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Computerized Prescriber Order Entry (CPOE) in the Outpatient Oncology Setting

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and the ST CPOE Guideline Development Group

Report Date: May 8, 2012

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Kukreti V, Cosby R, Cheung A, Hamasoor M, Hertz S, Kaiser L, et al. Safe chemotherapy: clinicians driving technology and not the other way around [abstract]. Presented at: 2012 World Cancer Congress; 2012 Aug 27-30; Montreal, QC.

EBS Evidence Summary 12-14: Section 1

Computerized Prescriber Order Entry (CPOE) in the Outpatient Oncology Setting: Evidentiary Base

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QUESTIONS

GLOBAL QUESTION

What are the features, functions and components of a Systemic Therapy (ST) Computerized Prescriber Order Entry (CPOE) system that are required to ensure safe, high-quality systemic treatment?

SPECIFIC QUESTIONS

1. Does ST CPOE decrease medication errors in chemotherapy prescribing compared to usual practice, and if so, what types of errors does it decrease?

2. Does ST CPOE generate new errors, and if so, what types of new errors does it increase?

3. What is the impact of ST CPOE on practice (e.g., workflow, workload, team communication)?

4. What are the strategies that enhance or limit implementation of ST CPOE?

5. What types of clinical decision supports are available, and are they effective or ineffective?

INTRODUCTION

Medication errors are deviations from the intended use of a medication. Delivery of the wrong medication or the wrong dosage, a missed dose, and a dose at the wrong time or by the incorrect route are examples. These types of errors can occur anywhere from medication ordering to medication administration and can compromise patient safety (1,2). Medication errors accounted for an estimated 7000 deaths in the United States in 1993 alone (3). A Canadian study (4) estimated that 7.5% of patients admitted to acute care hospitals in Canada in 2000 experienced at least one adverse event. Drug-related adverse events were the second most common type of these events, accounting for approximately 24% of all adverse events. Medication errors in oncology can be particularly serious because of the narrow therapeutic ranges of antineoplastic drugs and their high toxicities (5,6). Even a moderate difference from the intended dose can have serious consequences. Overdosing can result in considerably more toxicity than usual, and underdosing can result in an unfavourable therapeutic outcome (6). A recent 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 home (7). Another study in the chemotherapy setting reported an overall 3% medication error rate. Of these, 82% of the adult errors and 60% of the pediatric errors were potential adverse drug events (ADEs), and one third of these potential ADEs were considered potentially serious (8).

Computerized prescriber order entry (CPOE) has been consistently shown to reduce medication errors and ADEs in various settings (9-12), but their use in the oncology setting has not been as well established empirically. Most errors occur during the ordering stage of the medication pathway (13,14), and only a small percentage of hospitals in the United States use CPOE for complex chemotherapy regimens (15). It was decided, therefore, that a systematic review of the CPOE literature in the oncology setting was warranted. This systematic review and evidence summary was designed to cover many aspects of ST CPOE, including medication error reduction, medication error generation, other possible benefits, impact on practice, implementation strategies, and clinical decision supports.

METHODS

The EBS guidelines developed by the CCO PEBC use the methods of the Practice Guidelines Development Cycle (16). For this project, the core methodology used to develop the evidentiary base was the systematic review. Evidence was selected and reviewed by one member of the ST CPOE working group (Appendix 1), which is a subset of the ST CPOE Guideline Development Group (Appendix 2).

This systematic review is a convenient and up-to-date source of the best available evidence on ST CPOE in the oncology setting (Question 1) and on ST CPOE in the adult outpatient (oncology or non-oncology) setting (Questions 2-5). The body of evidence in this review is primarily comprised of two-arm trials, before/after comparisons, surveys, cohort studies, and qualitative studies. The systematic review is intended to promote evidence-based practice in Ontario, Canada. The PEBC is supported by the Ontario Ministry of Health and Long-Term Care. All work produced by the PEBC is editorially independent from the Ministry.

Literature Search Strategy

The MEDLINE (1996 through Nov [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 MEDLINE, EMBASE, CINAHL, and COMPENDEX literature search strategies can be found in Appendix 3.

Study Selection Criteria

Inclusion Criteria

Question 1

Articles were included if they were:

- published English-language reports of CPOE in the oncology setting,
- phase II or III randomized controlled trials (RCTs), other comparative studies, single-arm studies, practice guidelines, and systematic reviews, with or without meta-analyses,
- the most recent paper that evaluated a given data set.

Question 2

Articles were included if they were:

- published English-language reports of CPOE in the oncology setting,
- published English-language reports of CPOE (non-oncology) in the adult outpatient setting,
- phase II or III randomized controlled trials (RCTs), other comparative studies, single-arm studies, practice guidelines and systematic reviews, with or without meta-analyses,
- the most recent paper that evaluated a particular given data set.

Questions 3-5

Articles were included if they were:

- published English-language reports of CPOE in the oncology setting,
- published English-language reports of CPOE (non-oncology) in the adult outpatient setting,
- phase II or III randomized controlled trials (RCTs), other comparative studies, single-arm studies, practice guidelines and systematic reviews, with or without meta-analyses, process evaluations (summative and/or formative), surveys, qualitative (including studies using focus group or individual interviews, grounded theory,
- the most recent paper that evaluated a given data set.

Exclusion Criteria (all questions)

Abstracts, letters, editorials, notes, commentaries, and non-systematic reviews were not eligible. Any papers that only included theoretical or conceptual outcomes were excluded as well.

Synthesizing the Evidence

Owing to the varying designs of the identified studies and the lack of fully published RCTs, data were not pooled using meta-analytic techniques.

RESULTS

Literature Search Results

The MEDLINE search yielded 2108 hits, of which 379 were potentially relevant and were fully reviewed. Thirty-two were retained (Table 1, Appendix 4). The EMBASE search yielded 2486 unique hits, of which 70 were potentially relevant and were fully reviewed. Ten were retained (Table 1, Appendix 4). The CINAHL search yielded 935 hits, of which 19 were fully reviewed, and one was retained. The COMPENDEX search yielded 113 unique hits, of which 7 were potentially relevant, but none were retained (Table 1, Appendix 4). Asking experts for suggestions yielded one paper, which was retained.

Table 1. Literature search results.

Database	Dates Searched	Hits	Fully Reviewed	Retained
MEDLINE	1996 – July [week3] 2011	2108	379	32
EMBASE	1996 – week 29 2011	2486	70	10
CINAHL	1982 – July 28, 2011	935	19	1
COMPENDEX	1969 – August 4, 2011	113	7	0
Asking experts	Not Applicable	0	1	1

In total, 32 unique quantitative and 16 unique qualitative documents from the literature search met the eligibility criteria for this systematic review and are listed in Table 2.

Table 2. Studies selected for inclusion by question (not mutually exclusive).

Question/Topic	QUANTITATIVE PAPERS		QUALITATIVE PAPERS	
	Number of Documents	Reference Numbers	Number of Documents	Reference Numbers
Medication error reduction	5	(17-21)	NA	-----
Medication error generation	5	(18,20-23)	NA	-----
Impact of ST CPOE on practice	12	(22,24-34)	5	(35-39)
Implementation strategies	3	(40-42)	5	(43-47)
Clinical decision supports	9	(48-56)	6	(36,37,57-60)

Study/Trial Design and Quality

The quantitative studies included in this guidance document varied in type. There were five pre-/post-implementation studies, five two-arm trials, 11 surveys, six cohort studies, two RCTs, and one systematic review. As most of the studies were not randomized data, the quality of the studies is evaluated below (Table 3), based on four criteria: whether funding, control details, and power calculations were reported and whether blinded assessment was used. The systematic review was evaluated using the Assessment of Multiple Systematic Reviews (AMSTAR) instrument (61).

Of the 30 unique quantitative studies included in this systematic, 18 (60%) reported the funding source for the study. Control details were well reported for those studies for which it was applicable. For most of the included studies, blinding was either impossible because of the nature of the two arms in the study, or not applicable because of the nature of the study design. Of the two randomized trials, one was blinded (49), and one was not blinded for intervention but blinded for outcome (48). Power calculations were only reported in four studies (17,22,23,27).

The qualitative studies identified for each question are listed and summarized in table format for each question. As they were not reported on in detail, they were not evaluated for quality.

Kim et al. (18) evaluated CPOE in the pediatric setting using a pre-/post-CPOE implementation design. Compared to manual prescribing, CPOE resulted in fewer errors for: improper dosing on orders (2.3 versus [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% 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). There was no difference with respect to improper dosing on treatment plans (4.0 vs. 2.6%; RR, 0.66; 95% CI, 0.42 to 1.04) (Table 4). Unfortunately, p-values are not provided for any of the reported types of errors.

Table 3. Quality attributes of the quantitative studies used to inform each of the specific topics regarding ST CPOE addressed in this report.

TOPIC	STUDY	DESIGN	N	FUNDING REPORTED	CONTROL DETAILS	BLINDED ASSESSMENT	POWER CALCULATED
Medication Error Reduction (Oncology)	Huertas Fernandez 2006 (17)	2-arm trial	Manual = 30 CPOE = 30	No	Yes	NP	Yes
	Kim 2006 (18)	Pre/Post Implementation	Pre = 1259 Post = 1505	Yes	NA	NP	No
	Voeffray 2006 (19)	Pre/Post Implementation	Pre = 940 Post = 1505	No	NA	NP	No
	Small 2008 (20)	2-arm trial	Manual = 602 CPOE = 1339	No	Yes	NP	No
	Collins & Elsaid 2011 (21)	Pre/Post Implementation	Pre=412 Post = 126	No	NA	NP	No
Medication Error Generation (Oncology)	Beer 2002 (22)	2-arm trial	Manual = 696 CPOE = 140	No	Yes	NP	Yes
	Kim 2006 (18)	as above					
	Small 2008 (20)	as above					
	Collins & Elsaid (21)	as above					
Medication Error Generation (Non-oncology)	Henderson 2010 (23)	Survey	Computer = 1069 Manual = 188	Yes	Yes	NR	Yes
Impact on Practice (Oncology)	Beer 2002 (22)	as above					
	Khajouei 2010 (24)	2-arm trial	Order Set = 10 No order set =10	No	Yes	NR	No
Impact on Practice (Non-oncology)	Eslami 2007 (25)	Systematic Review	AMSTAR SCORE =6				
	Hollingworth 2007 (26)	2-arm trial	Manual = 19 CPOE=50	Yes	Yes	NP	No
	Devine 2010 (27)	Pre/Post Implementation	Manual = 132 CPOE = 312	Yes	Yes	NP	Yes
	Wang 2009 (28)	Survey	Manual = 89 CPOE = 139	Yes	Yes	NA	No
	Duffy 2010 (29)	Pre/Post Implementation Survey	Pre = 1101 Post = 944 Providers = 17	No	Yes	NA	No
	DesRoches 2010 (30)	Survey	Stand Alone = 370 Integrated = 565	Yes	NA	NA	No
	Rupp 2008 (31)	Survey	N=1094	Yes	NA	NA	No
	Tan 2009 (32)	Survey	Physicians = 118 Pharmacy = 61	No	Yes	NA	No
	Hammar 2010 (33)	Survey	N=259	Yes	NA	NA	No
	Rahimi 2011 (34)	Survey	N=74	No	NA	NA	No
Implementation Strategies (Oncology)	None identified						
Implementation Strategies (Non-oncology)	Paré 2006 (40)	Survey	N=91	No	NA	NA	No
	Devine 2010 (41)	Survey	Prescribers = 59 Staff = 58	Yes	Yes	NA	No
	Kralewski 2008 (42)	Survey	N=27 practices	No	NA	NA	No
Clinical Decision Supports (Oncology)	None identified						
Clinical Decision Supports (Non-oncology)	Tamblyn 2008 (48)	Cluster RCT	Automated CDS = 14 On-demand CDS = 14	Yes	Yes	Intervention = No Outcome = Yes	No
	Johnson 2010 (49)	RCT	SYW on = 57 days SYW off = 62 days	Yes	Yes	Yes	No
	Taylor 2004 (50)	Prosp Cohort	N=30	Yes	NA	NA	No
	Ko 2007 (51)	Survey	Physicians = 258 Pharmacist = 84	Yes	NA	NA	No
	Weingart 2011 (52)	Retro Cohort	N=229,663 alerts	Yes	NA	NA	No
	Riedmann 2011 (53)	Prosp Cohort	N=69	Yes	NA	NA	No
	Weingart 2003 (54)	Retro Cohort	N=3481 alerts	Yes	NA	NA	No
	Grizzle 2007 (55)	Retro Cohort	N=291,890 alerts	Yes	NA	NA	No
	Shah 2006 (56)	Prosp Cohort	N=18,115 alerts	Yes	NA	NA	No

CDS=clinical decision support; N=number; NA=not applicable; NP=not possible (e.g., to blind a handwritten vs. computer-generated prescription); NR=not reported; pros=prospective; RCT=randomized controlled trial; SYW=show your work; retro=retrospective

Outcomes

1. Does ST CPOE decrease medication errors in chemotherapy prescribing, and if so, what types of errors does it decrease?

Five studies demonstrating that CPOE decreases chemotherapy medication errors in the adult outpatient setting (17-21) were identified. Two were two-arm trials comparing errors from manual orders and CPOE at the same time (17,20), and three compared the error rate before and after CPOE implementation (18,19,21). All reported error reduction for at least some types of errors. For the sake of consistency, the percentage of a given type of error, when the information is provided, was calculated using the number of prescriptions in each arm as the denominator, rather than the number of errors. Percentages were recalculated, when needed, to ensure this consistency within and across each of the studies that provides this information.

Huertas-Fernandez et al. (17) compared manual (N=30) and computerized (N=30) prescriptions during one month in the medical oncology department of a university hospital. The chance of at least one error in a manual prescription was 100% compared to 13% in a computerized prescription ($p<0.001$). The median number of errors in manual versus computerized prescriptions was 5 versus 0 ($p<0.001$). The most common errors were errors of omission in manual compared to computerized prescriptions, including patient name ($p=0.0037$), age ($p<0.001$), height ($p=0.0393$), physician name ($p=0.0037$), physician signature ($p<0.001$), diagnosis ($p<0.001$), administration frequency ($p<0.001$), and duration of infusion ($p<0.001$) (Table 4).

Small et al. (20) also compared manual (N=602) and computerized (N=1339) prescriptions of complex chemotherapy prescriptions. The error rate in manual orders was 20.4%, and in computerized orders 11.8%. This represents an overall relative-risk (RR) reduction for errors of 42% (RR, 0.58; 95% CI, 0.47 to 0.72; $p<0.0001$). Moreover, the types of errors found differed significantly according to the prescription method ($p<0.001$). Specifically, computerized prescribing was associated with fewer dose or frequency errors, incomplete prescriptions, and unnecessary additional agents (Table 4). Small et al. (20) also categorized each prescribing error according to severity (minor, significant, serious, and life threatening). As a proportion of the total errors, computerized prescribing was associated with fewer minor errors (36.6 vs. 16.5%; p=not reported [NR]). Overall, the severity of errors differed significantly according to prescribing method ($p=0.001$). However, the direction of that effect is not reported and is not obvious, given the data reported (Table 4).

Voeffray et al. (19) evaluated prescribing errors for 15 months prior to CPOE implementation and 21 months following CPOE. The error rate pre-CPOE was 15%, and the error rate post-CPOE was 5%. Interestingly, 92% of the post-CPOE errors were found in prescriptions that were still being handwritten, because the prescribing module was not yet available for all prescriptions. The post-CPOE error rate was 1% when only the computerized prescriptions were included in the calculation. These authors (19) also categorized errors as either major or minor. Pre-CPOE, 19% of errors were major, and 81% of errors were minor, whereas, post-CPOE, all errors were minor (Table 4). They calculate the monthly average error rate to be 13.1% pre-CPOE and 0.6% post-CPOE, representing a 22-fold reduction in error rate.

Table 4. Error rates for manual and CPOE prescribing systems in the oncology setting.

METHOD	STUDY	N Prescriptions	OVERALL ERRORS (%)	ERRORS BY TYPE - Manual vs. CPOE (%, p-value)
2-arm Trial	Huertas Fernandez 2006 (17)	Manual = 30 CPOE = 30	100 13 p<0.001	**Errors of Omission (in favour of CPOE)** Patient Name – p=0.0037 Age – p<0.001 Height – p=0.0393 Physician Name – p=0.0037 Physician Signature – p=0.0037 Diagnosis – p<0.001 Administration Frequency – p<0.001 Duration of Infusion – p<0.001
	Small 2008 (20)	Manual = 602 CPOE = 1339	20.4 11.8 RR=0.58, p<0.0001	**Types of Errors** Dose or frequency errors – 6.8 vs. 1.9, <0.001 Incomplete prescriptions – 4.3 vs. 0.4, p=NR Unnecessary additional agents – 1.8 vs. 0.07, p=NR Cycle number or stage errors – 2.5 vs. 5.6, p=0.003 Wrong data entered – 0.7 vs. 1.0, p=NR **Severity of Errors** Minor – 36.6 vs. 16.5, p=NR Significant – 32.5 vs. 35.4, p=NR Serious – 25.2 vs. 41.8, p=NR Life threatening – 5.7 vs. 6.3, p=NR OVERALL – p=0.001
	Beer 2002 (22)	Manual = 696 CPOE = 140	7.14 7.47, p=ns	NR
Pre/Post Implementation	Voeffray 2006 (19)	Pre-CPOE = 940 Post-CPOE = 1505	15 5	**Pre-CPOE** Minor Errors – 81 Major Errors – 19 **Post-CPOE** Minor Errors - 100 Major Errors - 0
	Kim 2006 (18)	Pre-CPOE= 1259 Post-CPOE = 1116	NR	**Types of Errors** Improper dosing on orders – 2.3 vs. 0.6, p=NR Incorrect dosing calculations – 5.8 vs. 0.54, p=NR Missing cumulative dose calculations – 18 vs. 5.7, p=NR Incomplete nursing checklists – 4.8 vs. 2.5, p=NR Matching order and treatment plans – 1.1 vs. 6.0, p=NR Improper dosing on treatment plans – 4.0 vs. 2.63, p=NR
	Collins & Elsaid 2011(21)	Pre-CPOE = 412 Post-CPOE = 126	CPOE results in reduction in prescribing errors OR=0.31; 95% CI: 0.11-0.89, p=0.023	**Errors in Clinical Decision Making** Wrong dosing schedule/duration – 3.2 vs. 0.0, p=NR Dose that likely leads to high serum levels– 0.7 vs. 0.8, p=NR Dose that likely leads to low serum levels – 0.5 vs. 0.8, p=NR Dose that exceeds max range for the indication – 0.5 vs. 0.0, p=NR **Errors in Transcription** Omission or unclear drug name, route of administration – 0.2 vs. 0.0, p=NR **Errors related to Prescribing Policy** Prescribing policy not followed – 3.6 vs. 1.6. p=NR

CPOE=computerized prescriber order entry; max=maximum; NR=not reported; RR=relative risk; vs.=versus.
Shaded = types of errors that increased after CPOE implementation.

Collins and Elsaid (21) report on the prescribing errors for oral chemotherapy in an in-patient setting for a 24-month period prior to CPOE implementation and six months after implementation. They report that the implantation of CPOE significantly reduced the risk of prescribing error by 69% (odds ratio [OR], 0.31; 95% CI, 0.11 to 0.86; p=0.023). Errors were divided into three categories: errors in clinical decision making; errors in transcription; and errors related to prescribing policy, but significance levels for individual types of errors are not reported (see Table 4).

2. Does ST CPOE generate new errors, and if so, what types of new errors?

Oncology Setting

Four studies that demonstrated that CPOE may increase chemotherapy medication errors in the adult outpatient setting were identified (18,20-22). Small et al. (20) report that the types of errors found differed significantly according to the prescription method (p<0.001). Computerized prescribing was associated with greater cycle number or stage errors and instances of wrong data entered (e.g., height, weight). These authors also categorized each prescribing error according to severity. Serious errors were defined as those errors that might cause either harm or significant undertreatment. Such errors were not considered to be fatal. Some examples include the wrong regimen for the right indication, overdoses (<50% above the required dose), subtherapeutic single doses for curative treatment, and inadequate prophylaxis for severe toxicities. Life-threatening errors were defined as those errors that have the potential to result in death. Some examples include overdoses (>50% above the required dose), repeating an order for three-weekly chemotherapy regimen within only seven days of administration, the wrong chemotherapy regimen for potentially curative treatment, and insufficient rescue medication for high-dose chemotherapy. CPOE was associated with more serious (25.2 vs. 41.8%; p=NR), significant (32.5 vs. 35.4%; p=NR, and life-threatening (5.7 vs. 6.3%; p=NR) errors than was manual prescribing, although it is unknown if these differences are statistically significant as p-values are not provided (Table 4).

Beer et al. (22) took a different approach in that they measured pharmacist intervention rate, which was defined as any problem with a medication order that required physician clarification before the pharmacist could process that order. There was no statistically significant difference in the intervention rates for manual versus computerized orders (7.14% vs. 7.47%; p=ns) (Table 4). Unlike Small et al. (20) , Beer et al. (22) do not provide any information regarding the types of errors found or the types of interventions needed with respect to the chemotherapy orders. Neither of these papers (20,22) refer to any specific prescriber or system features that may have contributed to the increase in errors and/or interventions reported.

Kim et al. (18) evaluated CPOE in the pediatric setting using a pre-/post-CPOE implementation design. Compared to 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 this is statistically significant.

Collins and Elsaid (21) report on the prescribing errors for oral chemotherapy in an in-patient setting for a 24-month period prior to CPOE implementation and six months after implementation. After CPOE implementation, there were more errors with respect to doses that would likely lead to high (0.7 vs. 0.8%) or low (0.5 vs. 0.8%) serum levels. The significance levels for these types of errors are not reported (Table 4).

Non-Oncology Setting

One paper (23) was identified that looked at the consequences of computerization on general practice in Australia. They report a few unanticipated consequences such as performing more Pap tests, ordering more HbA1c tests, and providing more referrals of diabetic patients to ophthalmologists. No consequences involved medication prescribing.

3. What is the impact of ST CPOE on practice?

QUANTITATIVE STUDIES

Oncology Setting

Two studies were identified that measured the impact of CPOE on practice (22,24). Beer et al. (22) evaluated the effect of CPOE on pharmacy practice. In this two-arm trial comparing manual to computerized chemotherapy prescribing, pharmacist intervention rates were measured (see results of Question 2 above) as well as the time needed for the pharmacist to review each order. All medications listed on a given prescription for a given patient were considered to be one order regardless of the number of medications listed on that prescription. The amount of time to review each order was measured by stopwatch. 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 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; $p<0.0001$), computerized prescriptions required significantly more pharmacist review time than did manual prescriptions.

Khajouei et al. (24) compared the effect of predefined order sets versus no order sets on the efficiency of chemotherapy prescribing within a CPOE system. Ten hematology/oncology physicians were provided a clinical scenario and asked to order medications, using a predefined order set and not using the order set, in a counter-balanced design. Optimally, the predefined order set required 61 keystrokes and mouse clicks, and the situation without an order set required 86. These authors counted the number of excess keystrokes and mouse clicks made by each physician when they were placing the medication order, and report that there was a significantly lower number of excess keystrokes and mouse clicks when the medication order was placed using a predefined order set ($p<0.01$). These authors (24) also evaluated the usability problems associated with each type of medication ordering (with vs. without a predefined order set) and report that there were fewer usability problems overall with order sets compared to without order sets. Furthermore, there were a significantly fewer mean number of major (3.78 vs. 5.11; p=NR) and catastrophic (0.67 vs. 3.11; p=NR) usability problems per physician when using order sets.

Non-Oncology Setting

One systematic review of various aspects of CPOE systems contained a section evaluating the effect of CPOE on practice, specifically time (25). They evaluated one oncology-specific RCT (22) that is reported separately in this report (see Question 4 – Oncology Setting). The results of the non-oncology studies found that the time for direct and indirect patient care increased after the implementation of a CPOE system, although an observational study demonstrated that physicians did not perceive that electronic prescribing was more time consuming than manual prescribing.

Four studies comparing CPOE to no CPOE that evaluated the effect of CPOE on practice (26-29) were identified. Hollingworth et al. (26) conducted a time-motion study of

electronic (e)-prescribing and found that, on average, e-prescribers spent significantly less time on writing tasks than did manual prescribers (weighted mean difference =-3.0 min/hr; 95% CI, -5.6 to 0.2; $p<0.05$), and e-prescribers spend significantly longer time on computer tasks than did manual prescribers (weighted mean difference=3.9 min/hr; 95% CI, 0.3 to 7.5; $p<0.05$). Overall, e-prescribing tasks took slightly longer than did manual prescriptions (adjusted mean difference = 12.0 seconds; 95% CI: -1.6 to 25.6, p=nonsignificant [ns]), although this difference was not statistically significant. Moreover, these authors report that e-prescribing did not significantly disrupt prescriber or staff workflow related to a variety of tasks, including but not limited to talking to colleagues, phoning colleagues, talking to patients/family, examining charts, and phoning patients. Devine et al. (27) also conducted a time-motion study and found that e-prescribing took longer than manual prescribing in the primary care setting (mean adjusted difference per prescription = 25 seconds; 99.5% CI, 12.0 to 38.0; $p<0.01$).

Wang et al. (28) carried out a survey of the perceptions of primary care physicians, both e-prescribers and non-e-prescribers. E-prescribers were significantly more likely than non-e-prescribers to feel that the information they had available about a patient's medication history (a) enabled them to identify clinically important potential drug-drug interactions (83 vs. 67%; $p=0.004$) and (b) prevented calls from pharmacies regarding potential safety issues (68 vs. 53%; $p=0.02$). Moreover, e-prescribers 'agreed' or 'strongly agreed' that e-prescribing: was easy to use (79%), made their work simpler (53%), made work easier for staff (49%), and increased productivity (40%).

Duffy et al. (29) conducted a pre-/post-e-prescribing study in the family medicine setting. One year after the implementation of e-prescribing, there was a 22% reduction ($p\leq0.05$) in after-hours calls, especially with respect to upper respiratory infections, fever, nausea, vomiting, and diarrhea, and an 81% increase in calls related to medications ($p\leq0.05$). These authors also conducted a survey of e-prescriber satisfaction and found that, whereas 71% respondents agree that e-prescribing takes less time than does manual prescribing, and 75% agree that e-prescribing leads to fewer prescription errors than does manual prescribing, only 29% agree that e-prescribing reduces within-office-hours medication questions, callbacks, and workload compared to manual prescribing, and only 44% agree that e-prescribing reduces after-hours medication questions, callbacks and workload compared to manual prescribing.

One study that undertook a survey which compared e-prescribing in integrated versus stand-alone systems (30) in the outpatient setting was identified. Physicians using an integrated system (i.e., integrated with an electronic health record [EHR]) were significantly more likely to report that they e-prescribe most or all of the time (78 vs. 58%; $p<0.001$). They also report that those prescribing within an integrated system found it easier to reconcile a patient's medication list (80 vs. 50%; $p<0.001$) and found that there were fewer calls from pharmacies regarding prescribing errors ($p=0.005$).

Four non-comparative surveys of community pharmacists and/or pharmacy personnel views on e-prescribing were identified (31-34). Rupp and Warholak (31) surveyed 1094 pharmacists, technicians, and student interns in 276 chain community pharmacies in six states in the United States (response rate = 65%). Respondents rated e-prescribing more favourably than manual prescribing for the following outcomes with respect to workflow and communication: efficiency of patient care, communication with patients, communication with prescribers, overall relations with patients, and overall relations with prescribers.

Tan et al. (32) surveyed 118 doctors and 61 pharmacy staff (response rate not reported) in Singapore about their perceptions regarding e-prescribing. The majority of the physician respondents expressed satisfaction with several workflow issues, including the ability to create a new prescription, review prescription history, track health maintenance

items, and amend prescriptions, as well as the speed of the system and the time required to enter prescription or patient information. A smaller majority of pharmacy personnel expressed their satisfaction with workflow issues pertinent to them, including the ability to download new prescriptions, read and understand the prescriptions, recall previously dispensed prescriptions, and process prescriptions, as well as the time required to process prescriptions and prescription amendments.

Hammar et al. (33) surveyed 500 community pharmacists in Sweden about their perceptions of e-prescribing and achieved a 52% response rate (N=259). Most respondents perceived that e-prescribing improved relationships with patients (81%) and prescribers (62%) and improved communication with patients (87%) and prescribers (65%).

Rahimi and Timpka (34) surveyed 74 Swedish pharmacists in one municipality regarding their perceptions of e-prescribing. The response rate was 70% (N=52). The majority of respondents reported that e-prescribing was useful for several workflow issues, including but not limited to reducing calls because of both incomplete and ambiguous prescriptions, faster prescription-processing time, overall time savings, ease of accessing e-prescribing systems, and ease of entering data into e-prescribing systems. The most important barrier to the acceptance of e-prescribing technology was the loss of working time to computer-related problems.

QUALITATIVE STUDIES

Five qualitative studies pertaining to the impact of CPOE on practice were identified (35-39). They are briefly summarized in Table 5 below. These studies used various qualitative methods including interviews, focus groups and grounded theory to identify the impact of CPOE on practice. Collectively, many issues were identified that facilitate (ex. ease of changing doses and renewing prescriptions) and impede (ex. security concerns, duplication of work) practice particularly with respect to workflow. Understanding the impact of these issues may help in implementation of CPOE.

Table 5: Qualitative papers pertaining to the impact of CPOE on practice.

STUDY	TYPE OF STUDY	PARTICIPANTS	THEORETICAL FRAMEWORK STATED	OUTCOME(S)
Kozakiewicz 2005 (35) (oncology setting)	FMEA	Multidisciplinary team including: Clinical Pharmacist Oncology Nurse Manager Staff Oncology Nurse Oncology Clinical Nurse Specialist Information Service Representative	Yes	Developed a uniform and safe chemotherapy ordering system.
Ash 2007 (36)	Interviews Grounded Theory	Not specified	Yes	Workflow issues identified include: • Security concerns depending on the location of the computer stations • Duplication of work • Discomfort of IT personal when having to fix a computer in an exam room with a patient in the room • Having to work through lunch, which also leads to loss of socialization time • Easier identification of workflow weaknesses • Tension among those who planned the implementation of the system
Weingart 2009 (37)	Focus Groups	Clinicians	No	Workflow issues identified included: • Ease of changing doses • Ease of renewing prescriptions • Assurance of legibility • Ease of sending prescriptions to pharmacies • Unreliability of successfully sending prescriptions to pharmacies • Inability to merge patient entries • Inability to get a patient's full medication list no matter who the prescriber • Inability to enter allergy information • Inability to write prescriptions for commonly ordered medications
Agarwal 2010 (38)	Focus Groups Direct Observation Semi-structured Interviews	Physicians Practice managers Nurses Other medical staff	No	Technological viewpoints can either facilitate or impose barriers on the effective use of e-prescribing. Understanding the impact of these viewpoints may help in any technological implementation
Lapane 2011 (39)	Focus Groups	Clinicians Office staff	No	The perceived efficiencies of e-prescribing such as knowing formularies, processing refills, and decreased errors were realized once e-prescribing was implemented.

4. What are the strategies than enhance or limit implementation of ST CPOE?

QUANTITATIVE STUDIES

Oncology Setting

No studies of the implementation of ST CPOE in the oncology setting were identified that met the criteria established.

Non-Oncology Setting

Three studies were identified that looked at strategies that enhance or impede the implementation of CPOE (40-42). Paré et al. (40) evaluated the effect of a new construct known as 'psychological ownership' on physicians' acceptance of CPOE technology. They surveyed 125 physicians currently using a CPOE system and achieved a response rate of 73% (N=91). Their results indicate that in order to foster physicians' adoption of the new technology, a positive attitude toward that new system must be developed. Specifically, physicians who had acted as system 'champions' during CPOE implementation were found to have significantly stronger feelings of ownership of the new system than were non-champions ($p=0.001$). Compared to non-champions, champions also had significantly higher scores on perceived usefulness ($p=0.021$) and perceived ease of use ($p=0.04$) of the CPOE system and attitudes ($p=0.036$) towards this technology.

Devine et al. (41) conducted a survey of prescribers and staff in a large independent medical group to assess their attitudes towards e-prescribing as they transitioned from paper to CPOE, in order to inform strategies to increase successful adoption of the technology. The survey was sent to 188 respondents and achieved a 62% response rate. They found that prescribers (but not staff) who used a computer at home for professional reasons improved scores on several domains, including intent to use ($p=0.01$), perceived usefulness ($p=0.001$) and perceived ease of use ($p=0.02$). Moreover, self-assessed computer knowledge improved scores on perceived usefulness ($p=0.01$) and perceived ease of use ($p<0.001$).

One other study looked at specific variables (physician, structural, and cultural) that affect physician use of e-prescribing technology (42) in 27 primary care medical group practices that had e-prescribing available. They report that the only physician variable that influenced the use of computerized prescribing was speciality. Specifically, family physicians and pediatricians had higher use rates than did internists ($p=0.001$). Two practice structure features significantly influenced CPOE adoption rates; practice size and multispecialty practices. In particular, larger practices had higher adoption rates ($p=0.02$), as did practices with more than one specialty ($p=0.03$). Finally, several cultural characteristics of the practice affected CPOE adoption rates. Specifically, adoption rates were higher in practices that had high levels of organizational trust ($p=0.04$) and a business approach to decision making within the practice ($p=0.00$) and that valued physician autonomy ($p=0.01$) and adaption to change ($p=0.00$). Conversely, practices that highly valued cohesiveness had lower CPOE adoption rates ($p=0.02$), as did those that valued quality of care ($p=0.05$).

QUALITATIVE STUDIES

Five qualitative studies pertaining to strategies that enhance or limit the implementation of CPOE were identified (43-47) and are briefly summarized in Table 6. These studies used various qualitative methods including interviews, focus groups and process evaluation. Several of the more in-depth studies focus on key components of successful CPOE implementation and include but are not limited to involving stakeholders in decision making to ensure ownership and empowerment, providing on-site training and support prior to implementation and providing on-going customized support and maintenance after implementation.

Table 6: Qualitative papers pertaining strategies that enhance or limit implementation of CPOE.

STUDY	TYPE OF STUDY	PARTICIPANTS	THEORETICAL FRAMEWORK STATED	OUTCOME(S)
Ash 2003 (43)	Consensus Statement	Experts in CPOE	No	Considerations to guide CPOE implementation: • Motivation for implementation • CPOE vision, leadership and personnel • Cost • Integration: workflow, health care processes • Value to users/Decision support systems • Project management and staging of implementation • Technology • Training and Support 24/7 • Learning/Evaluation/Improvement
Ash 2005 (44)	Semi-structured Interviews Focus Groups Observation	Physicians Nurses Pharmacists IT staff Administrators Others	No	Twelve themes were generated from the data that included both inpatient and outpatient data. Authors conclude that the key to successful CPOE implementation is to maximize the upsides, minimize the downsides and have a plan on how to manage unintended consequences.
Greenberg 2006 (45) (oncology setting)	Descriptive Paper	Cancer institutions in Ontario	No	Key components to success: • Have a fully staffed project team • Get support of clinical and administrative leadership • Involve stakeholders in decision making to ensure sense of ownership and empowerment • Provide in-depth, on-site training • Involve on-site pharmacists in the set-up of the system • Test the system extensively • Provide on-going customized support and maintenance
Crosson 2008 (46)	Multi-method Qualitative Case Study	Practices scheduled for implementation of e-prescribing	No	Implementation must be carefully planned. E-prescribing users should be aware of the effects on their prescribing systems and workflow. High-quality technical support should be provided. Plan changes to prescription workflow before implementation.

Hoffman 2011 (47)	Process Evaluation	Clinical Informatics Specialists Physicians Physician Assistants Nurse Practitioners Nurses Pharmacists	No	Key components to success: • Commitment to the priority of patient safety by the organization and department leaders as well as staff. • Appropriate resources for safe implementation of CPOE including support to respond promptly to issues that arise during implementation. • Dedication and collaboration among the healthcare and technical support providers involved. • Process redesign undertaken by a multidisciplinary team of healthcare and technical providers. • Use of risk assessment tools (ex., FMEA) • Logical step-wise implementation rather than an all-at-once approach. • Use of existing paper order sets to structure the electronic versions of each regimen. • Development of electronic order sets by multidisciplinary teams. • Sufficient functionality that allows for continuous review of a given order set; sequence order sets based on an anchoring order. • Sufficient flexibility so that not only can the process adjust to the software but also so that the software can adjust to the process. • Staff trainers should be included in the process redesign and development processes. • Continuous (24/7) support for staff after each go-live stage until all staff is comfortable with the new system.

5. What are the types of clinical decision supports and how can they be effective or ineffective?

QUANTITATIVE STUDIES

Oncology Setting

No studies of effective and ineffective clinical decision supports within a CPOE system were identified that met the criteria established.

Non-Oncology Setting

Two RCTs of computerized decision supports (CDS) (48,49) were identified. Tamblyn et al. (48) conducted a cluster RCT in primary care. They randomized physicians to either automated or on-demand drug CDS. Physicians could set and change the severity level of the alerts they wished to view (Level 1 – definite and serious adverse effect; Level 2- likely adverse effect; and Level 3 – possible adverse effect). In the on-demand group, CDS was requested for 0.9% of the prescribing problems identified. The prescription was altered 75.6% of the time. In the automated arm, 10.3% of the alerts were seen, and prescriptions were altered 12.1% of the time. Most of the alerts were either ignored or not even seen in either group.

Johnson et al. (49) performed an RCT designed to bridge the gap that exists in the communication between the prescriber and the pharmacist. They implemented a "Show Your Work" (SYW) system that attaches alerts and any override comments to the e-prescription. They compare CPOE with and without SYW. There was no difference in the callback rate with or without the SYW system in place (p=ns).

Four non-comparative studies of CDS were also retained (50-53). Taylor and Tamblyn (50) evaluated the reasons for physician non-adherence to drug alerts in general practitioners. They found that 55% of drug alerts were ignored. Most of these pertained to toxicity, potential allergic reactions, therapeutic duplication, and known drug intolerances. The two most often cited reasons for ignoring alerts were that the interaction was already known and/or the alert was not clinically relevant. These two reasons were cited for 79% of all ignored alerts.

Ko et al. (51) conducted a survey designed to elicit physician and pharmacist opinions on computerized drug-drug interaction alerts in the Veteran's Affairs system in the United States. Response rates among physicians and pharmacists were 36% and 59%, respectively. Although the order differed, both groups agreed that the top three changes to drug-drug interaction alerts should be to (1) make it more difficult to override lethal interactions, (2) display alerts one time for each patient, and (3) provide management options for an alert.

Weingart et al. (52) evaluated whether or not physicians were more likely to accept drug-drug interaction alerts that had been judged to be clinically important by a group of experts. They convened a group of five experts to rate a series of drug-drug interaction alerts. Unfortunately, inter-rater reliability among the experts was quite low (Kappa ≤0.40 for all seven attributes they measured, with four of these being ≤0.20). They then compared the expert panel results to how 2872 clinicians, who generated 229,663 electronic drug-drug interaction alerts over the course of one year, responded. The clinician alert acceptance rate increased 2.7% for alerts that the expert panel determined would result in an adverse event, 2.3% when the physician lacked prior knowledge of the information provided by the alert, and 3.3% when the physician could easily act on the alert.

Riedmann et al. (53) used a two-round Delphi approach to determine how to improve the delivery of drug alerts in a CPOE system. They invited 214 CPOE experts to participate, but only 34.1% participated in the first round and 32.2% in the second round. Of those who participated in both rounds, only 36.2% were healthcare providers who actually used CPOE.

The top five context factors for prioritizing and filtering alerts were (1) severity of the adverse event, (2) clinical status of the patient, (3) probability of the adverse event occurring, (4) patient risk factors, and (5) strength of the evidence for the alert. They also determined that the best ways to deliver alerts and reduce adverse events were through an active alerting system and a proactive prescription simulation. They estimate that 25% of adverse drug events could be averted if these two methods of alerting are implemented.

Two retrospective studies of computerized drug alerts were identified (54,55). Weingart et al. (54) reviewed 3481 drug interaction and drug allergy alerts generated over a three-month period. The report that physicians overrode 91.2% of the drug allergy alerts and 89.4% of the high-severity drug-drug interaction alerts. Interestingly, 36.5% of the alerts were deemed to be inappropriate by two physician reviewers.

Grizzle et al. (55) retrospectively reviewed 291,890 drug-drug interaction alert overrides at six Veteran's Affairs Medical Centres in the United States over a one-year period of time. Override reasons were sorted into 14 categories and then rated as to whether it was clinically useful or not to the pharmacist in determining the potential for an adverse event. Seventy-two percent of the alerts were considered critical, and 20% of the override reasons for these critical drug alerts were considered to be clinical useful to the pharmacist for order verification. Interestingly, 53% of the responses to the reason for override were "no reason provided."

Finally, Shah et al. (56) tried to improve clinician acceptance of drug alerts by designating only the critical/high severity (Level 1) alerts to be interruptive. Specifically, these alerts interrupted workflow in that physicians could not proceed with the prescription order without eliminating the contraindication. Level 2 and 3 alerts were non-interruptive. Level 2 alerts could be overridden as long as a reason for the override was provided. Level 3 alerts were displayed but did not require any action on the part of the physician. Sixty-seven percent of the interruptive drug alerts were accepted by physicians. These authors present a list of recommendations for improved alert acceptance as follows:

- Minimize workflow interruptions by presenting only the most relevant contraindications and mandating an interruption to workflow only for high-severity alerts.
- Minimize false-positive alerts by keeping alerts up to date based on the most current literature.
- Cancel versus modify actions. There should be recognition when evaluating clinical decision support that any modification that eliminates the contraindication represents acceptance of that alert.
- Facilitate clinician actions by including automatic ways in the system for clinicians to eliminate a drug contraindication.
- Collect override reasons. A clinician may have a good reason overriding an alert. This information should be collected and used in revisions to the alert system.
- Create a central repository of knowledge-base information for public sharing.

QUALITATIVE STUDIES

Six qualitative studies pertaining to effective and ineffective clinical decision supports were identified (36,37,57-60) and are summarized in Table 7. These studies used various qualitative methods including interviews and focus groups. Many of these studies identified similar issues with alerts including receiving too many alerts that may be perceived to be clinically trivial and disruptive leading to alert fatigue and ignoring of alerts. Alerts must be carefully chosen such that only those that are most likely to benefit patients are generated.

Table 7: Qualitative papers pertaining to effective and ineffective clinical decision supports.

STUDY	TYPE OF STUDY	PARTICIPANTS	THEORETICAL FRAMEWORK STATED	OUTCOME(S)
Ash 2007 (36)	Interviews Grounded Theory	Not specified	Yes	Alerts issues identified include: • Receiving too many alerts • Receiving alerts at inappropriate times
Lapane 2008 (57)	Focus Groups	Prescribers Staff	No	To improve overriding of alerts, prescribers recommend the following changes: • Increase the specificity of the alerts • Allow prescribers to set the severity threshold for alerts • Keep drug alert algorithms up to date by running them against current medication regimens
Vaziri 2009 (58)	Workshop	Primary care practitioners System developers Information suppliers Academics	No	• Clinicians are frustrated by unnecessary alerts. It draws their attention away from other important information • Alerts are disruptive • Alerts are often cancelled before even being read • Clinical risk assessment might be a method of choosing the alerts that are most likely to have the greatest patient benefit
Weingart 2009 (37)	Focus Groups	Clinicians	No	Alerts issues identified included: • Too many drug allergy and drug interaction alerts • Too many clinically trivial alerts • Too many alerts generated for interactions with out-of-date medications • Habitual ignoring of alerts • Alerts most helpful when clinician was unfamiliar with either the drug or the patient • Alerts prompted clinicians to advise patients about potential medication side effects, to check examination findings or to order laboratory tests • Unwillingness to forgo receiving alerts because they did not want to miss anything that was potentially important.
Riedmann 2011 (59)	Semi-structured Telephone Interviews	Experts in CPOE	No	Context factors related to alerts that were identified were the severity of the effect and the strength of the evidence for the alert.
Robertson 2011 (60)	Semi-structured Interviews	General Practitioners General Practitioner Trainees	No	• Clinical decision support systems (CDSSs) need to take into account the time pressures of practice and the need to integrate information systems that complement the practitioner's clinical needs as well as their patterns of practice. • High quality, inexpensive and continuously updated resources need to be available to everyone. • Incentives and/or a national strategy may be required.

ONGOING TRIALS

No studies identified to date have been prospectively planned clinical trials. Therefore, it is difficult to search for ongoing studies that would meet the inclusion criteria for this review, because there is no relevant registry or database containing this information.

DISCUSSION

Patient safety has garnered much attention for many years, particularly since the 1999 Institute of Medicine (62) report estimating that, in the United States alone, 80,000 people are hospitalized and 7000 die every year owing to medication errors in the inpatient setting, many of which are preventable. CPOE is one promising technology for the reduction of medication errors in both inpatient and outpatient settings. Medication errors in the oncology setting can be particularly serious given the toxicity of chemotherapeutic agents. The results of this systematic review have clearly demonstrated that there is a paucity of oncology-specific CPOE literature. Most studies take place in non-oncology inpatient settings, likely because this is where CPOE was first taken up. The few studies that are available demonstrate that CPOE in the oncology setting does reduce medication errors (17-21) but the potential for increased errors also exists (18,20-22). Therefore, the CPOE system, CDS, and associated interface design elements must be carefully designed to reduce the potential for error. Moreover, vigilance in the form of constant monitoring and updating of systems must be maintained. Studies that demonstrate specific types of error generation are useful for identifying deficiencies that can be fixed either through technical changes (i.e., computer programming) or process changes.

CPOE can also have an impact on practice, particularly workflow and communication between healthcare professionals as well as between healthcare professionals and patients. Unfortunately, these studies do not show consistent results, probably reflecting the true nature of how things work in a real-world situation. In the oncology setting, Beer et al. (22) demonstrated that computerized prescriptions took pharmacists longer to review than did manual prescriptions even if there were no problems with the prescription (a negative impact), whereas Khajouei et al. (24) found that using predefined order sets resulted in less key strokes and fewer usability problems than did not using order sets (a positive impact). Several non-oncology studies also found that e-prescribing had a negative impact on workflow in terms of time and workload (25-27,30), whereas other studies reported a positive impact with respect to time and workload (28,31,32,34), productivity (28), and communications (31,33). One study reported both a positive and negative impact on different aspects of time and workload (29). The results of the qualitative studies (37-39) are similar to the empirical evidence. The totality of this evidence reveals that CPOE, as with any new technology, will have both positive and negative impacts on practice.

Only a handful of studies have evaluated CPOE implementation in the outpatient setting, either empirically or qualitatively. The empirical studies all look at very different aspects that may affect implementation, including the use of a CPOE 'champion' (40), respondent use of a home computer for work (41), and physician, structural and cultural variables (42). Overall, combined with the qualitative data, some common themes are the need for a strong vision and motivation for introducing CPOE, the involvement of stakeholders in decision making, the provision of in-depth, on-site and ongoing training before and after launch, and setting in place mechanisms to efficiently respond to problems identified by end-users (40,43,45-47).

Many studies looking at CDS systems were identified, both quantitative and qualitative. The overall message when looking at the totality of the data is that most alerts derived by clinical decision support systems are ignored, generally because there are too many of them, and they are not perceived to be clinically relevant (36,48,50,57). This leads

to alert fatigue. Alerts, especially interruptive alerts, need to be carefully chosen to be the most likely to benefit patients, and the clinical decision support systems that generate the alerts need to be constantly updated and refined to achieve this goal (37,58,60).

There are some limitations to this systematic review. The overarching question that sought to identify the features, functionalities, and components that are required to ensure safe and high-quality systemic treatment could not be directly answered, because the research on CPOE does not structure itself in this way. For this reason, several specific questions were asked that were designed to speak to the issues of the global question posed. The current CPOE literature focuses on the role of, and the impact on, physicians and pharmacy personnel. Unfortunately, none of the outpatient literature looks at the impact on the workflow of nurses, which is definitely a limitation in the CPOE research in general that should be considered as an area for future research.

CONCLUSIONS

CPOE with CDS is a promising technology for the reduction of medication errors and potential adverse drug events associated with those medication errors. Based on the review of the literature included in this guideline, the following conclusions are identified:

1. CPOE systems should be used in outpatient chemotherapy delivery to decrease chemotherapy related medication errors. Although the focus of this evidence summary was outpatient CPOE, it is likely that many of the principles in this document would also apply to inpatient CPOE.
2. Clinical, technical, and leadership champions need to be identified to support the use of CPOE within the organization.
3. A multidisciplinary team approach in the design, selection, workflow evaluation, implementation and/or evaluation, and ongoing monitoring of the CPOE system should be used.
4. CPOE processes that compliment current practice and work-flow processes to enhance adoption by clinicians should be ensured.
5. CPOE systems, clinical decision supports, and associated interface design elements must be carefully designed to reduce the potential for error.
6. The development and implementation of a risk-assessment process to identify actual/potential unanticipated consequences and new errors generated, as well as the development of strategies to modify the system accordingly, are warranted.

CONFLICT OF INTEREST

In accordance with the PEBC Conflict of Interest (COI) Policy, the guideline authors, ST CPOE Expert Panel members, and internal and external reviewers were asked to disclose potential conflicts of interest. Three authors declared they had no conflicts. One other (VK) declared conflicts and reported receiving more than $5000 in a single year from honoraria from Roche, Celgene, and Ortho Biotech pharmaceutical companies for talks, educational work and consultancy. However, the topics were unrelated to ST CPOE. In addition, this author has received an NCIC grant for barcoding use for delivering chemotherapy within the past five years.

For the Expert Panel, all members declared they had no conflicts of interest.

The COI declared above did not disqualify any individuals from performing their designated role in the development of this guideline, in accordance with the PEBC COI Policy. To obtain a copy of the policy, please contact the PEBC office by email at ccopgi@mcmaster.ca.

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Appendix 1. Members of the ST CPOE Working Group Panel.

Chair:

Vishal Kukreti	Medical Oncologist	Princess Margaret Hospital, Toronto, ON

Panel Members:

Anne Cheung	Pharmacist	Cancer Care Ontario, Toronto, ON
Roxanne Cosby	Methodologist	PEBC, McMaster University, Hamilton, ON
Sara Lankshear	Nursing	Cancer Care Ontario, Toronto, ON

Appendix 2. Members of the ST CPOE guideline development group

Chair:

Vishal Kukreti	Medical Oncologist	Princess Margaret Hospital, Toronto, ON

Members:

Anne Cheung	Pharmacist	Cancer Care Ontario, Toronto, ON
Roxanne Cosby	Methodologist	PEBC, McMaster University, Hamilton, ON
Garry Cruickshank		eHealth Ontario, Toronto, ON
Jennifer Daley-Morris	Pharmacist	Southlake Regional Hospital, Newmarket, ON
Sherrie Hertz	Clinical Programs	Cancer Care Ontario, Toronto, ON
Sean Hopkins	Pharmacist	Ottawa Hospital, Ottawa, ON
Diana Incekol	Nursing	University Health Network, Toronto, ON
Gregory Knight	Medical Oncologist	Grand River Regional Cancer Centre, Kitchener, ON
Sara Lankshear	Nursing	Cancer Care Ontario, Toronto, ON
Darrilyn Lessels	Clinical Educator	Lakeridge Health Centre, Oshawa, ON
Jonathan Noble	Physician	Sudbury Regional Hospital, Sudbury, ON
Rachel White	Human Factors Specialist	University Health Network, Toronto, ON
Nancy Young	Nursing	Ottawa Hospital, Ottawa, ON

Appendix 3. Literature search strategy.

MEDLINE

1. exp Medical Order Entry Systems/
2. exp Drug Therapy, Computer-Assisted/
3. computerized physician order entry.mp.
4. computerized prescriber order entry.mp.
5. computerized provider order entry.mp.
6. cpoe.mp.
7. or/1-6
8. limit 7 to english language

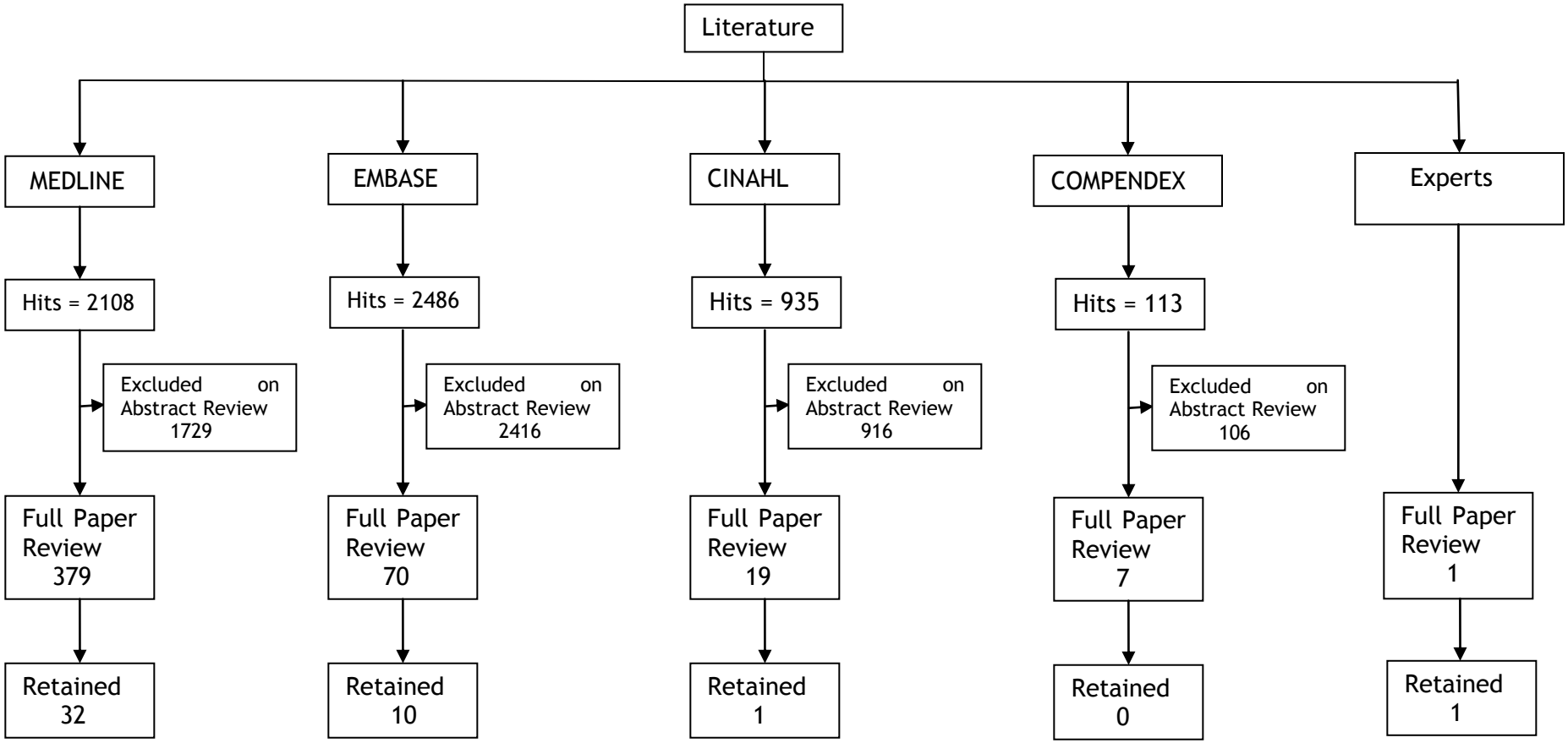
EMBASE

1. exp computerized provider order entry/
2. computerized physician order entry.mp.
3. computerized prescriber order entry.mp.
4. CPOE.mp.
5. MOE.mp
6. medication order entry.mp.
7. exp computer assisted drug therapy/
8. or/1-7
9. limit 8 to english language

CINAHL

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.

COMPENDEX

1. computerized physician order entry OR computerized prescriber order entry OR computerized provider order entry OR medication order entry OR cpoe.

Appendix 4. Flow diagram of literature search results.