



Computerized prescriber order entry in the outpatient oncology setting: from evidence to meaningful use

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ABSTRACT

Background

Chemotherapy is an effective treatment in the fight against many cancers. Medication errors in oncology can be particularly serious given the narrow therapeutic window of antineoplastic drugs and their high toxicities. Computerized prescriber order entry (CPOE) has consistently been shown to reduce medication errors and adverse drug events in various settings, but its use in the oncology setting has not been well established. To gain a better understanding of the meaningful use of CPOE systems in the outpatient chemotherapy setting, we undertook a systematic review of systemic therapy CPOE.

Methods

A province-wide expert panel consisting of clinical experts, health information professionals, and specialists in human factors design provided guidance in the development of the research questions, search terms, databases, and inclusion criteria. The systematic review was undertaken by a core team consisting of a medical oncologist, nurse, pharmacist, and methodologist. The MEDLINE, EMBASE, CINAHL, and COMPENDEX databases were searched for relevant evidence.

Results

The database searches resulted in 5642 hits, of which 9 met the inclusion criteria and were retained. In the oncology setting, CPOE systems generally reduce chemotherapy medication errors; however, specific types of errors increase with the use of CPOE. These systems affect practice both positively and negatively with respect to time, workload, and productivity.

Conclusions

Despite the paucity of oncology-specific research, CPOE should be used in outpatient chemotherapy delivery to reduce chemotherapy-related medication errors. Adoption by clinicians will be enhanced by CPOE processes that complement current practice and workflow processes.

KEY WORDS

Computerized prescriber order entry, outpatients, systematic review

1. BACKGROUND

Chemotherapy is an important type of treatment in the fight against many cancers. The very nature of chemotherapy's toxicity profile also creates potential for harm—and possibly death—if chemotherapy is not ordered, prepared, dispensed, and administered cautiously by members of the health care team.

Medication errors can occur anywhere during the medication process from ordering to administration, and errors can compromise patient safety^{1,2}. A Canadian study³ estimated that 7.5% of patients admitted to acute care hospitals in Canada in 2000 experienced at least 1 adverse event. Drug-related adverse events were the second most common type of event, accounting for approximately 24% of all adverse events.

Medication errors in oncology can be particularly serious, given the narrow therapeutic window and the high toxicities of antineoplastic drugs^{4,5}. In a study conducted by Leape *et al.*⁶ of adverse drug events, 39% of errors occurred in the physician order phase, with drug dosing accounting for 28% of all errors. Specific to chemotherapy, Gandhi *et al.*⁷ revealed that the most common source of error was within the order phase and that, compared with non-chemotherapy medication errors, chemotherapy

errors were 48% more likely to be serious in nature. A study of outpatient care in the oncology setting found that 7% of adult visits and 19% of pediatric visits were associated with a medication error, either in the clinic or at home⁸. Serious consequences can follow from even a small difference in the intended dose: overdosing can result in considerably more toxicity than usual, and underdosing can result in an unfavourable therapeutic outcome⁵.

With the introduction of health information technology systems such as systemic treatment computerized prescriber order entry (ST CPOE), the link between meaningful use and meaningful benefit has to be carefully considered⁹. The overarching goals of meaningful use are to enhance practice efficiencies and to improve patient outcomes by optimizing the use of health information technology¹⁰. Computerized prescriber order entry has consistently been shown to reduce medication errors and adverse drug events in various settings^{11–14}, but its use in the oncology setting has not been as well established. A systematic review of the CPOE literature specifically within the ambulatory oncology setting was therefore warranted. The focus on the ambulatory oncology setting was chosen because that setting represents more than 90% of all chemotherapy administered. The present systematic review and evidence summary was designed to cover many aspects of ST CPOE, including medication error reduction, medication error generation, effects on practice, implementation strategies, and clinical decision supports.

Within Ontario, the implementation of ST CPOE systems has grown by 23% since 2004, with 75.5% of all outpatient parenteral chemotherapy visits in 2010 being supported with some type of ST CPOE system¹⁵. To support this growing need, Cancer Care Ontario's clinically-driven Systemic Treatment Information Program provides information management, information technology, and e-health solutions to improve the quality, safety, and efficiency of systemic treatment across Ontario. In accordance with meaningful-use goals, the vision of the Systemic Treatment Information Program for improved patient safety is to reach the goal of having 90% of all parenteral systemic treatment (outpatient) visits supported by ST CPOE across Ontario. That vision was the nexus for undertaking a systematic review of the topic to evaluate the costs and return on investment associated with such technology solutions. The aim of the present review was therefore to gain a better understanding of the meaningful use of CPOE systems in the outpatient chemotherapy setting and to promote evidence-based practice in the meaningful use of ST CPOE systems regardless of the given software application.

2. METHODS

The practice guidelines development cycle¹⁶ was used to guide the review, and the systematic review

was used as the core methodology to develop the evidentiary base. An expert panel representing various specialty areas such as clinical oncology, pharmacy, nursing, and human factors design provided guidance in the development of the research questions, search terms, databases, and inclusion criteria.

2.1 Literature Search Strategy and Study Selection Criteria

The MEDLINE (1996 through November, week 3, 2011), EMBASE (1996 through week 46, 2011), CINAHL (1982 through November 24, 2011), and COMPENDEX (1969 through November 24, 2011) databases were searched for relevant evidence. The full literature search strategies are set out in Table 1. Articles were included in the review if they were published English-language reports of CPOE in the oncology setting for medication error reduction and if they generated outcomes (for example, effects on practice, implementation strategies). Research methodology was restricted to phase II or III randomized controlled trials, other comparative studies, single-arm studies, practice guidelines, and systematic reviews for all outcomes, and also qualitative studies for effects on practice, implementation strategies, and clinical decision support outcomes. Evidence was selected and initially reviewed by one author (RC), with other authors reviewing selected abstracts and articles as required.

2.2 Data Extraction

All data were extracted by the methodologist (RC) and later confirmed by an independent data audit. In the data audit, a student uninvolved in any portion of document development independently read the included studies and verified all the data extracted by the methodologist.

3. RESULTS

3.1 Literature Search Results

The searches of the selected databases yielded a total of 5642 hits. An initial review by RC of titles and abstracts against the inclusion and exclusion criteria resulted in the identification of 475 papers that were selected for retrieval and full review. The papers were randomly divided into two groups and reviewed against the criteria, with VK and SL reviewing one group, with RC and AC reviewing the other group. That approach allowed for a comparison of the reviews and the identification of papers for inclusion in the systematic review. Suggestions from the expert panel yielded one paper, which was retained. In total, seven unique quantitative and two unique qualitative papers met the eligibility criteria for the systematic review (Figure 1). The research designs described in the quantitative studies included 2-arm trials^{17–20}

TABLE 1 Literature search strategy

Database		EMBASE	CINAHL	COMPENDEX
MEDLINE	exp Medical Order Entry Systems/ exp Drug Therapy, Computer-Assisted/ computerized physician order entry.mp. computerized prescriber order entry.mp. computerized provider order entry.mp. cpoe.mp. or/1-6 limit 7 to english language	exp computerized provider order entry/ computerized physician order entry.mp. computerized prescriber order entry.mp. CPOE.mp. MOE.mp medication order entry.mp. exp computer assisted drug therapy/ or/1-7 limit 8 to english language	1. TX computerized physician order entry OR TX computerized prescriber entry OR TX computerized provider entry OR TX medication order entry OR TX cpoe or TX moe OR TX computer assisted drug therapy.	computerized physician order entry OR computerized prescriber order entry OR computerized provider order entry OR medication order entry OR cpoe.

and pre–post study designs^{21–23}. The subsection that follows describes the outcomes of the review as they relate to the original research questions. The studies and their results are not mutually exclusive to the distinct research questions (as depicted in Table II).

3.2 The Impact of ST CPOE on Medication Errors

Five studies^{17,18,21–23} demonstrating that CPOE reduces chemotherapy medication errors in the adult outpatient setting were identified. All reported error reduction for at least some types of errors. Huertas–Fernandez *et al.*¹⁷ compared manual and computerized prescriptions during 1 month in the medical oncology department of a university hospital. The chance of at least 1 error was 100% in a manual prescription compared with 13% in a computerized prescription ($p < 0.001$). The median number of errors in manual compared with computerized prescriptions was 5 compared with 0 ($p < 0.001$). The most common errors were errors of omission in manual compared with computerized prescriptions, including patient name ($p = 0.0037$), age ($p < 0.001$), and height ($p = 0.0393$); physician name ($p = 0.0037$) and signature ($p < 0.001$); diagnosis ($p < 0.001$); administration frequency ($p < 0.001$); and duration of infusion ($p < 0.001$).

In a much larger study, Small *et al.*¹⁸ also compared manual and computerized complex chemotherapy prescriptions. The error rate was 20.4% in manual orders; in computerized orders, it was 11.8%. That difference represents an overall reduction in the relative risk (RR) for errors of 42% [RR: 0.58; 95% confidence interval (CI): 0.47 to 0.72; $p < 0.0001$]. Moreover, the types of errors differed significantly according to the prescription method ($p < 0.001$), with CPOE being associated with fewer dose or frequency errors, incomplete prescriptions, and unnecessary additional agents. As a proportion of total errors, minor errors were fewer with computerized prescribing [16.5% vs. 36.6% with manual prescribing, $p =$ not reported (NR)]. Overall, the severity of errors differed significantly by prescribing method ($p = 0.001$).

Voeffray *et al.*²² evaluated prescribing errors for 15 months before and 21 months after CPOE implementation. The error rate was 15% pre-CPOE and 5% post-CPOE, with 92% of the post-CPOE errors being found in handwritten prescriptions. Pre-CPOE, 19% of errors were major, and 81% of errors were minor; post-CPOE, all errors were minor. The monthly average error rate was reported to be 13.1% pre-CPOE and 0.6% post-CPOE, representing a reduction to less than one twentieth of the original error rate.

Kim *et al.*²¹ evaluated CPOE in the pediatric setting using a pre–post CPOE implementation design. Compared with manual prescribing, CPOE resulted in fewer errors of improper dosing on orders (2.3% vs. 0.6%; RR: 0.26; 95% CI: 0.11 to 0.61), incorrect dosing calculations (5.8% vs. 0.54%; RR: 0.09; 95%

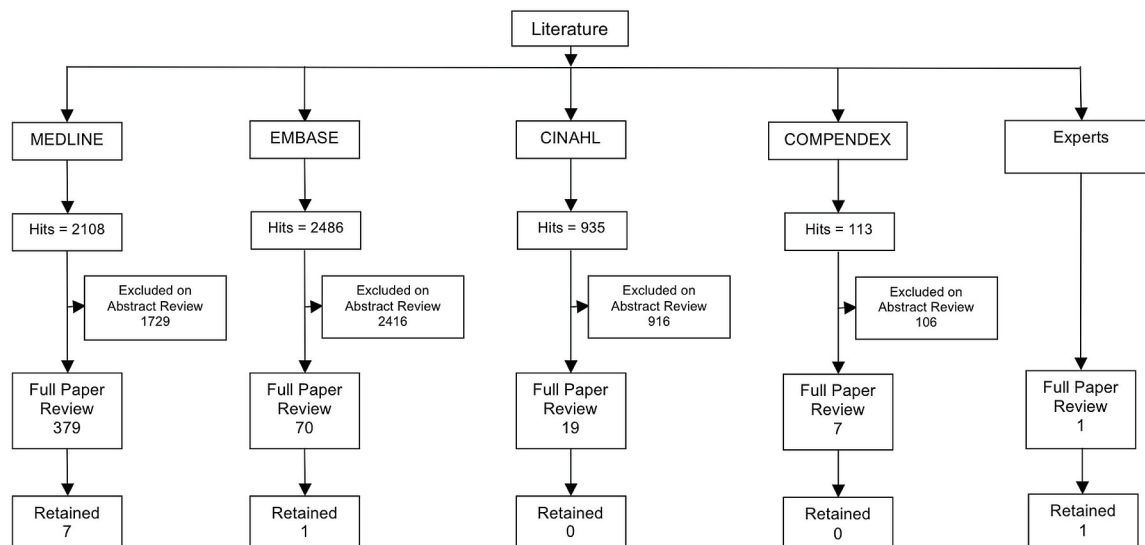


FIGURE 1 Flow diagram of literature search results.

TABLE II Studies selected for inclusion, by question (not mutually exclusive)

Question or topic	Selected articles			
	Quantitative		Qualitative	
	(n)	References	(n)	References
Medication error reduction	5	Huertas Fernandez <i>et al.</i> , 2006 ¹⁷ Kim <i>et al.</i> , 2006 ²¹ Voeffray <i>et al.</i> , 2006 ²² Small <i>et al.</i> , 2008 ¹⁸ Collins and Elsaid, 2011 ²³	NA	—
Medication error generation	4	Beer <i>et al.</i> , 2002 ¹⁹ Kim <i>et al.</i> , 2006 ²¹ Small <i>et al.</i> , 2008 ¹⁸ Collins and Elsaid, 2011 ²³	NA	—
Impact of ST CPOE on practice	2	Beer <i>et al.</i> , 2002 ¹⁹ Khajouei <i>et al.</i> , 2010 ²⁰	1	Kozakiewicz <i>et al.</i> , 2005 ²⁴
Implementation strategies	0	—	1	Greenberg <i>et al.</i> , 2006 ²⁵
Clinical decision supports	0	—	0	—

NA = none available; ST CPOE = systemic therapy computerized prescriber order entry.

CI: 0.03 to 0.34), missing cumulative dose calculations (18% vs. 5.7%; RR: 0.32; 95% CI: 0.14 to 0.77), and incomplete nursing checklists (4.8% vs. 2.5%; RR: 0.51; 95% CI: 0.36 to 0.80). No difference with respect to improper dosing on treatment plans was observed (4.0% vs. 2.6%; RR: 0.66; 95% CI: 0.42 to 1.04). Unfortunately, *p* values were not provided for any of the reported error types.

Collins and Elsaid²³ reported on prescribing errors for oral chemotherapy in an inpatient setting for a 24-month period before CPOE implementation and

6 months after implementation. The implementation of CPOE significantly reduced the risk of prescribing errors by 69% (odds ratio: 0.31; 95% CI: 0.11 to 0.86; *p* = 0.023). Table III summarizes error rates for manual and CPOE prescribing systems in the oncology setting.

3.3 Generation of New Errors

Four studies^{18,19,21,23} demonstrating that CPOE might increase chemotherapy medication errors were identified. Small *et al.*¹⁸ reported that error types differed

TABLE III Error rates for manual and computerized prescriber order entry (CPOE) prescribing systems in the oncology setting

Reference	Prescriptions (n)	Overall errors (%)	Errors by type (% manual/pre-CPOE or vs. CPOE/post-CPOE) ^a
<i>Two-arm trials</i>			
Beer <i>et al.</i> , 2002 ¹⁹	Manual: 696	7.14	Not reported (NR)
	CPOE: 140	<i>p</i> =NS 7.47	
Huertas Fernandez <i>et al.</i> , 2006 ¹⁷	Manual: 30	100	Errors of omission (in favour of CPOE) Patient name (<i>p</i> =0.0037) Age (<i>p</i> <0.001) Height (<i>p</i> =0.0393) Physician name (<i>p</i> =0.0037) Physician signature (<i>p</i> =0.0037) Diagnosis (<i>p</i> <0.001) Administration frequency (<i>p</i> <0.001) Duration of infusion (<i>p</i> <0.001)
	CPOE: 30	<i>p</i> <0.001 13	
Small <i>et al.</i> , 2008 ¹⁸	Manual: 602	20.4	Types of errors Dose or frequency errors: 6.8 vs. 1.9 (<i>p</i> <0.001) Incomplete prescriptions: 4.3 vs. 0.4 (<i>p</i> =NR) Unnecessary additional agents: 1.8 vs. 0.07 (<i>p</i> =NR) Cycle number or stage errors: 2.5 vs. 5.6 (<i>p</i> =0.003) Wrong data entered: 0.7 vs. 1.0 (<i>p</i> =NR) Severity of errors Minor: 36.6 vs. 16.5 (<i>p</i> =NR) Significant: 32.5 vs. 35.4 (<i>p</i> =NR) Serious: 25.2 vs. 41.8 (<i>p</i> =NR) Life threatening 5.7 vs. 6.3 (<i>p</i> =NR) Overall (<i>p</i> =0.001)
	CPOE: 1339	RR: 0.58; <i>p</i> <0.0001 11.8	
<i>Pre-post implementation</i>			
Kim <i>et al.</i> , 2006 ²¹	Pre-CPOE: 1259	NR	Types of errors Improper dosing on orders: 2.3 vs. 0.6 (<i>p</i> =NR) Incorrect dosing calculations: 5.8 vs. 0.54 (<i>p</i> =NR) Missing cumulative dose calculations: 18 vs. 5.7 (<i>p</i> =NR) Incomplete nursing checklists: 4.8 vs. 2.5 (<i>p</i> =NR) Matching order and treatment plans: 1.1 vs. 6.0 (<i>p</i> =NR) Improper dosing on treatment plans: 4.0 vs. 2.63 (<i>p</i> =NR)
	Post-CPOE: 1116		

TABLE III Continued

Reference	Prescriptions (n)	Overall errors (%)	Errors by type (% manual/pre-CPOE or vs. CPOE/post-CPOE) ^a
<i>Pre-post implementation</i>			
Voeffray <i>et al.</i> , 2006 ²²	Pre-CPOE: 940	15	Minor errors: 81 vs. 100
	Post-CPOE: 1505	5	Major errors: 19 vs. 0
Collins and Elsaid, 2011 ²³	Pre-CPOE: 412	Reduction in prescribing errors with CPOE (OR: 0.31; 95% CI: 0.11 to -0.89; <i>p</i> =0.023)	Errors in clinical decision making
	Post-CPOE: 126		Wrong dosing schedule or duration: 3.2 vs. 0.0 (<i>p</i> =NR)
			Dose likely leading to high serum levels: 0.7 vs. 0.8 (<i>p</i> =NR)
			Dose likely leading to low serum levels: 0.5 vs. 0.8 (<i>p</i> =NR)
			Dose exceeding maximum range for the indication: 0.5 vs. 0.0 (<i>p</i> =NR)
			Errors in transcription
			Omitted or unclear drug name, route of administration: 0.2 vs. 0.0 (<i>p</i> =NR)
			Errors related to prescribing policy
			Prescribing policy not followed: 3.6 vs. 1.6 (<i>p</i> =NR)

RR = relative risk; OR = odds ratio; CI = confidence interval.

^a Boldface type signals errors that increased after CPOE implementation.

significantly by the prescription method ($p < 0.001$). Computerized prescribing was associated with more frequent cycle number or stage errors and instances of wrong data entered (for example, height, weight). These authors also categorized each prescribing error according to severity, with serious errors defined as those that might cause either harm or significant undertreatment. Life-threatening errors were defined as those possibly resulting in death. Compared with manual prescribing, CPOE was more frequently associated with serious (25.2% vs. 41.8%, $p = \text{NR}$), significant (32.5% vs. 35.4%, $p = \text{NR}$), and life-threatening errors (5.7% vs. 6.3%, $p = \text{NR}$).

Beer *et al.*¹⁹ took a different approach, in that they measured the pharmacist intervention rate, which was defined as any problem with a medication order that required physician clarification before the pharmacist could process the order. They observed no statistically significant difference in the intervention rate for manual and computerized orders (7.14% vs. 7.47%, $p = \text{nonsignificant}$, Table III). Neither Small *et al.*¹⁸ nor Beer *et al.*¹⁹ referred to specific prescriber or system features that might have contributed to the increase in errors or interventions.

Kim *et al.*²¹ evaluated CPOE in the pediatric setting using a pre-post CPOE implementation design. Compared with manual prescribing, CPOE resulted in more errors for matching order and treatment plans (1.1% vs. 6.0%; RR: 5.4; 95% CI: 3.1 to 9.5), although it is unknown if that result was statistically significant.

Collins and Elsaid²³ reported on prescribing errors for inpatient oral chemotherapy during a 24-month period before CPOE implementation and 6 months after implementation. After CPOE implementation, more dosing errors likely leading to high (0.7% vs. 0.8%) or low serum levels (0.5% vs. 0.8%) were observed. The significance levels for the errors were not reported.

3.4 Effect of ST CPOE on Clinician Practice

Beer *et al.*¹⁹ evaluated the effect of CPOE on pharmacy practice. Pharmacist intervention rates were measured, as was the time the pharmacist needed to review each order. All medications listed on a given prescription were considered to be a single order regardless of how many were listed. The time to review each order was measured. If a pharmacist intervention was needed to complete the order review, the timing of the review process continued throughout the duration of the pharmacist intervention. The mean time to complete a prescription order review was significantly longer for a computerized prescription than for a manual prescription (11.1 minutes vs. 5.96 minutes, $p < 0.001$). Even when categorized by orders that required an intervention (18.32 vs. 13.49, $p < 0.001$) and those that did not (10.56 vs. 5.35, $p < 0.0001$), significantly more pharmacist review time was required for computerized prescriptions than for manual prescriptions.

Khajouei *et al.*²⁰ compared the effect of predefined order sets on the efficiency of chemotherapy prescribing within a CPOE system. In a counterbalanced design, 10 hematology or oncology physicians were provided a clinical scenario and asked to order medications using and not using a predefined order set. Optimally, the predefined order set scenario required 61 keystrokes and mouse clicks, and the non-order set scenario required 86 ($p < 0.01$).

One qualitative study pertaining to the impact of CPOE on oncology practice was identified²⁴. In a failure mode and effects analysis conducted with a multidisciplinary team, the team was able to affect practice by developing a uniform and safe chemotherapy ordering system.

3.5 Strategies to Enhance Implementation of ST CPOE

Based on the implementation of a ST CPOE system in 11 organizations across Ontario, Greenberg *et al.*²⁵ identified several key components to successful implementation, including having a fully staffed project team; enlisting the support of clinical and administrative leadership; involving stakeholders in decision-making to ensure a sense of ownership and empowerment; providing in-depth, on-site training; testing the system extensively; and providing ongoing customized support and maintenance.

4. DISCUSSION

Patient safety has garnered much attention, particularly since the 1999 report from the U.S. Institute of Medicine²⁶ which estimated that, in the United States alone, 80,000 people are hospitalized and 7000 die every year because of medication errors in the inpatient setting, many of which are preventable. Computerized prescriber order entry is one promising technology for the reduction of medication errors in the inpatient and outpatient settings alike.

Medication errors in the oncology setting can be particularly serious, given the toxicity of chemotherapeutic agents. The results of the present systematic review clearly demonstrated the paucity of oncology-specific CPOE literature, but the studies cited here are consistent with the existing systematic reviews describing the benefits of CPOE systems^{14,27} and the unanticipated outcomes²⁸. The few studies included in this review demonstrate that CPOE in the oncology setting does contribute to a decline in the incidence of medication errors^{17,18,21–23}, as it does, in some instances, to the potential for increased errors^{18,19,21,23}. The CPOE system, clinical decision supports, and associated interface elements must be carefully designed to optimize the benefits of ST CPOE systems.

Systemic therapy CPOE can also affect practice, particularly workflow, communication between health care professionals, and communication between health care professionals and patients. Unfortunately, the

study results are not consistent, probably reflecting the true nature of variability in the practice setting. Several non-oncology studies have also found that e-prescribing has had a negative effect on workflow in terms of time and workload^{27,29,30,31}, but other studies report a positive effect with respect to time and workload^{32–35}, productivity³², and communications^{33,36}. One study reports both positive and negative effects on various aspects of time and workload³⁷. The results of qualitative studies in oncology and non-oncology settings^{38–40} resemble the empirical evidence. The totality of the evidence reveals that, as with any new technology, CPOE will have both positive and negative effects on practice.

Only a handful of studies have evaluated CPOE implementation, either empirically or qualitatively, in the outpatient setting, and none were in the oncology setting. Empirical non-oncology studies all look at very different factors that might affect implementation, including the use of a CPOE “champion”⁴¹; respondent use of a home computer for work⁴²; and physician, structural, and cultural variables⁴³. Some common themes emerging from those studies are the needs for a strong vision and motivation for introducing CPOE; for the involvement of stakeholders in decision-making; for the provision of in-depth, on-site, and ongoing training before and after launch; and for the establishment of mechanisms to efficiently respond to problems identified by end users^{26,41,44–46}.

5. CONCLUSIONS

Computerized prescriber order entry is a promising technology for the reduction of medication errors and the potential adverse drug events associated with those medication errors. Based on a review of the literature, the following 6 strategies are presented:

- CPOE systems should be used in outpatient chemotherapy delivery to reduce chemotherapy-related medication errors.
- Clinical, technical, and leadership champions are vital to support the successful adoption of CPOE within an organization.
- A multidisciplinary team approach should be used in the design, selection, workflow evaluation, implementation or evaluation (or both), and ongoing monitoring of the CPOE system.
- To enhance adoption by clinicians, CPOE processes that complement current practice and workflow processes should be ensured.
- CPOE systems, clinical decision supports, and associated interface elements must be carefully designed to reduce the potential for error.
- Development and implementation of a risk-assessment process to identify actual or potential unanticipated consequences and the generation of new errors are warranted, as is the development of strategies to modify the system accordingly.

The meaningful-use campaign emphasizes the need to use technology in a meaningful manner to improve the quality of care and to be able to measure the effectiveness of the technology solution. When optimally designed and implemented, ST CPOE systems can contribute to achieving the goals of meaningful use—specifically, improvement in quality, safety, and efficiency, and enhancement of care coordination. The paucity of ST CPOE research in the oncology setting warrants consideration, because the current literature is limited with respect to measuring the effectiveness of such systems in providing the desired clinical outcomes beyond error reduction, a topic that will need to be investigated in future research. Other considerations, such as a standardized design and architecture for these systems to correlate with best clinical practice, would be beneficial. Meaningful use is optimized by quality measurement—in this case, by focusing on the clinical processes within which these systems are used. Measures could include utilization rates, triggered alert rates (in parallel with override rates), and clinically important metrics such as adverse-event and near-miss rates. Lastly, CPOE systems are moving toward becoming integrated special-application modules within complex medication management systems, with associated processes such as e-prescribing. Careful analysis of error reduction, effects on practice, and generation of new errors will need to be considered.

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7. CONFLICT OF INTEREST DISCLOSURES

The authors have no financial conflicts of interest to declare.

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