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Abstract
Incorporation of clinical decision support (CDS) capabilities is required to realize the greatest benefits from computerized provider order entry (CPOE) systems. Discussions at a conference on CDS in CPOE held in San Francisco, California, June 21–22, 2005 produced several papers in this issue of JAMIA. The first paper reviews CDS for electronic prescribing within CPOE systems;1 the second describes current controversies regarding creation, maintenance, and uses of CPOE order sets for CDS;2 and the third presents issues related to certification as a potential means of validating CPOE systems for widespread use.3 This manuscript summarizes all of the discussions at the meeting and provides a pragmatically oriented view of how to implement CPOE with CDS.

Introduction
Implementation of clinical decision support (CDS) within computerized provider order entry (CPOE) systems requires ongoing difficult and expensive endeavors. Project leaders must coordinate the efforts of clinical, technical, and human factors engineering experts over long periods of time. Institutional justification for installing CPOE systems and adding CDS is often lacking, with the result that only about 10% of U.S. hospitals had fully adopted CPOE by 2002.4 One justifiable reason for moderate to large medical centers to adopt CPOE with CDS is to reduce substantially the high number of medication errors that regularly occur.5 While CPOE systems with relatively modest levels of clinical decision support can reduce serious medication error rates substantially,6,7 some errors will still occur. More advanced CDS capabilities in CPOE may include computer-based guidance for usual and maximum medication doses, and dose adjustments for compromised renal function or advancing age. Advanced CDS within CPOE prescribing can be highly beneficial.1,7,8

Fortunately, implementing many of the best safety-related CDS interventions in CPOE may be easy to accomplish. For example, computerization of prescribing with CDS enables pediatric dosing based on age and weight.1 Limiting drug and dosage choices can also reduce unnecessary variation. Likewise, selecting evidence-based, disease-specific order sets for patient care can make the “right orders for the patient” the default.9 However, designing a complex yet flexible, protocol-based, safe dosing approach to chemotherapy remains a relatively unsolved problem in most institutions implementing CDS within CPOE. This should serve as a reminder that CPOE with CDS has not yet fully addressed all medication dosing problems. CPOE has many easy-to-implement benefits outside the medication and safety realms. For example, CPOE systems can help clinicians to make more cost–effective use of the clinical laboratory,3 to deliver clinical knowledge for educational purposes at the point of care,3 and to implement clinical guidelines and order sets.2

Technical Issues Related to CPOE and CDS Discussed at the Meeting
Presenters at the meeting (see Appendix, available online at www.jamia.org) included an international array of CPOE and CDS experts. The conference addressed many issues related to medication ordering and safety. A key priority when ordering new medications is reconciling the history of
drug allergies electronically. While allergies from prior admissions should be available for new admissions, the current lack of nationally accepted standards for recording medication allergies records makes long-term maintenance and cross-institutional interchange of such information challenging. Discussants at the meeting noted that, in addition to recording allergy triggering agents—which should include not only medications but also non-drug allergies such as latex, intravascular contrast, and foods—the nature of the allergic reactions should also be recorded. A reliable and auditable means of removing incorrect allergies from a patient’s electronic record must exist. Common cross-sensitivities with related drugs should be considered, although carte blanche acceptance of all possible cross-sensitivities can contribute to excessive false-positive allergy alerts. Contraindications for drug use should require a strong evidence base before being incorporated into a CDS system.

Meeting participants also discussed CPOE-based drug–drug interaction checking. While important, if not implemented correctly, this CPOE feature often leads to alerts for so many low-clinical-relevance interactions that clinician–users ignore the most critical interaction alerts due to “information overload” or “inability to recognize the needle in the haystack.” Not only should CDS–CPOE checking be done for drug–drug interactions, but also for duplicate drugs, drug–disease, drug–lab, and drug–pregnancy issues. Drug interactions should also be classified by severity. Alerts should present users with the ability to order available alternatives. The very few truly life-threatening drug interactions (i.e., those that should never be given together) should generate a “hard stop” response in the CPOE system so that an order for the combination will not be implemented; potentially serious reactions should have an interruptive action and require a reason for override; and, interactions with less serious potential consequences might be presented through a non-interruptive mode.

The process of drug ordering can also be simplified and made safer by setting up predetermined lists with patient-appropriate doses within order sets. Another advantage of these predetermined order sets is that they can be updated and distributed more easily on the computer than by paper. Schedules for periodic review of predetermined lists should be established and adhered to by appropriately qualified clinical expert maintainers.

Meeting participants noted that tying a reliable, up-to-date electronic patient record system to the CPOE system can facilitate pre- and post-admission testing, and facilitate accuracy of medication reconciliation now mandated by the Joint Commission on Accreditation of Healthcare Organizations (JCAHO). Within CPOE systems, CDS elements should promote related laboratory test monitoring for common drugs such as statins, oral anticoagulants, ACE inhibitors, and others.

An important topic discussed at the meeting was the optimal method for providing patients with computer-stored educational information about their prescriptions. While many individuals now seek information on the Internet, they may often not find credible advice, or even worse, find incorrect information. Physicians today may communicate with their patients by e-mail to answer questions or provide advice on the need for booster vaccines or other medical care. Eventually, the patient’s electronic medical record will be available online. As the public becomes more health care savvy, the Institute of Medicine’s (IOM) goal of providing patient-centered care may become more of a reality.

Making CPOE and CDS safer and more user-friendly will demand that human factor engineering principles be integrated into systems. Human perception, memory, reliability, and other aspects of cognitive psychology should be carefully considered. These are discussed in detail below.

When fully implemented as part of a complete electronic medical record (EMR) system, well-designed CPOE systems may produce an extraordinary effect on care provider satisfaction. Valuable time is lost at present when clinicians must “chase down” paper charts, physically visit the radiology department to view films, and engage in “telephone tag” to obtain simple advice from colleagues. To paraphrase what Confucius said three millennia ago, the essence of knowledge is having it available to apply—in real time.

While most of the discussion during the meeting focused on the inpatient setting, participants recognized that many CPOE–CDS applications must also function in the outpatient setting. While the decision support needed differs somewhat, most of the key principles remain the same. Issues of how to plan and manage care optimally across the inpatient–outpatient continuum represent another unsolved challenge to current CDS applications within CPOE systems.

Finally, the meeting discussed the importance of standards in facilitating CPOE and CDS implementations. A standardized medical terminology for ordering and results has to be developed and maintained. Relevant standards activity exists at the national level, with references at government Web sites such as the National Library of Medicine, at standards organizations such as HL-7, and at professional organizations’ Web sites, such as AMIA and HIMSS.

**Discussion of Non-technical Issues Related to CDS and CPOE**

Mastery of available clinical information is no longer possible, if it ever was in the first place. With over 20,000 biomedical journals and more than 300,000 randomized controlled clinical trials, availability of electronic search resources is mandatory. Online medical, surgical, pediatric, and nursing textbooks are just the beginning. Guidelines and options for order sets are now available electronically. “Point-of-care” information can potentially make care safer and improve its quality. However, how does an institution or the nation get from here to there? Technology is only part of the solution—the socio-technical issues are at least as important. Care providers at the level of individuals and institutions are slow to change. Clinical leaders in organizations must pro-actively take responsibility for making iterative improvements. Those implementing systems must monitor them for adverse effects on both patient care and on caregivers’ workflows. Similar monitoring must occur to ensure that desired goals are achieved. Continuous refinement based on ongoing end-user feedback must guide progress. Some key metrics of technological systems that influence clinicians’ ease of use, and happiness, include: easy access to
workstations; point-of-care entry and viewing of documentation, including availability of wireless mobile carts for “rounding” activities; speed and timeliness of the CPOE system screen flips (no delays longer than a few seconds); and, secure remote access to clinical systems from office or home. Taking care of these technical issues and clinical work flow challenges will eliminate most barriers to using the system.

Poor planning and implementation by administration or by the clinical leadership or the information technology group can result in poor performance or even failures. Collaboration requires use of the golden rule and adherence to the “three legged stool” model—where operations, clinicians, and information technology personnel work together to build trust. All need to focus on continuous modification and feedback, and must operate as a learning organization.

In determining the overall success of the project, the processes of planning for and executing a CPOE and CDS implementation can be as important as the selection of the systems to install. Implementation of CPOE and CDS systems should generally be done step-wise—unit-by-unit within a hospital—because the house-wide “big bang” approach carries serious risks. During the implementation, having adequate numbers of computer workstations placed at easy-to-access locations is critical—planners must determine beforehand the maximum number of clinician users likely to be active at one time on each ward or in each clinic, and accommodate this scenario. Similarly, one must plan to replace outdated workstations and networking gear on a regular, rotating basis, with a planned equipment life cycle of 3–4 years at most. Overall, experience from many sites suggests a preferred order of implementation for CPOE as part of an EMR system that works well. Institutions should begin with “basics” such as automating laboratory and radiology results reporting, followed by a pharmacy system that helps to manage orders with built-in CDS. Addition to the general EMR of online transcriptions of history and physical and operative notes and electronic signatures comes next. Nursing documentation and the electronic medical administration record (eMAR) may optionally follow next, or occur after CPOE is implemented. Only when the building blocks are in place, and clinician–users are comfortable with technology, should the arduous task of CPOE and CDS implementation occur gradually.

When implementing systems, it is important to keep in mind the Ten Commandments for Effective Clinical Decision Support published by Bates et al.:15

1. Speed is everything—this is what information system users value most.
2. Anticipate needs and deliver in real time—deliver information when needed.
3. Fit into the user’s work flow—integrate suggestions with clinical practice.
4. Little things can make a big difference—improve usability to “do the right thing.”
5. Recognize that physicians will strongly resist stopping—offer alternatives rather than insist on stopping an action.
6. Changing direction is easier than stopping—changing defaults for dose, route, or frequency of a medication can change behavior.
7. Simple interventions work best—simplify guidelines by reducing to a single computer screen.
8. Ask for additional information only when you really need it—the more data elements requested, the less likely a guideline will be implemented.
9. Monitor impact, get feedback, and respond—if certain reminders are not followed, readjust or eliminate the reminder.
10. Manage and maintain your knowledge-based systems—both use of information and currency of information should be carefully monitored.

The financial commitment required to implement CPOE and CDS is considerable. Cost savings for the total system will mean increased costs for some subsystems, especially given the current reimbursement scheme. While it is the “right” thing to do from the societal perspective, it also has to make sense for the hospital, and the Chief Financial Officer has to be convinced. Inadequate documentation of the patient’s diagnoses represents one of the main tripping points in maximizing compliance with external quality and reimbursement agencies. If electronic systems can capture correct diagnoses during CPOE or CDS to improve compliance with billing directives, it is possible to improve case-mix determinations and reimbursement. Ideally, such systems can help delivered care, documented care, and coded care to become the same.

**Conclusion**

Clinical decision support provides value when a CPOE system is in place. Implementing CPOE alone is not enough. The conference pointed out that barriers may seem formidable, but that an approach can succeed that elicits leadership support early, identifies and involves strong champions, and involves a committed administration that provides adequate financial support. Attention to detail is critical to provide appropriate support for clinicians’ work flows, adequately fast system response times, and near-perfect system reliability. National CDS resources are not uniformly available at present, so institutions must rely on themselves and on variable offerings from commercial vendors. During such complex implementations, institutions must remain cognizant of, and carefully monitor, errors that these systems can cause as well as the errors that they prevent.14-16

Finally, implementing institutions must reach an internal consensus regarding which decision support features, “rules,” and alerts to use, and must determine the most appropriate place to insert them into CPOE systems. Human factors engineering experience can help to decide the best ways to implement CDS. Decision support can become outdated if it is not kept current using credible, evolving biomedical information. The clinician–users of such systems must actively provide feedback that system maintainers rapidly and regularly address in order to attain an optimal approach to using CDS in CPOE.

**References**