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Review Article

Computerized provider order entry in the clinical laboratory

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Abstract

Clinicians have traditionally ordered laboratory tests using paper-based orders and requisitions. However, paper orders are becoming increasingly incompatible with the complexities, challenges, and resource constraints of our modern healthcare systems and are being replaced by electronic order entry systems. Electronic systems that allow direct provider input of diagnostic testing or medication orders into a computer system are known as Computerized Provider Order Entry (CPOE) systems. Adoption of laboratory CPOE systems may offer institutions many benefits, including reduced test turnaround time, improved test utilization, and better adherence to practice guidelines. In this review, we outline the functionality of various CPOE implementations, review the reported benefits, and discuss strategies for using CPOE to improve the test ordering process. Further, we discuss barriers to the implementation of CPOE systems that have prevented their more widespread adoption.

Key words: Computerized provider order entry, laboratory operations, test utilization

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INTRODUCTION

Accurate and efficient clinical laboratory testing is a critical component of high-quality patient care. The laboratory testing process consists of many steps, beginning with test selection and ordering, followed by sample collection and transport, sample processing and analysis, and finally, result reporting and interpretation. Errors or inefficiencies at any step of this testing chain can undermine the entire process and lead to suboptimal patient management. While laboratory staff are heavily involved in managing much of this process, they have traditionally been less directly involved in test selection, leaving the primary responsibility for this key first step to clinicians. However, without sufficient support in test selection, clinicians face several challenges, perhaps the most significant of which is that the menu of available tests has expanded, in both number and complexity, particularly with new molecular assays.[1] Compounding the expanding menu are time pressures placed on physicians. Most clinicians simply cannot be expected to stay up-to-date with every complex test and diagnostic algorithm outside their specialty.[2,3] Clinicians may compensate for not knowing which test to order by ordering many tests, some of which are unneeded, putting patients at risk for wasteful or even harmful follow-up care.[4] Alternatively, clinicians may fail to order needed tests, leading to delayed or incorrect diagnoses.[4-7]

Electronic systems that allow ordering providers to directly input laboratory test orders, known as Computerized Provider Order Entry (CPOE) systems, may provide a key leverage point to improve laboratory test ordering efficiency, laboratory utilization, and patient care. Appropriate implementation and use of CPOE systems can help to overcome many of the aforementioned challenges to test selection. Herein, we present an overview of laboratory CPOE systems,

including descriptions of multiple CPOE features and implementations. We focus on the demonstrated benefits of CPOE and the strategies employed to achieve these benefits. The article is based upon a combination of our experience with the implementation and use of CPOE systems and a review of the literature. Representative studies are cited to illustrate or support key concepts and provide examples of CPOE strategies and benefits.

Computerized provider order entry

Computerized Order Entry refers to a broad class of computer systems that allow clinicians to order diagnostic tests, medications, and other procedures using computer systems at or near patient care areas. Computerized Provider Order Entry (CPOE) differs from other forms of computerized order entry in that a provider with decision-making authority directly enters the test request. Computerized order entry systems that allow non-providers (unit secretaries, assistants) to enter testing requests into the system do not permit many of the ordering support functions discussed in subsequent sections of this review. Providers in CPOE systems are typically physicians, but in many health systems, nurse practitioners and other authorized providers are also able to enter orders. While this article is devoted primarily to the laboratory aspects of CPOE systems, it is important to recognize that the functionality of most CPOE systems extends well beyond laboratory orders. Advanced systems have functionality encompassing virtually every type of order, including medications, nursing instructions, imaging, consultations, and diagnostic procedures.

Computerized provider order entry prevalence

The precise fraction of hospitals utilizing CPOE is not known. In a 2007 report, Sittig *et al*., noted that approximately 10% (448 of 4,500) of United States (US) hospitals listed in the HIMSS analytics database use CPOE systems, per self-report.[8] Federal initiatives in the US, including "meaningful use," may provide financial incentives for the adoption of certain health information technologies, including CPOE.[9,10] In addition, federal healthcare payment reform, with incentives for improved resource utilization and quality, may provide additional motivation for US institutions to adopt CPOE. Outside the US, few surveys of CPOE prevalence have been published. A 2009 review reported that 20% of medical centers in the Netherlands had CPOE and estimated that hospital-wide CPOE is present in less than 2% of hospitals in the United Kingdom and Germany.[11]

Computerized provider order entry configurations

There is wide variability in the features provided by available laboratory CPOE systems.[12] One of the key determinants of the utility and functionality of a given laboratory CPOE system is the ability of the system to interact with other portions of the electronic health record. All CPOE systems must interface with other electronic health record systems to receive up-to-date demographics and visit information. A key additional system that the laboratory CPOE system may interface with is the Laboratory Information System (LIS). The LIS is the system responsible for laboratory data management, and plays a critical role in coordinating laboratory workflow.[13,14] An electronic interface from CPOE to the LIS permits the CPOE system to electronically send orders to the LIS. A CPOE system that is electronically interfaced with the LIS is said to have "order communication." The following section will address the workflow and features of CPOE with and without order communication.

Computerized provider order entry without order communication

Laboratory CPOE modules can be configured and installed without connectivity to the LIS. Even without order communication, CPOE systems may offer many of the benefits discussed in subsequent sections, including the capacity to advise clinicians on test indications, to alert users to redundant orders, and to improve testing workflow. A representative CPOE system lacking order communication is illustrated in Figure 1. As shown, providers place orders for laboratory tests in CPOE but there is no electronic transfer of these orders to the LIS. Clinical support staff may generate a paper requisition and tube labels after review of CPOE orders. The paper requisition and labels may be printed from the CPOE system or a nurse, phlebotomist or assistant viewing the order may fill out a pre-printed paper requisition and manually create labels. Following specimen collection, the labeled sample and paper requisition are sent to the laboratory. After arriving in the laboratory, the samples are manually "accessioned," a process whereby specimen information and test orders are manually entered into the LIS. The LIS can then print unique bar-coded labels for the specimen. The samples must be relabeled with the LIS labels before further processing and analysis can occur.

There are several major drawbacks to CPOE implementations lacking order communication. The primary limitation is that the link between the CPOE and the LIS involves paper and numerous manual steps, which are inefficient and error-prone.[15] The total turnaround time (order to result) for such a system, especially one that involves paper requisitions, is considerable, with numerous staff performing tasks such as filling out requisitions or accessioning specimens that are essentially eliminated in interfaced systems. In addition, by not accessioning specimens until they arrive in the laboratory, such systems do not permit the duplicate test checking, minimum volume calculations, and preferred tube logic that are features of the CPOE-LIS order entry interface.

Computerized provider order entry with order communication

Order communication functionality allows the CPOE system to automatically transmit provider orders to the

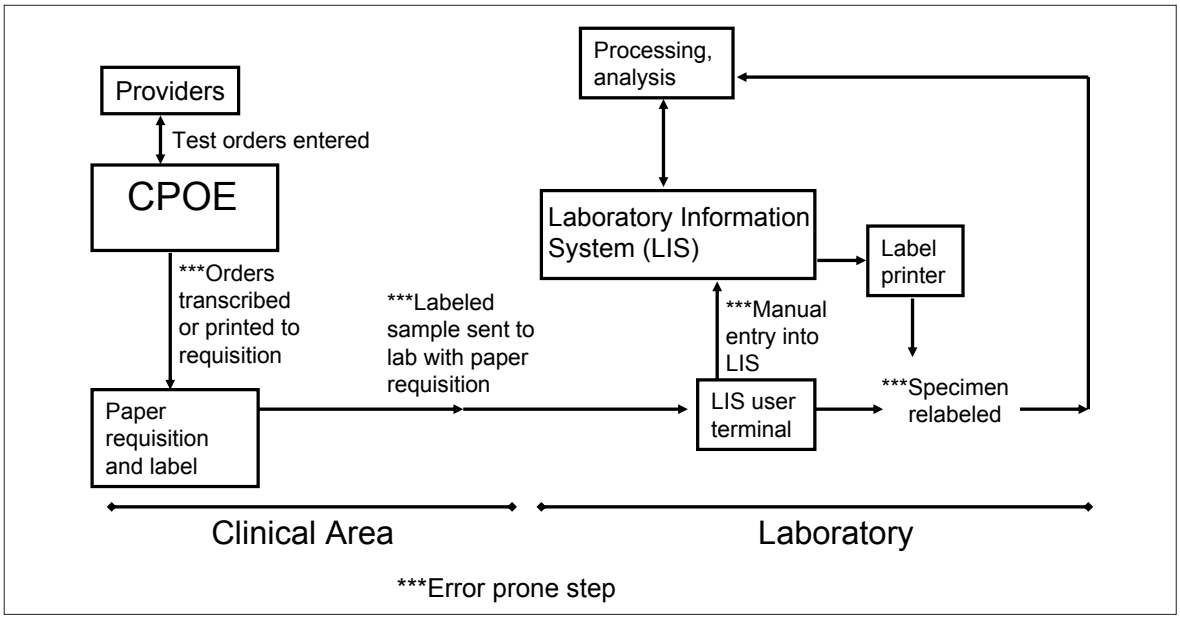

Figure 1: CPOE system lacking order communication functionality. There are several manual and/or paper-based steps in this process that are prone to errors, as noted by asterisks (***) (CPOE, Computerized Provider Order Entry)

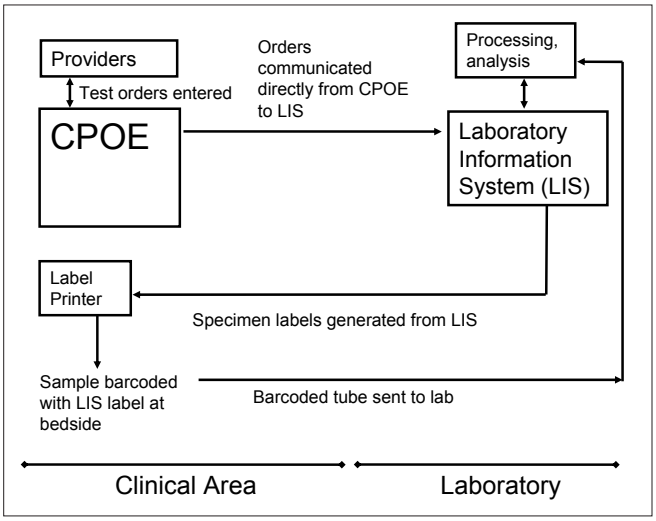

Figure 2: CPOE system with order communication functionality. Compared to Figure 1, this system avoids several potentially inefficient and error-prone steps by directly communicating orders from the CPOE system to the Laboratory Information System (LIS) (CPOE, Computerized Provider Order Entry)

LIS. An example of a system with order communication is shown in Figure 2. This is typically accomplished using an electronic interface based on Health Level 7 (HL7) interfacing standards. HL7 messages are of a standard format and are used widely to communicate certain types of laboratory data, including orders and results, between information systems.

Ordering providers may notice few differences between a CPOE system with order communication and a system without order communication. However, many of the downstream steps are different and the efficiency and quality of the process may be dramatically different. In systems with order communication, the CPOE system directly transmits the order into the LIS, creating an LIS order at the time of CPOE test ordering. In addition, the LIS is able to generate bar-coded specimen labels proximate to the time of specimen collection. The labels produced for bedside labeling correspond to the LIS order, so in-laboratory relabeling is not necessary. Label printers can be located in patient rooms, on handheld devices, or at a central nursing station or phlebotomy center. Handheld devices with label printers are available that can download orders from the LIS and subsequently scan a patient's identification wristband to generate LIS specimen labels at the point of care. An advantage of near-patient labeling is that the collection date and time can be automatically captured by the system and transmitted to the LIS. Once samples have been labeled with LIS bar-coded labels, the specimens only need to be scanned as "received" when they arrive in the laboratory, and are then able to be directly loaded onto automated systems for processing and analysis. In some laboratory automation systems, the specimen receipt process can occur automatically on the pre-analytic module of the automated equipment, further streamlining the process. By eliminating manual steps and leveraging the logic and routing capabilities of the LIS, order communication can reduce the risk of mislabeled specimens, incorrect container types, lost requisitions, and incorrect testing.

Interface with the clinical data repository

CPOE systems may also interface with a variety of clinical information systems, including the clinical data repository (CDR). The CDR is a general term for systems that may alternatively be known as the clinical information

system (CIS) or the electronic health record (EHR). The CDR consists of the databases and systems that store patient electronic health records, including electronic reports and results from laboratory, imaging, pathology, and other diagnostic services. Interfaces to CPOE from the CDR are essential in order to provide advanced clinical decision support during the order entry process. Interfacing can permit CPOE systems to display relevant clinical information to the ordering provider at the time of order entry. The CDR information link is essential for the implementation of certain decision support functions as discussed in this review.

Computerized provider order entry benefits

A principal benefit of CPOE is that it provides a platform to streamline workflow, standardize laboratory test ordering, promote adherence to guidelines, and deliver decision support alerts [Table 1]. The impact of laboratory CPOE has been assessed by numerous measures including turnaround time, error avoidance, and resource utilization. Several studies have reported laboratory test turnaround time improvements with CPOE.[16-18] For example, Thompson *et al*., found that following the implementation of CPOE in the intensive care unit of a teaching hospital, the average time from ordering to resulting of stat laboratory tests decreased from a median of 148 min to 74 min.[16] In addition to improving laboratory turnaround time, CPOE systems have been demonstrated to improve the overall utilization of laboratory resources.[17,19-21] Following CPOE implementation at a UK hospital, Nightingale *et al*., not only found a decrease in total laboratory test volume and laboratory costs, but also an increase in the appropriate ordering of ten tests judged to have been previously underutilized.[21] This study offered evidence that the CPOE system did not simply reduce across the board test ordering, but rather improved the overall appropriateness of test orders. Further, improvements in laboratory utilization may translate into hospital-wide savings. Hwang *et al*., evaluated the impact of a CPOE system that included both medication and laboratory orders and demonstrated that patients were receiving fewer stat laboratory tests and had shorter hospital stays following implementation of CPOE.[19] In each of these examples, the implemented CPOE system had numerous attributes that may have been contributory to utilization and efficiency improvements. The specific CPOE strategies that may be responsible for the reported improvements are reviewed below [Table 2].

Table 1: Reported benefits of laboratory CPOE

Reduced test turnaround time
Decreased transcription errors
Reduced nursing manual steps (paper requisitions, transcription)
Reduced laboratory manual steps (requisition handling, accessioning)
Elimination of preprinted requisitions
Reduced ambiguous orders and missed tests
Reduced redundant test orders
Improved test utilization
Improved compliance with laboratory testing guidelines
Improved ability to create and modify clinical templates

Table 2: CPOE strategies to improve test utilization

CPOE ordering templates
CPOE alerts for redundant test orders
CPOE ordering constraints to minimize recurring orders
Display of relevant prior laboratory data on CPOE ordering screens
Integration of practice guidelines into CPOE ordering screens
Improving CPOE test search to permit improved test selection
CPOE corollary test alerts
Displaying test cost on CPOE ordering screens
Unbundling CPOE test panels into their individual components

User interface modifications

One of the most basic yet effective interventions to alter test utilization is to modify CPOE test ordering screens. A typical screen modification involves making commonly used and often appropriate tests more convenient to order than tests that are only occasionally indicated.[22,23] Such modifications presumably reduce over-ordering of tests by reducing the "impulse-buy" mentality. Another strategy that may be employed is to "unbundle" testing panels, requiring providers to select the individual tests instead of ordering the panel. Neilson *et al*., found that a combination of ordering frequency constraints and unbundling of metabolic panel tests decreased the use of the previously bundled tests by 51%.[24]

Recurring orders

Overutilization of inpatient laboratory tests may occur due to orders for recurring or "until discontinued" tests. CPOE systems that permit recurring orders may actually facilitate the overutilization of laboratory testing. With CPOE, clinicians may place recurring orders (e.g. CBC and electrolytes every morning until discontinued) but may fail to cancel them after the test is no longer clinically necessary. To curtail overutilization stemming from these types of orders, Vanderbilt University Hospital implemented CPOE pop-up boxes to alert clinicians of orders scheduled for longer than 72 h and offered clinicians the opportunity to voluntarily cancel these orders.[24] A 24% reduction in orders for metabolic panel tests was attributed to this CPOE alert. CPOE systems provide a leverage point for restricting recurrent orders, although significant leadership may be required, as once recurrent orders are institutionalized on templates and in the culture of the hospital, they can be challenging to eliminate.[23]

Templates

In most implementations of CPOE, ordering templates play an important role in standardizing care and encouraging adherence to clinical guidelines. Templates

typically consist of an integrated order set including medication, laboratory and other orders appropriate for a particular clinical setting or diagnosis. For example, an admission template for myocardial infarction might include specific dietary orders (e.g. low-salt diet), laboratory orders (e.g. serial troponin assays), medication orders (e.g. aspirin, beta blockers), and nursing instructions. When placing orders for a specific patient, clinicians may start with the standard template and then make modifications to address the unique clinical circumstances of the patient. Another advantage of using CPOE templates is that when clinical guidelines change, templates can be readily updated and the change in guideline is thus made immediately apparent to all ordering providers.

Ordering messages and practice guidelines

CPOE provides a platform for informing clinicians of practice guidelines and facilitates the tracking of deviations from the guideline. The Massachusetts General Hospital Blood Transfusion service integrates evidence-based guidelines into CPOE blood product ordering screens.[23] For example, when ordering red blood cells (RBCs), clinicians must select an indication based on the patient's age, hematocrit, and state of stress. Orders for RBCs not meeting guidelines are flagged by the computer system and transfusion service staff are electronically alerted to review flagged orders with the ordering clinician. In another example from transfusion medicine, Rana *et al*., demonstrated a significantly decreased rate of inappropriate transfusion upon integration of a transfusion algorithm into CPOE.[25] In a cardiac intensive care unit setting, Wang *et al*., found that integration of practice guidelines into standard admissions order templates significantly decreased the use of laboratory tests without compromising care.[26]

Display of test cost

In several studies, display of cost information during order entry has been demonstrated to influence utilization.[27,28] In a randomized controlled trial in an outpatient primary care setting, display of laboratory test cost on the CPOE ordering screen led to a 14% reduction in the number of tests ordered.[27] Bates *et al*., studied the effects of displaying cost information at a teaching hospital and noted a non-statistically significant 4.5% reduction in ordered tests.[28] In the US, there are financial incentives for reducing inpatient test utilization due to the costs of inpatient care being bundled into a single payment using the diagnosis-related group (DRG) payment schema. However, these incentives may be challenging to translate into reduced utilization by simply displaying costs to providers, as providers may not be vested in cost reduction activities.

Test search

With several hundred to thousands of tests on a typical laboratory menu, search functionality is found in most laboratory CPOE implementations. With search, clinicians enter search terms and the system returns a list of corresponding tests. Clinicians then select the specific test they wish to order from the returned list. Search terms can include test names, corresponding synonyms and even corresponding disease states.[29] For example, a search for "celiac disease" might return "anti-transglutaminase IgA" and "endomysial IgA antibody," two tests that may be ordered in the workup of celiac disease. By not requiring the clinician to know the exact names of the tests involved, the search function is made considerably more user-friendly. A user-friendly search function may help prevent free text ordering by providers. Free text orders cannot be electronically interfaced and must be manually translated into specific test names or codes, leading to inefficiencies, errors, and ambiguity. Monitoring free text orders may enable the CPOE team to improve the search process or contact ordering clinicians who routinely utilize free text inappropriately.[30]

Add-on test management

After a specimen has been processed and tested, clinicians may wish to order subsequent tests on the unused portion of the sample remaining in the laboratory. These tests are known as add-on tests and the management of add-ons often requires significant laboratory resources.[31] Most CPOE systems do not support add-on testing. Thus, clinicians wishing to order add-on tests must call the laboratory with a verbal order, and laboratory staff must manually retrieve the sample and enter the orders for additional testing into the LIS. Such systems are often inefficient given the multiple manual steps involved, and the order may lack appropriate documentation. Extending CPOE systems to handle add-on testing can be logistically challenging as the add-on test process does not follow the same steps as a new test order.[32] One study did report the implementation of add-on order functionality within CPOE and demonstrated marked improvement in the efficiency of the process as well as the completeness of CPOE add-on documentation as compared to the prior verbal process.[33]

Computerized provider order entry benefits: decision support

Clinical decision support

Many of the features and advantages of CPOE systems described thus far involve providing general test information or testing advice to guide clinicians toward improved ordering practices. However, these systems do not provide patient-specific advice. While the literature varies in its use of the term "clinical decision support system" (CDSS), it generally includes those systems that integrate multiple electronic patient data sources to offer clinicians patient-specific diagnostic testing or treatment advice.[34] To provide patient-specific testing

advice, the laboratory CPOE system must have real-time, electronic access to patient data, which may include test results and medications. This is accomplished via an interface between the CPOE system and the clinical data repository. CPOE systems with CDSS typically interact with users via alert messages that are triggered by various rules as described below.

Clinical decision support alerts

Alert messages are a common method that CPOE systems use to interact with users and typically consist of "pop-up" boxes displayed to clinicians at the time of order entry. Alert messages can be classified as interruptive or non-interruptive.[35] Non-interruptive alerts simply provide information to ordering providers, but do not require specific action or halt the provider's workflow. In contrast, interruptive alerts stop the workflow until the advice provided by the alert is either overridden or accepted. Overriding interruptive alerts may require the clinician to enter a reason for the override into the medical record.

While non-interruptive alerts may be less effective in influencing orders, interruptive alerts consume clinician time and must be used sparingly.[35,36] One strategy is to reserve interruptive alerts for only the most critical issues and use non-interruptive alerts for less serious concerns. Designers of CPOE systems must also be cognizant of the concept of "alert fatigue."[37] Alert fatigue can occur when providers encounter alerts, particularly irrelevant ones, frequently, and begin to ignore them. Use of increasingly sophisticated support systems that provide more patient-specific alerts may reduce unnecessary or irrelevant alerts and help combat alert fatigue.

Redundant test cancellation

While there is no standard definition for a "redundant test," it often is used to refer to the proportion of test requests that are cancelled by clinicians when they are made aware of prior results for the test.[38] It has been estimated that eliminating redundant laboratory tests could save US hospitals more than 5 billion dollars per year.[39] CPOE systems can alert a provider when a particular test has already been ordered or recently resulted, allowing the provider to cancel the duplicate request before it is ordered. For example, a clinician may decide that their Complete Blood Count (CBC) request is unnecessary after being presented with multiple CBC results from prior days. In addition, CPOE systems can display other relevant laboratory values. For example, the system might display a patient's prior normal CBC results to a provider considering iron deficiency studies, as a patient with normal CBC parameters would be unlikely to benefit from an evaluation for iron deficiency.

A randomized controlled study at a primary care outpatient practice demonstrated a significant reduction in tests ordered and charges per visit when prior laboratory results were displayed on the ordering screen.[40] Bates *et al*., investigated a CPOE function that alerted clinicians to potentially redundant test orders and allowed them to voluntarily cancel redundant orders or override the alerts.[41] In response to the redundant test alerts, providers canceled the test in question 69% of the time. Similarly, Chen *et al*., demonstrated a 19.5% decrease in antiepileptic monitoring tests following implementation of a CPOE function that alerted clinicians to redundant tests and provided ordering guidelines.[42]

Corollary order alerts

Not infrequently, placing one order requires clinicians to place another order. Orders that are necessitated by other orders are called corollary or consequent orders. An example of a corollary order would be a laboratory order for peak and trough gentamicin levels when ordering the antibiotic gentamicin. CPOE systems can display alerts to remind clinicians to place the corollary order. One example of corollary order alerts and their impact was reported by Overhage *et al*.[43] The system suggested laboratory tests based on ordered medications and permitted the clinician to accept, modify or reject corollary orders such as partial thromboplastin time and platelets when ordering heparin, glucose when ordering insulin, and creatinine and antibiotic levels when ordering aminoglycoside antibiotics. The percentage of appropriate corollary orders was significantly higher in the intervention group receiving alert messages as compared to the control group. Further, pharmacists had to intervene less frequently for orders written by intervention group clinicians.

Expert systems and computerized provider order entry

The potential of advanced clinical decision support systems for laboratory testing has been shown by the ability of expert systems to improve the diagnostic approach in controlled settings. Smith and McNeely described a "Laboratory Advisory System (LAS)," an interactive expert system that provided patient-specific assistance in test selection.[44] Clinicians entered a clinical problem list and the LAS then asked focused questions to obtain additional clinical information about each problem and recommend tests. Clinicians were able to accept or reject each recommendation. The LAS, when used by six physicians in a simulation of a general, private practice setting, reduced testing cost, time to diagnosis, and promoted closer adherence to established testing guidelines.

Knowledge Management

When efficiently presented and in the proper context, information about a given test may have a strong influence on whether the test is ordered. Information relevant to a test ordering decision would include test indications, guidelines, turnaround time, cost, and alternatives. Thus, for every test that may be ordered there is a collection of data that needs to be maintained

about that test. Laboratory Information System (LIS) dictionaries contain information about each test including a unique ordering code, reference ranges and collection information. However, many of the fields important in clinical decision-making, including turnaround time, indications, guidelines for use, cost, and alternatives, are either not present in the LIS or not easily accessible.

With the continued progress towards electronic interfacing of provider order entry systems with the LIS, there is a growing need for order entry applications to be in synchrony with the LIS. Such synchronization can be difficult since the group responsible for CPOE is often outside the domain of Pathology and has numerous other priorities and limited resources. The development of a knowledge management system that serves as a repository of laboratory testing information may offer a solution to the aforementioned challenges.[30] Knowledge management may be broadly defined as the process through which organizations generate value from their intellectual and knowledge-based assets. A knowledge management system for laboratory information can catalog laboratory staff knowledge and serve as a permanent bank of knowledge that remains even as individual staff members change roles or move to other facilities. In addition to CPOE, numerous other clinical applications utilize laboratory data and may benefit from having a laboratory information repository. For example, an online laboratory handbook may be generated from the same knowledge management system used for CPOE.[30]

Computerized provider order entry scope

Laboratory CPOE systems are most commonly deployed in hospital and emergency room settings and encompass most clinical laboratory testing areas, including chemistry, hematology, and microbiology. Most of the CPOE benefits and strategies described in this review have been reported in inpatient and emergency department settings. The use of laboratory CPOE systems for outpatients presents a unique set of challenges stemming from the heterogeneity of outpatient practice. For example, practices may lack practice management systems and other electronic health systems capable of interfacing with the CPOE system. For practices that do not draw specimens within the practice, CPOE systems may also need to communicate laboratory orders to phlebotomy centers. Finally, in the outpatient setting, days or weeks may elapse between the time an order is placed and when the specimen is collected. To meet the challenges present in the outpatient setting, some laboratories, particularly large commercial ones, have developed web-based portals that allow outpatient clinicians to order tests and view results. Web-based portals permit clinicians to input laboratory orders and print requisition and tube labels onsite or electronically transmit orders to phlebotomy centers.

Computerized provider order entry and surgical pathology

In surgical pathology, CPOE systems are currently used only rarely, and with limited functionality. Surgical pathology CPOE requirements are substantially different from that of laboratory CPOE due to differences in workflow. In surgical pathology, the provider is often a surgeon or endoscopist, and test requests and specimens may change based on the findings of the procedure. Other challenges to the use of CPOE in surgical pathology include the complexity of workflow, with a referring clinician, surgeon, and pathologist all potentially involved in requesting tests. Further, many institutions use a separate LIS for surgical pathology and clinical laboratories, requiring additional interfaces to permit CPOE order communication to the surgical pathology LIS. Nonetheless, future systems may permit the electronic entry of information about a surgical specimen, including patient history and diagnostic requests. Systems could potentially transmit this information to the surgical pathology LIS and generate bar-coded specimen labels at the time of the procedure.

Barriers to computerized provider order entry implementation

With the reported benefits of CPOE systems, it may seem surprising that a substantial minority of hospitals utilize this technology. A major barrier to installing CPOE systems is the cost of purchasing the software and systems [Table 3]. Unfortunately, relatively little information is publicly available regarding the cost structures for commercially installed CPOE systems and how these are related to return on investment. Related cost barriers include the cost of technical support, maintenance, infrastructure upgrades, and training.

A common concern of clinicians and other end-users is that CPOE will negatively affect their workflow or

Table 3: Barriers to CPOE Implementation

Financial
Capital for software, hardware, and interfaces
Staffing for development, implementation, training, and troubleshooting
Operating costs for maintenance, service, support
Technical/Logistical
Need for sufficient computer terminals
Limited space in clinical areas for computer terminals
Difficulty hardwiring existing buildings
Substantial personnel required to provide training
Need to provide 24x7 technical support
Clinical
Perception of less clinician autonomy in decision-making
Increased time may be required to enter orders
Systems may require alterations in workflow
Users may have difficultly adapting to new systems

efficiency. Ordering tests with CPOE systems may require more time as compared to paper requisitions. For example, Bates *et al*., reported that the fraction of time clinicians spent ordering tests nearly doubled for medicine interns following the initial implementation of CPOE.[45] However, this time increase was offset by savings the system offered in administrative duties such as looking for charts. CPOE may alter the traditional work structure by making it difficult to change or write orders at the bedside.[46] Clinicians have also expressed concern that electronic protocols and CPOE templates may restrict clinical judgment.[46,47] An additional concern is that clinicians may become over-reliant on templates, accepting template orders without making appropriate modifications.[46] However, others have argued that CPOE system development is far from complete, and that there remain numerous opportunities for user interface improvement and improved usability.[48,49]

CONCLUSIONS

CPOE systems offer the clinical laboratory a powerful tool to promote appropriate laboratory test selection and enhance the accuracy and efficiency of the entire laboratory testing process. Potential CPOE benefits as outlined in this review include improved test utilization, reduced costs, fewer errors, and better adherence to practice guidelines. Numerous strategies have been employed within the context of CPOE systems to improve workflows and ordering practices. One of the key determinants of the utility and functionality of a given laboratory CPOE system is the ability of the system to interact with other portions of the electronic health record. Given the variability of systems and implementations, laboratory directors must carefully plan CPOE implementations to ensure that the system will meet the institution's goals and be compatible with its workflows.

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