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Interruptive alerts - only one part of the solution for clinical decision support

Authors: Yogini Jani and Bryony Dean Franklin

Affiliations: University College London Hospitals NHS Foundation Trust & UCL School of Pharmacy

Address correspondence to: yogini.jani@nhs.net

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It is widely accepted that electronic health records, computerized provider order entry (CPOE) and electronic prescribing systems represent a way forward for patient safety. Even relatively basic electronic prescribing systems have been shown to improve patient safety by eliminating the 'technical' prescription writing errors of clarity and completion, such as those related to poor handwriting or missing information.[1, 2] However, reductions in errors relating to clinical decisions are likely to require more advanced systems incorporating clinical decision support systems (CDSS), which may also be linked to patient-specific information. A recent overview highlights that CDSS "...is comprised of software designed to be a direct aid to clinical-decision making, in which the characteristics of an individual patient are matched to a computerised clinical knowledge base and patient-specific assessments or recommendations are then presented to the clinician for a decision." [3] Within electronic prescribing and CPOE systems, such recommendations are often presented to the user as interruptive pop-up alerts, including those relating to allergies, drug-drug interactions and potentially inappropriate doses.

The systematic review by Cerqueira and colleagues[4] in this issue of *BMJ Quality & Safety* focuses on the effectiveness of such interruptive alerts on prescribing behaviour in outpatient and ambulatory care settings. The review specifically excluded other types of CDSS, as well as non-interruptive alerts. The authors identified only nine comparative studies of interruptive alerts that met their inclusion criteria, of which three were randomised controlled trials, with randomisation at either the level of the practice or the prescriber. Eight of the nine studies were from North America. The effectiveness of interruptive alerts on prescriber behaviour was conceptualised as prescriber acceptance of the alerts leading to changes in prescribing practices, medication costs, and/or prescribing errors. The authors conclude that seven of the nine studies demonstrated significant provider behaviour change, although effect sizes were often small, and confidence intervals wide. However, despite the review's broad conceptualisation of effectiveness, none of the studies assessed patients' health outcomes. The authors of the review also note that in the few studies that captured prescriber feedback, the alerts were often considered inappropriate, intrusive, and of limited value, with only one study reported to include more positive feedback. Cerqueira and colleagues do not discuss prescriber feedback in depth, but one interpretation of these findings could be that interruptive CDSS alerts change prescriber behaviour with little evidence for patient benefit and at the expense of prescriber irritation.

As highlighted by Cerqueira and colleagues,[4] interruptive alerts are associated with a number of problems in both inpatient and outpatient settings. As well as affecting prescriber experience, these include increasing the time required for prescribing tasks, high rates of overrides (some of which may be inappropriate, putting patients at risk), low alert sensitivity, and alert fatigue. [5] Other unintended negative consequences, such as delays in prescribing and adverse outcomes due to inappropriate acceptance of irrelevant alerts have also been reported.[6] In the hospital setting, greater benefits have been reported for more tailored alerts, such as drug allergy alerts or dosing recommendations based on patient characteristics, with higher acceptance rates suggesting increased alert specificity.[7]

Given these issues, the general principle of interruptive alerts as a way of improving safety warrants further exploration. Distractions and interruptions are contributory factors to errors and reduce situational awareness in clinical workflow.[8] Yet, interruptive alerts continue to be used in electronic prescribing and CPOE systems to present clinical decision support with the aim of improving safety. This apparent paradox may be due to a fundamental distinction between what we generally think of as 'interruptions', which detract attention *away* from the primary task,[9] and 'interruptive alerts', which provide an intentional disruption as *part of* the primary task. In the former, the primary task often needs to be suspended for a period of time, whereas the pause is more disruptive with interruptive CDSS alerts, to intentionally prompt a review of the primary task. In the context of integrated electronic health records, where users may be

accessing the systems for various reasons and therefore be presented with alerts unrelated to their primary task, the distinction of whether alerts act as interruptions or disruptions becomes more important and requires further research.

Most research in this field has evaluated the impact of single CDSS features such as alerts or decision guiding recommendations in isolation, rather than a composite of different types of CDSS, or in the context of wider system design with very few replication studies.[10, 11] We therefore suggest that the widespread use of electronic health record systems and emerging evidence for alternative CDSS designs [12, 13], combined with advances in the fields of clinical informatics and artificial intelligence (AI) make this the right time to recalibrate our conceptualisation of CDSS. This recalibration involves four key considerations. First, we need to move away from the widely held association of CDSS with interruptive pop-up alerts, and instead focus on broader design concepts, including any on-screen tools that support and facilitate clinical decision-making or improve adherence to recommended processes of care. Such facilitative decision support design can include a range and mix of proactive and reactive approaches (table 1). This may include making best use of more basic CDSS features such as drug dictionaries, formularies and preference lists, through the application of nudge theory and behaviour change frameworks to nudge users towards safe and appropriate prescribing. Second, better use should be made of more advanced features, such as patient- or user-dependent rule-based pre-populated doses, order sets, and tiered or graded alerts with optimised alert sensitivity and specificity; these may deliver greatest gain with minimum disruption.[14] Third, current evidence on the challenges, disadvantages, limitations and usability flaws of the different types of CPOE and CDSS should be used to improve system design. This should include using human factors approaches to learn from studies of unanticipated behaviours to explore how the prescriber was led to such behaviours and to improve system design to support those behaviours that lead to positive outcomes. Finally, the application of AI and machine learning tools may also provide more refined, adaptive decision support systems that can iteratively enhance decision-making recommendations based on patient and prescriber characteristics. This could support alert-based CDSS with greater sensitivity and specificity, or to optimise non-alert based CDSS such as pre-populated doses and order sets.

Given some of the unique features of CDSS, the design of evaluation studies also requires careful consideration. Evaluations need to consider broader CDSS design features including the timing and context of the information provided to influence prescribers,[15] rather than studying the impact of individual features, such as alerts, in isolation.[16] Comparative studies of nudge frameworks with interruptive alerts or forcing functions, are also needed to assess the potential pitfalls of each approach. For example, there may also be unintended consequences with nudge interventions, if users accept default or suggested doses without adjusting doses when needed for specific patients. Randomised controlled trials that consider an intervention containing different elements as one overall 'treatment' are also unlikely to be useful to study the unique features of CDSS in real world settings, where it may be challenging to control for cross-over effects due to patient care being delivered by different teams and different individual prescribers. Although modelling approaches have been recommended, these too are limited in the assessment of both actual prescriber behaviours and other factors such as cognitive workload.[17, 18] Future research is needed using mixed methods and adaptive study designs such as platform trials[19, 20] to assess the impact of these interventions on patient outcomes, used in combination with rapid ethnography to understand the behavioural aspects. These alternative research approaches allow the continuous study of multiple interventions or components and in effect, the development of a learning health system[21] that embeds knowledge generation into routine practice.

In conclusion, we argue that interruptive alerts are only one part of the solution to improve patient safety through electronic prescribing and CPOE systems. Further safety improvements can only be achieved if

CDSS design is facilitative, with minimal cognitive disruption or burden, and includes greater consideration of human factors principles. There is also the need for better research, measuring actual impact on patient outcomes.

Table 1: Terminology and approaches used in Clinical Decision Support System (CDSS) design.

Design feature	Description	Example
Interruptive alert	Pop-up; temporarily stops the primary task; requires acknowledgement or cancellation to continue	Drug allergy or drug interaction alerts
Facilitative interruptive alert	As above but facilitates next steps by providing options for follow on actions e.g. alternative choices	As above but suggests suitable alternative e.g. second line antibiotic choice for patient with penicillin allergy
Non-interruptive alert	Alert that appears on screen but does not interrupt or stop the primary task	Sidebar presenting additional information that may be actioned after the primary task is complete
Graded or tiered alerts	Alerts (either interruptive or non-interruptive) that include information about the likelihood or severity of the risk associated with the information being presented	Contra-indications graded as higher risk than precautionary warnings
Drug dictionary	List of all the medicines available for prescribing	Commercial and non-commercial drug databases that facilitate choice of medicines to prescribe
Formulary	List of all the medicines available for prescribing in that organisation or for that user or patient group	Organisation-level formulary that restricts the choice of medicines available to prescribe
Preference list	Selection of medicines that are commonly or frequently prescribed by the user or user group	Preference list for acute admissions presenting with myocardial infarction, set at a system level, to nudge the user to prescribe by protocol
Pre-populated doses or frequencies	Recommended dose or frequency is suggested when a medicine is selected; may be based on age or indication	Nudge to prescribe the appropriate low molecular weight heparin dose for prophylaxis
Order sets	Structured and standardised collection of orders for a given condition; usually based on evidence or guidelines	Post-operative medication orders for specific procedures to nudge the user to prescribe by protocol
Forcing function	Requires action to progress i.e. restricts and prevents further actions until the issue has been addressed; often used in combination with interruptive or non-interruptive alerts	Mandatory entry of essential information e.g. entry of age for a paediatric prescription

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