Computerized order entry, clinical decision support, and safer prescribing

Pontefract, Sarah; Ferner, Robin

DOI:

[10.1097/FAD.0000000000000026](https://doi.org/10.1097/FAD.0000000000000026)

License:

Other (please specify with Rights Statement)

Document Version

Peer reviewed version

Citation for published version (Harvard):

Pontefract, S & Ferner, R 2017, 'Computerized order entry, clinical decision support, and safer prescribing', *Adverse Drug Reaction Bulletin*, vol. 305, no. 1, pp. 1179–1182.
<https://doi.org/10.1097/FAD.0000000000000026>

[Link to publication on Research at Birmingham portal](#)

Publisher Rights Statement:

This document is not the Publisher's version of record, it is the author accepted manuscript.

Computerized order entry, clinical decision support, and safer prescribing. Pontefract, S.K.; Ferner, R.E. *Adverse Drug Reaction Bulletin*: August 2017 - Volume 305 - Issue 1 - p 1179–1182
doi: 10.1097/FAD.0000000000000026

General rights

Unless a licence is specified above, all rights (including copyright and moral rights) in this document are retained by the authors and/or the copyright holders. The express permission of the copyright holder must be obtained for any use of this material other than for purposes permitted by law.

- Users may freely distribute the URL that is used to identify this publication.
- Users may download and/or print one copy of the publication from the University of Birmingham research portal for the purpose of private study or non-commercial research.
- User may use extracts from the document in line with the concept of 'fair dealing' under the Copyright, Designs and Patents Act 1988 (?)
- Users may not further distribute the material nor use it for the purposes of commercial gain.

Where a licence is displayed above, please note the terms and conditions of the licence govern your use of this document.

When citing, please reference the published version.

Take down policy

While the University of Birmingham exercises care and attention in making items available there are rare occasions when an item has been uploaded in error or has been deemed to be commercially or otherwise sensitive.

If you believe that this is the case for this document, please contact UBIRA@lists.bham.ac.uk providing details and we will remove access to the work immediately and investigate.

Computerized order entry, clinical decision support, and safer prescribing

S K Pontefract¹

R E Ferner^{1,2}

¹Institute of Clinical Sciences, College of Medical and Dental Sciences, University of Birmingham, Birmingham, B15 2TT, UK

²West Midlands Centre for Adverse Drug Reactions, City Hospital, Birmingham, B18 7QH, UK
s.k.pontefract@bham.ac.uk

Summary

Unintended harms from medicines caused by adverse drug reactions and medication errors are common. The medication process is very complex, and error can occur in the development, manufacture, distribution, prescribing, dispensing, administration, and monitoring of medicines. The prescriber, to avoid error, must first make careful decisions tailored to account for numerous factors that differ from patient to patient, then communicate orders that others must execute meticulously and whose consequences must be adequately monitored.

Introduction

Drug treatment for an individual should be as safe, effective, and cost-effective as possible. Rational therapeutics seeks to achieve an acceptable balance between maximal efficacy and maximal safety, and has sometimes been referred to as ‘balanced prescribing.’¹

The numerous factors that inform prescribing decisions, and the complexities of dispensing and administering the correct medicine in the correct way, place high technical and cognitive demands on those involved in the medication process. This inevitably makes the process error-prone.² A medication error is ‘*a[n unintentional] failure in the treatment process that leads to, or has the potential to lead to, harm to the patient,*’ where failure means that the treatment does not reach some attainable standard, and the treatment process runs from the prescribing decision onwards.^{3 4}

The burden of medication errors

The burden of medication errors is substantial, but neither the number of errors nor the number of opportunities for error is easily ascertained. It is even more difficult to know whether detected errors are important, since their consequences or potential consequences can differ from insignificant to fatal.⁵ A systematic review of computer-assisted prescribing in hospital included 16 articles.⁶ One early study observed errors during 4.9% of in-patient episodes,⁷ while studies in the Netherlands and Australia reported baseline error rates exceeding 99%.^{8 9} The Institute of Medicine in the US estimated rates of prescribing errors from 12.3 to 1400 per 1000 admissions, and of administration errors from 2.4 to 11.1 per 100 opportunities or doses; these wide ranges underline the uncertainties.¹⁰

The complexity of the medication process

The risks of human error are increased when tasks are complex or unfamiliar, and when their effects cannot immediately be appreciated. There are many opportunities for error in the medication process—one consensus analysis found 60 different types.¹¹ The analysis omitted errors in monitoring therapy, which contribute to serious harm in the use of gentamicin, for example.

The simplest prescribing decisions involve a consideration of the indication, that is, the reason for treatment; contra-indications, which are reasons why a medicine must not be given; warnings of precautions to be taken and risks to consider in the context of the

individual; special considerations such as the co-existence of more than one condition, concomitant treatments, or the prior experience and preference of the individual; the relevant form, dosage, route of administration, and duration of treatment; and the circumstances in which monitoring or stopping treatment are required. Around twenty pieces of information are needed to write (or generate) a single prescription on a routine hospital prescription chart to identify the prescriber, recipient (patient), medicine, and conditions of use. Information about the patient and their medication can be provided directly from the patient or their carers, in addition to hospital and general practice records and possibly the community pharmacist. However, the information is commonly incomplete, out-of-date, difficult to interpret, or inaccessible out of hours.

Computers and prescribing

Inevitably, hand-written prescription charts can be difficult to read, incomplete, and error-prone. The practice of using computers to type prescriptions (medication orders) in general practice was described in the 1980s, when computers for use by doctors were ‘still in their infancy despite their enormous potential.’¹² Computerized Physician Order Entry (CPOE) is now the norm in UK general practice, with the advantages that prescriptions are legible, essential information is present on all prescriptions, and general practitioners have comprehensive records of medicines prescribed. CPOE in hospitals is less common, but is rapidly increasing, encouraged by financial incentives from the NHS to drive the digitisation of care records.

Effects of CPOE

A US study estimated that CPOE reduced medication errors overall by about 50%; but the estimate of the number of medication errors prevented nationally ranged from 90 000 to 27.1 million per year.¹³ Rates have also been shown to fall in specialist settings such as critical care, with one study reporting a fall in error rate from 6.7% to 4.8% of prescriptions when CPOE without decision support replaced written prescriptions.¹⁴ However, dosage errors were found to increase. A potentially fatal intercepted error occurred when diamorphine was prescribed electronically using the pull-down menus at a dose of 7 mg/kg instead of 7 mg total, which could have led to a 70-fold overdose.

A study that examined errors specific to computerized prescribing in paediatrics identified one error per 100 patient-days that was specifically related to design features of the system

used.¹⁵ Seven of 20 identified errors were serious. These included duplicate prescriptions for paracetamol, a selection error leading to prescription of intraperitoneal rather than intravenous ceftriaxone, and a keypad error in which a dose was typed as 5 mg rather than 50 mg. The same research group, using interrupted time series analysis to examine errors before and after the introduction of a CPOE system, detected 70 non-intercepted serious medication errors during the periods of observation.¹⁶ CPOE reduced the rate by just 7%, and the rate of dosing errors, the most common form of paediatric medication error, did not fall, even though the system included automated weight-based dosage checking designed to prevent dosing errors.

Westbrook *et al* (2012) demonstrated that rates of ‘procedural’ errors—errors where prescriptions were incomplete, unclear, or non-compliant with the law or local regulations, fell from 8% to 0.5% of hospital admissions after the introduction of commercial prescribing systems.¹⁷ Their study, which did not explicitly state whether the systems incorporated decision support, found no overall reduction in ‘clinical’ errors, that is, errors in which correctly written prescriptions specified or omitted medicines in error, or where there was an error in the formulation, strength, dose, route, or other characteristic of the drug, or where a specified medicine interacted with or duplicated the actions of another. They did, however, record a statistically significant fall in the proportion of serious errors.

A review of 34 studies of errors with CPOE distilled the principal sources of error: poor computer display; uncritical acceptance of ‘help’ in the form of drop-down menus and auto-population of fields; poorly comprehensible wording; default settings that were not always appropriate; inflexible prescribing rules; ‘automatic’ functions, such as repeat prescribing; and incompatibility with the users’ work pattern.¹⁸ It is perhaps not surprising then a series of attributes of CPOE, including the way of ‘searching for the desired drug,’ how medications were displayed or described, and methods of ‘composing or entering the drug regimen’, have been described.¹⁹

Selection errors

There are advantages in presenting a drug dictionary of locally available medicines so that the first few letters of a drug name bring up a list of candidate preparations. However, the wrong drug formulation can be selected through technical error (clicking when the computer mouse is pointing to the wrong line) or misreading, or failure to read all available information. For

example, a patient came to harm when penicillamine 250 mg four times daily was prescribed in error for penicillin V 250 mg four times daily.²⁰

Clinical decisions support (CDS)

Instructions on the use of medicines can be complex.²¹ More generally, prescribers need information on the drug prescribed, its indications, contra-indications, dosing ('posology'), and potential interactions at the point of prescribing. CDS can provide warnings or alerts at the point of prescribing, which may be advisory, require action by the prescriber, or prevent the prescriber from proceeding altogether.^{22 23}

Systems can provide complex decision support, demonstrated by a detailed taxonomy of CDS tools developed to assess the capabilities systems to include: (1) medication dosing support (for example, maximum single dose checking...); (2) 'order facilitators,' that is, for example, complete prescription sentences or sets of prescriptions (order sets), where two or more drugs are commonly co-prescribed; (3) alerts and reminders, for example of possible drug–drug interactions; and provision of relevant information, such as patient test results; (4) expert systems that offer support, for example, in antibiotic choice; and (5) workflow support, such as structured discharge summaries.²⁴ Bates *et al* have set out the 'Ten Commandments for effective CDS.'²⁵ The first of these is that speed of interaction with the computer system is essential: a screen should change in less than one second. Also important is the ability to help at the point help is needed, rather than forcing the user to search for assistance.

The four CDS systems that account for about three-quarters of all systems used in UK general practices were tested against 18 medication safety scenarios, such as the inadvertent prescription of methotrexate tablets daily.²⁶ At the time of the study, no system displayed alerts for more than 7 of 18 scenarios. This justifies the assertion that computer-aided prescribing 'leaves holes in the safety net.'²⁷ A study of consultations in general practice found that of 117 alerts triggered by 81 prescriptions, only three were examined by the prescriber, and in no case was the prescription altered.²⁸ The authors characterized this CDS as 'too much, too late.'

Alerts

'Alert fatigue,' the tendency to ignore alerts, whether or not they are clinically relevant, is a danger if too many alerts are presented.²⁹ Some of the difficulties may be overcome by

grading alerts, so that interruptive alerts, which require action by the prescriber, are only triggered in clinically critical (high-risk) circumstances.^{30 31} A controlled study found that 100% of the most severe alerts were acted on at a site where interactions were graded, while only 34% were acted on at the comparator site where they were not.³²

Repeated assessment of the frequency with which alerts are triggered and prescribers' responses to these (i.e. accepted, overridden) may help identify whether the alerts are clinically useful.³³ In a simulation study, 20 prescribers compared a system before and after re-design. The average time to resolve alerts fell from 85 seconds to 56 seconds, and the number of prescribing errors from 4 to 2.³⁴

A study of over 50 000 drug–drug interaction alerts in CDS systems graded both the knowledge quality (inappropriate, potentially inappropriate, appropriate) and the display characteristics, textual information, and prioritization (poor, moderate, or excellent) and examined users' responses.³⁵ In two sites, override rates exceeded 80%, while in the third site, the rate was 53%. Alert acceptance was largely determined by the way in which the alert was displayed; neither the quality of the knowledge, nor the text of the message, significantly affected acceptance rates.

Effectiveness

A Cochrane review found evidence that in randomized controlled trials, computerized advice on drug dosage effectively increased the proportion of patients with plasma aminoglycoside concentrations within the therapeutic range, and in addition reduced the risk of nephrotoxicity.³⁶ The reviewers reported that such systems may also improve anticoagulation, but are not demonstrated to benefit the control of insulin, anaesthetic agents, anti-rejection drugs, or antidepressants.

An umbrella review of the benefits of adding CDS software to CPOE systems, commissioned by the US Agency for Healthcare Research and Quality, concluded that 'CPOE and CDS does not appear to reliably prevent clinical [adverse drug events] ... it remains a work in progress.'³⁷ Alert fatigue was identified as a major problem. The reviewers noted that where systems had reduced errors, they had used CDS systems with patient-specific alerts. A retrospective analysis of 811 prescribing errors that caused harm in Pennsylvania judged that

over one-fifth (21.5%, n = 174) of the serious prescribing errors were likely to have been ‘intercepted and therefore possibly preventable if CPOE with CDS were used.’³⁸

A final consideration, often overlooked, is that computer systems are not 100% reliable or secure,^{39 40} One case series of malfunctions in CDS systems included failure to trigger an alert to amiodarone when the internal code-number for amiodarone was changed; having found this error by chance, the investigators examined patterns of alerting, and detected three further malfunctions related to automatic alerts.⁴¹

Conclusions

Systematic studies of CPOE and CDS sufficiently large to demonstrate changes in rare events have not been yet conducted. Their benefits are offset by subtle, but sometimes important, unintended consequences. Although they are widely and increasingly used, and have clear advantages in ensuring legible and complete prescriptions, and a reduction in error rates, they have not yet generally been proven to reduce serious patient harm.

References

- ¹ Aronson JK. Balanced prescribing. *Brit J Clin Pharmacol* 2006; 62: 629-632.
- ² McDowell SE, Ferner HS, Ferner RE. The pathophysiology of medication errors: how and where they arise. *Br J Clin Pharmacol* 2009; 67(6): 605-13
- ³ Ferner RE, Aronson JK. Medication errors, worse than a crime. *Lancet* 2000; 355(9208): 947-8
- ⁴ European Medicines Agency. Medication Errors. Accessed at http://www.ema.europa.eu/ema/index.jsp?curl=pages/special_topics/general/general_content_000570.jsp
- ⁵ Garfield S, Reynolds M, Dermont L, Franklin BD. Measuring the severity of prescribing errors: a systematic review. *Drug Saf* 2013; 36(12): 1151-1157
- ⁶ Nuckols TK, Smith-Spangler C, Morton SC, et al. The effectiveness of computerized order entry at reducing preventable adverse drug events and medication errors in hospital settings: a systematic review and meta-analysis. *Systematic Reviews* 2014, 3:56
- ⁷ Bates DW, Leape LL, Cullen DJ, Laird N, Petersen LA, Teich JM, Burdick E, Hickey M, Kleefield S, Shea B, Vander Vliet M, Seger DL: Effect of computerized physician order entry and a team intervention on prevention of serious medication errors. *JAMA* 1998; 280(15): 1311–1316
- ⁸ van Doormaal JE, van den Bemt PMLA, Zaal RJ, Egberts ACG, Lenderink BW, Kosterink JGW, Haaijer-Ruskamp FM, Mol PGM: The influence that electronic prescribing has on medication errors and preventable adverse drug events: an interrupted time-series study. *J Am Med Inform Assoc* 2009; 16(6): 816–825
- ⁹ Westbrook J, Reckmann M, Li L, Runciman W, Burke R, Lo C, Baysari M, Braithwaite J, Day R: Effects of two commercial electronic prescribing systems on prescribing error rates in hospital in-patients: a before and after study. *PLoS Med* 2012;9(1): e1001164
- ¹⁰ Aspden P, Wolcott J, Bootman L, Cronewell LR, Eds. Preventing Medication Errors: quality chasm series. The National Academies Press. Washington DC, 2007
- ¹¹ Lisby M, Nielsen L, Brock B, Mainz J. How should medication errors be defined? Development and test of a definition. *Scandinavian Journal of Public Health*. 2012; 40(2): 203-210.
- ¹² Preece JF, Ashford JR, Hunt RG. Writing all prescriptions by computer. *J R Coll Gen Pract* 1984; 34(269): 655-7
- ¹³ Radley DC, Wasserman MR, Olsho LE, Shoemaker SJ, Spranca MD, Bradshaw B. Reduction in medication errors in hospitals due to adoption of computerized provider order entry systems. *J Am Med Inform Assoc* 2013 May 1;20(3):470-6
- ¹⁴ Shulman R, Singer M, Goldstone J, Bellingan G. Medication errors: a prospective cohort study of hand-written and computerised physician order entry in the intensive care unit. *Crit Care* 2005; 9(5): R516-21
- ¹⁵ Walsh KE, Adams WG, Bauchner H, Vinci RJ, Chessare JB, Cooper MR, Hebert PM, Schainker EG, Landrigan CP. Medication errors related to computerized order entry for children. *Pediatrics* 2006; 118(5): 1872-9
- ¹⁶ Sard BE, Walsh KE, Doros G, Hannon M, Moschetti W, Bauchner H. Retrospective evaluation of a computerized physician order entry adaptation to prevent prescribing errors in a pediatric emergency department. *Pediatrics* 2008; 122(4): 782-7
- ¹⁷ Westbrook JI, Reckmann M, Li L, Runciman WB, Burke R, Lo C, Baysari MT, Braithwaite J, Day RO. Effects of two commercial electronic prescribing systems on prescribing error rates in hospital in-patients: a before and after study. *PLoS Med*. 2012 Jan;9(1):e1001164

-
- ¹⁸ Brown CL, Mulcaster HL, Triffitt KL, Sittig DF, Ash JS, Reygate K, Husband AK, Bates DW, Slight SP. A systematic review of the types and causes of prescribing errors generated from using computerized provider order entry systems in primary and secondary care. *J Am Med Inform Assoc* 2017; 24(2): 432-440
- ¹⁹ Brigham and Women's Hospital, Harvard Medical School, and Partners Healthcare. Computerized Prescriber Order Entry Medication Safety (CPOEMS) Uncovering and Learning from Issues and Errors. Silver Springs, MD: US Food and Drug Administration. 2015. Accessed at <https://psnet.ahrq.gov/resources/resource/29442/computerized-prescriber-order-entry-medication-safety-cpoems-uncovering-and-learning-from-issues-and-errors>
- ²⁰ Ferner RE. More errors in prescribing and giving medicines. *J Med Defence Union*. 1995; 11 230-82.
- ²¹ Anonymous. Summary of Product Characteristics for Digoxin Tablets BP. Bristol Laboratories Ltd. 2014.
- ²² Eberhardt J, Bilchik A, Stojadinovic A. Clinical decision support systems: potential with pitfalls. *J Surg Oncol* 2012; 105(5): 502-510
- ²³ Beeler PE, Bates D W, Hug BL Clinical decision support systems. *Swiss Med Wkly* 2014; 144: w14073.
- ²⁴ Wright A, Sittig DF, Ash JS, et al. Development and evaluation of a comprehensive clinical decision support taxonomy: comparison of front-end tools in commercial and internally developed electronic health record systems. *Journal of the American Medical Informatics Association: JAMIA*. 2011;18(3):232-42
- ²⁵ Bates DW, Kuperman GJ, Wang S, Gandhi T, Kittler A, Volk L, Spurr C, Khorasani R, Tanasijevic M, Middleton B. Ten commandments for effective clinical decision support: making the practice of evidence-based medicine a reality. *J Am Med Inform Assoc* 2003; 6: 523-530. doi: 10.1197/jamia.M1370.
- ²⁶ Fernando B, Savelyich BS, Avery AJ, Sheikh A, Bainbridge M, Horsfield P, Teasdale S. Prescribing safety features of general practice computer systems: evaluation using simulated test cases. *BMJ* 2004; 328(7449): 1171-2
- ²⁷ Ferner RE. Commentary: Computer aided prescribing leaves holes in the safety net. *BMJ* 2004; 328: 1172
- ²⁸ Hayward J, Thomson F, Milne H, Buckingham S, Sheikh A, Fernando B, Cresswell K, Williams R, Pinnock H. 'Too much, too late': mixed methods multi-channel video recording study of computerized decision support systems and GP prescribing. *J Am Med Inform Assoc*. 2013 Jun;20(e1):e76-84
- ²⁹ Coleman JJ, van der Sijs H, Haefeli WE, Slight SP, McDowell SE, Seidling HM, Eiermann B, Aarts J, Ammenwerth E, Slee A, Ferner RE. On the alert: future priorities for alerts in clinical decision support for computerized physician order entry identified from a European workshop. *BMC Medical Informatics and Decision Making* 2013; 13:111
- ³⁰ Horsky J, Phansalkar S, Desai A, Bell D, Middleton B. Design of decision support interventions for medication prescribing. *Int J Med Inform* 2013;82(6): 492-503
- ³¹ Thomas SK, McDowell SE, Hodson J, Nwulu U, Howard RL, Avery AJ, Slee A, Coleman JJ. Developing consensus on hospital prescribing indicators of potential harms amenable to decision support. *Br J Clin Pharmacol* 2013; 76(5): 797-809
- ³² Paterno MD, Maviglia SM, Gorman PN, Seger DL, Yoshida E, Seger AC, Bates DW, Gandhi TK. Tiering drug-drug interaction alerts by severity increases compliance rates. *J Am Med Inform Assoc* 2009; 16(1): 40-46
- ³³ Coleman JJ, Hodson J, Thomas SK, Brooks HL, Ferner RE. Temporal and other factors that influence the time doctors take to prescribe using an electronic prescribing system. *J Am Med Inform Assoc* 2015; 22(1): 206-212

-
- ³⁴ Russ AL, Zillich AJ, Melton BL, Russell SA, Chen S, Spina JR, Weiner M, Johnson EG, Daggy JK, McManus MS, Hawsey JM, Puleo AG, Doebbeling BN, Saleem JJ. Applying human factors principles to alert design increases efficiency and reduces prescribing errors in a scenario-based simulation. *J Am Med Inform Assoc* 2014; 21(e2): e287-296
- ³⁵ Seidling HM, Phansalkar S, Seger DL, Paterno MD, Shaykevich S, Haefeli WE, Bates DW. Factors influencing alert acceptance: a novel approach for predicting the success of clinical decision support. *J Am Med Inform Assoc* 2011; 18(4): 479-484
- ³⁶ Gillaizeau F, Chan E, Trinquart L, Colombet I, Walton RT, Rège-Walther M, Burnand B, Durieux P. Computerized advice on drug dosage to improve prescribing practice. *Cochrane Database of Systematic Reviews* 2013, Issue 11. Art. No.: CD002894
- ³⁷ Ranji SR, Rennke S, Wachter RM. Computerised provider order entry combined with clinical decision support systems to improve medication safety: a narrative review *BMJ Qual Saf* Published Online First: 12 April 2014. doi: 10.1136/bmjqs-2013-002165
- ³⁸ Rider BB, Gaunt MJ, Grissinger M. Prescribing errors that cause harm. *Pennsylvania Patient Safety Advisory* 2016; 13 (3): 81-90
- ³⁹ Chinthapalli K. The hackers holding hospitals to ransom. *BMJ* 2017; 357: j2214
- ⁴⁰ BBC News. How cyber attack is disrupting NHS. Accessed at <http://www.bbc.co.uk/news/live/39901370>
- ⁴¹ Wright A, Hickman TT, McEvoy D, Aaron S, Ai A, Andersen JM, Hussain S, Ramoni R, Fiskio J, Sittig DF, Bates DW. Analysis of clinical decision support system malfunctions: a case series and survey. *J Am Med Inform Assoc* 2016; 23(6):1068-1076