67 incidents), 32.4% moderate harm (33 incidents), 1.0% severe harm (1 incident) and 1.0% catastrophic harm (1 incident). Table 2 shows incidents by level of harm.

Table 1: Frequency of Incidents Within Each Category and Subcategory

Subcategory of Incidents	Number of Incidents	Percentage (%) of total number of Incidents
Administration - drug incompatibility	3	0.8
Administration - incorrect day or time	14	3.6
Administration - incorrect dose	32	8.3
Administration - incorrect drug	16	4.1
Administration - incorrect frequency	20	5.2
Administration - incorrect rate	10	2.6
Administration - incorrect route	11	2.8
Administration - non-administration / dose omitted or significantly delayed	67	17.3
Administration - self-administration error	6	1.6

Administration - extravasation	36	9.3
SUBTOTAL ADMINISTRATION INCIDENTS	215	55.6
Discharge - delay in Pharmacy processing of TTO	4	1.0
Discharge - delay in prescribing of TTO	2	0.5
Discharge - patient discharged with incomplete set of medication or no medication	8	2.1
SUBTOTAL DISCHARGE INCIDENTS	14	3.6
Other - clinical trial error (prescribing, dispensing, administration, protocol violation)	4	1.0
Other - contraindication to the use of the medicine	16	4.1
Other - discrepancy in medication documentation records (CDs, drug chart, etc.)	4	1.0
Other - drug wastage (financial loss)	6	1.6
Other - faulty medicinal product	2	0.5
Other - incorrect injectable drug preparation: prescribing, administration, manufacturing (incorrect concentration/diluent, incorrect volume, incorrect drug /dose, incorrect label/ details missing on label)	4	1.0
Other - incorrect monitoring / failure to monitor therapeutic levels	7	1.8
Other - mismatching between patient and medicine (misidentification)	2	0.5
Other - missing medication or drug chart	5	1.3
Other - new adverse drug reaction / unexpected response / oversensitivity to drug	44	11.4
Other - patient with known allergy prescribed or administered a drug they are allergic to	4	1
Other - storage or transportation issues	2	0.5
Other - wrong expiry / omitted expiry / passed expiry date	2	0.5
SUBTOTAL OTHER INCIDENTS	102	26.4

Pharmacy - clinical pharmacist screening error	2	2.6
Pharmacy - incorrect directions on label	1	0.3
Pharmacy - incorrect information or pharmacy advice (endorsement on chart, verbal or written information)	1	0.3
Pharmacy - significant delay in supply or failure to supply (not TTOs)	1	0.3
Pharmacy - transcription error	1	0.3
Pharmacy - Unavailable Medication Stock	4	1.0
SUBTOTAL PHARMACY INCIDENTS	10	2.6
Prescribing - failure to prescribe a planned prescription	10	2.6
Prescribing - incorrect day or time	3	0.8
Prescribing - incorrect dose	19	4.9
Prescribing - incorrect drug	10	2.6
Prescribing - incorrect frequency	3	0.8
Prescribing - incorrect rate	1	0.3
SUBTOTAL PRESCRIBING INCIDENTS	46	11.9
GRAND TOTAL	387	100

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Table 2: Frequency and Type of Reported Incidents Associated With Harm

Category of Type of Incident	Level of Harm associated with Incident (row % of each category)				Total (column % of total incidents in category)
	Low	Moderate	Severe	Catastrophic	
Administration	193 (89.8)	22 (10.2)	0	0	215 (55.6)
Discharge	14 (100)	0	0	0	14 (3.6)
Other	67 (65.7)	33 (32.4)	1 (1.0)	1 (1.0)	102 (26.4)
Pharmacy	8 (80.0)	2 (20.0)	0	0	10 (2.6)
Prescribing	39 (84.8)	7 (15.2)	0	0	46 (11.9)
Total (% of total incidents)	321 (83.0)	64 (16.5)	1 (0.3)	1 (0.3)	387 (100)

Of the 33 incidents in the 'Other' category that were of moderate harm, 24 (72.7%) were due to a new adverse drug reaction, unexpected response to a drug or oversensitivity to a drug. Most of these incidents relate to opioid sensitivity.

In 18.6% (n = 72) of all incidents, the likelihood of the incident occurring could have been reduced by EPMA without configuration, 18.1% (13 incidents) of these were in the moderate harm category with none in the severe or catastrophic category. Nearly two thirds (65.3%, n = 47) of the incidents that would have been reduced by EPMA without configuration were in the category 'administration', which included drug-drug interaction and duplicate administration. A further 7.5% (n = 29) of the incidents could have been reduced by EPMA with configuration, 20.1% (6 incidents) of these were in the moderate or severe harm categories (5 moderate harm incidents and 1 severe harm incident). The vast majority of these incidents (79.3%, n = 23) were administration and prescribing, most of these were due to an incorrect dose. In 11.1% (n = 43) of all incidents, the likelihood of the incident occurring could have been reduced by an EPMA system with further development, 9.3% (4 incidents) of these incidents were in the moderate harm

category, with none in the severe or catastrophic category. Nearly 50% (21 out of 43) were administration related, mostly within the subcategories of incorrect dose, frequency and non-administration. Development needed to prevent the incorrect dosing was mostly linking the system with infusions (including guard rails) and integration with laboratory data. Half (10 out of the 21) of the administration incidents were neonatal related, with 8 of these involving gentamicin dosing (within incorrect frequency, dose or day or time subcategories).

Our study suggests that EPMA would not be able to reduce the likelihood of the incident in 62.8% (n = 243) of all incidents where harm was identified (see Table 3), 53.9% (n =131) of these incidents were classed as 'Administration' and 29.6% (n = 72) were 'Other'. Just over half (60.9%, 131 out of 215) of the administration incidents could not have been prevented by EPMA under any circumstance. Most of these incidents were due to lack of communication, distractions, or shortage in staff – where EPMA has no impact. For prescribing incidents, 45.7% (21 out of 46) could not have been prevented by EPMA with many falling in the 'failure to prescribe' and 'incorrect dose' categories, where the latter is not always preventable by EPMA systems that do not have clinical decision support capabilities. For the vast majority of 'Other' incidents (70.6%, 72 out of 102), EPMA could not have reduced the likelihood of the incident occurring, with all incidents classified as new adverse drug reaction having this outcome.

Table 3 shows that in about 20% of incidents associated with low harm (18.4%, n = 59) and moderate harm (20.3%, n = 13), EPMA could have reduced the likelihood of the incident occurring without configuration. In contrast, 62.3% (n = 200) of low harm incidents and 65.6% (n = 42) of moderate harm could not have been prevented with EPMA.

Table 3: Degree of Harm and associated EPMA Outcome

Degree of Harm of Incidents	EPMA Outcome* (row % per degree of harm)				Grand Total (column % of total)
	A	B	C	D	
Low	59 (18.4)	23 (7.2)	39 (12.2)	200 (62.3)	321 (83.0)
Moderate	13 (20.3)	5 (7.8)	4 (6.3)	42 (65.6)	64 (16.5)
Severe	0	1 (100)	0	0	1 (0.3)
Catastrophic	0	0	0	1 (100)	1 (0.3)
Grand Total (% of total)	72 (18.6)	29 (7.5)	43 (11.1)	243 (62.8)	387 (100)

* Outcomes:

A. EPMA (Nervecentre) would reduce the likelihood of this incident occurring without configuration.
B. EPMA (Nervecentre) could reduce the likelihood of this incident occurring with some configuration.
C. EPMA could reduce the likelihood of this incident occurring with development.
D. EPMA could not reduce the likelihood of this incident occurring in any circumstances.

Discussion

Summary of Findings

This study found that administration incidents were the most common type of medication-related incidents that caused patient harm (n = 179, 46.3%). Most of the incidents that caused patient harm were classified as low harm (n = 321, 83.0%) with 64 (16.5%) classified as moderate harm. In 18.6% of all harmful incidents (n=72), the likelihood of the incident occurring could have been reduced by EPMA without additional configuration, and a further 7.5% (n=29) of incidents would have been reduced with configuration. Most of the incidents (62.8%, n =243) could not be mitigated by EPMA in any circumstance, even with integration with other technologies. For 18.4% of the low-harm incidents (n=59) and 20.3% (n=13) of the moderate-harm incidents, EPMA could reduce the likelihood of the incident occurring without configuration. Most of the low-harm (n=200, 62.3%) and moderate-harm (n = 42, 65.6%) incidents could not be reduced under any circumstance, which provides scope for further development of EPMA systems.

Strengths and Limitations

Reporting systems in hospitals, such as DATIX, will inevitably involve underreporting given that reporting is voluntary and time consuming, which means that reporting bias is

a limitation of our study. Therefore, the DATIX reports in this study may not be fully representative of all incidents occurring. We analysed reported incidents, which means that incidents that could not have been prevented by any EPMA system, such as new adverse drug reactions, were included in our analysis, and is a limitation of our study. This study reviewed only harmful incidents, thus focusing on what might be regarded as the most important incidents, but potentially missing out on learning from no-harm incidents that had the potential to cause harm.

It was noted that DATIX reports often varied in detail and sometimes this meant it was down to the reviewer's interpretation to decide where in the medication process the error occurred when assessing the potential impact of EPMA. To overcome this problem, any uncertain or ambiguous reports were taken to the wider team to discuss; in some cases, reports were excluded due to insufficient detail (see Figure 2).

Nervecentre was used as the EPMA system for this study. Other systems implemented in different hospitals may offer different benefits and liabilities, but the experience of our team suggests that our assessments are applicable to other EPMA systems used in the NHS.

The classification system we use for medication incidents was based on the DATIX reporting system which is commonly used in the UK. We acknowledge that this makes it difficult to make comparisons with international studies of incident reporting, although the World Health Organisation recognises that there are several different systems for classifying patient safety incidents and the data from them are not directly comparable [15]. Also, we note that the main purpose of the study was to assess the preventability of incidents by EPMA, and here we have been able to make some comparisons with the international literature.

Comparison with Existing Literature

The findings show that administration incidents are the most common type of patient harm incidents reported at the Trust. Although this is consistent with current national estimates [6], the national figures show that administration incidents contribute an even higher proportion of total incidents. The reduction of incidents by EPMA shown in this study is supported by studies that have looked at error rates before and after EPMA implementation, which found that error rates were reduced [16-20]. For example, Franklin [20] found that the introduction of an electronic prescribing system reduced the percentage of prescribing errors by 47%.

Gates [21] concluded that although electronic systems significantly reduced prescribing errors, he found no significant effect of electronic prescribing systems on patient harm. Westbrook [22] also found that an electronic medication management system reduced prescribing error rates, but there was no evidence of a reduction in harm. In contrast, our research found that 37.8% of low harm incidents (n=121) and 34.4% of moderate harm incidents (n=22) could be reduced by EPMA, on its own, with configuration or with development, which agrees with Holdsworth [23] who found that EPMA reduced medication errors that caused harm.

Implications for secondary care

This study has identified the potential impact of EPMA on medication-related harm in one NHS Trust, but the findings are likely to be relevant to secondary care in the UK and beyond. It is important to recognise that while certain types of incidents can be prevented by EPMA, others are less amenable to electronic solutions. This includes incidents where the predominant causes are communication failures, distractions, inadequate staff numbers, and failures such as drug extravasation; strategies in addition to EPMA are needed to address these types of incidents. In a survey of chief pharmacists in NHS Trusts, Shemilt [24] found that although electronic prescribing systems enforced

policies through the use of mandatory fields, staff would sometimes bypass these fields in order to expedite workflow.

In addition, it is important for healthcare providers to be aware that there can be unintended adverse consequences from EPMA [25,26], although the benefits generally outweigh the risks. Negative consequences can include an increase in clinician workload and changes in clinical workflow [25]. Discrepancies between the structured and free-text portions of the electronic record can lead to adverse drug events [26]. Understanding the adverse consequences of EPMA will enable developers to improve their systems.

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Author Contributions

TA, TH, TD, AK and BI designed the study. MC and KH conducted and analysed the study with support from all the other authors. MC and KH wrote the work up and BB wrote the first draft of the publication. All authors reviewed and commented on the draft publication and BB edited the final manuscript.

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Competing Interests

The authors report no competing interests.

Ethical Approval

The study was approved by the Clinical Effectiveness Department at the Nottingham University Hospital NHS Trust; ethical committee approval was not required.

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Figure 1: Flowchart showing the number of incidents identified in the outpatient setting and excluded before the in-depth review of incidents

Figure 2: Flowchart showing the change in number of incidents during the in-depth review.