Recommendations for Monitoring and Evaluation of In-Patient Computer-based Provider Order Entry Systems: Results of a Delphi Survey

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Abstract
A survey of 20 clinical informaticists with experience in implementing Computer-based Provider Order Entry (CPOE) systems revealed the lack of easily accessible measurements of success. Using a Delphi approach, the authors, together with a group of CPOE experts, selected eight key CPOE-related measures to assess system availability, use, benefits, and e-iatrogenesis. We suggest collecting these measures on a widespread/national basis would be wise stewardship and result in tighter feedback about both clinician workflow and patient safety. Establishing reliable benchmarks against which new implementations and existing systems can be compared will enhance organizations' ability to effectively manage and hence to realize the full benefits of their CPOE implementations.

Introduction
Implementing computer-based provider order entry (CPOE) is one of the most difficult organizational change efforts a healthcare system can undertake. To further confound the issue, recent reports suggest that in addition to the known difficulties with changes in clinician workflow there are myriad unintended adverse consequences that routinely occur [1]. As with any complex sociotechnical system, one must understand it as fully as possible before one can improve, or even, manage it. For an organization to have the best chance to identify and manage both these known and unknown difficulties, use of a sound CPOE measurement or monitoring system is required.

To begin addressing this need we developed an initial set of recommendations for organizations interested in measuring and monitoring their CPOE systems [2]. After presenting these recommendations to our colleagues we learned that a) there were too many measures, b) they were too difficult to measure, c) many of the measures had confounding factors that limited their usefulness, and d) no one had a good idea of what the “expected values” were for any of the measures. In a further attempt to address these particularly difficult issues, we used a modified Delphi approach with the goals of a) identifying the most important and easiest measures to make and b) creating estimated benchmarks for each measure.

Background
We developed the following CPOE-related measures based on an extensive review of the literature and several iterative feedback sessions with a group of CPOE experts [2]. The small group of experts identified 18 potential CPOE measures that we grouped into four main categories. These categories parallel the “Structure, Process, Outcome” measurements first identified by Donabedian [3] in his effort to monitor and assess healthcare quality. Here, we use measures of CPOE availability to represent this capacity: robust CPOE availability is essential before any of the intended benefits can occur. Donabedian described process measures as those that evaluate “the performance in the diagnosis and management of disease.” Process measures for CPOE indicate how much the system is actually being used by clinicians, because installing CPOE and making it available will have little or no impact on an organization unless CPOE is integral to care delivery. Only after we have ensured that the system is available and used can we begin to measure the impact or outcomes associated with it [4]. Finally, we have added an additional outcome-related category, namely monitoring for potential e-iatrogenic events. Briefly, e-iatrogenesis is any harm to the patient caused by the use of information technology [5].

The 18 original CPOE measures include the following:

Availability (Structure) – What CPOE features and functions are available to clinicians?
- Percentage of system uptime (or downtime) (measured every minute) of the CPOE application. This should include both planned and unplanned downtime of all parts of the system that affect users, e.g., database, network,
applications, application interfaces, workstations, etc. Failure to include the “planned” downtime in this measure makes the information technology infrastructure appear more reliable, but from the frontline clinician’s, or patient’s, viewpoint it represents a significant gap. A particularly difficult concept to incorporate in this measure is how to take into account a “partial downtime” in which an isolated computer, or an entire floor of a hospital’s system goes down, or perhaps just a portion of the clinical data in the system becomes unavailable.

- **Mean response time** of a CPOE system as measured (to the tenth of a second) from the users’ perspective (includes delays resulting from database, network, application, workstation, etc.). This could be measured by submitting a simple medication order for a “test patient” every day at midnight. A simple automated query could then be developed that would request this order’s details be displayed on a workstation in a clinical setting every minute for the next 24 hours (i.e., 1440 times). The time the order was requested until the time the details were available could be logged to a file. Using these data, one could calculate the mean system response time and plot the system response time versus time of day, 24 hours a day, 7 days a week. If there are no data stored at a particular time in the log file for any query, then one should assume that the system is “down” for that minute. Again, while the information technology staff may argue over who is responsible for the poor system response time, the clinicians are only interested in finding out how fast the system responds.

- **Ratio of workstations, handheld devices, mobile computers, and printers to staffed beds**. These data should be sorted by hospital unit. Comparison of this ratio across organizations can help an organization understand whether it has enough hardware to satisfy clinical needs. Additional factors that must be considered here include: a) the total number of additional clinical functions that are “live” on any particular unit (e.g., if nurses are using the system for clinical documentation in addition to the CPOE function); and b) the presence of students (i.e., medical, nursing, pharmacy, respiratory therapists, etc.). These additional functions and users will require significantly more system access points.

- **Percentage of all clinical in-patient units** (e.g., ICUs, acute care nursing units) with CPOE live as determined by whether a process exists for clinicians to enter their orders for patients on that unit and have them carried out. This measure is particularly important during the “roll-out” phase of any CPOE project. Once an organization reaches 100% CPOE availability, the measure can be retired. The total time required to go live at the first CPOE pilot site until 100% CPOE availability should be recorded and reported so that future CPOE implementers can gain some insight into the mean time to full CPOE availability for similar organizations using CPOE products from the same vendor.

**Utilization (Process) – How is the CPOE system being used and who is using it?**

- **Percentage of active** (responsible for some aspect of patient care) clinicians (MDs, RNs, PAs, etc.) who login to some portion of the CIS infrastructure on a weekly basis. This measure helps the organization learn how far it has to go before it can expect high percentages of CPOE use. This is a good measure during the initial CPOE-rollout period. Once the system is up and running and all clinicians are using the system, this measure can be retired.

- **The percentage of all orders** (i.e., medications, laboratory, radiology, etc.) entered by physicians, or others responsible for making clinical decisions (i.e., MD, DO, PA, or Nurse practitioner). This is the key measure for any CPOE system, and what we call % CPOE [2].

- **Total number and percentage of order sets that are actually used** in a 12-month time period. This helps the clinical decision support system developers understand whether the clinical content they have developed is being used as expected. The 12-month period was chosen to take into account specific order sets that may be more heavily used during certain seasons of the year.

- **Percentage of all orders whose default values are modified** by the ordering provider: the ratio of how many times an item’s default was changed, to the total number of times it was ordered – sum over all ordered items. A high change rate (>25%) may indicate that the default values are not appropriate.

**Quality or Benefits Derived From Use of the System (Outcome) – What effect is the CPOE system having on your organization?**

- **Percentage of all (and total number of each) clinical alert(s) that actually fire** on a weekly,
monthly or quarterly basis. This measure helps system designers figure out if the sensitivity is too high or the specificity is too low for their alerts. It can also help identify specific alerts that account for a large percentage of the alert burden on clinicians.

- **Percentage of all orders requiring co-signing** that are not co-signed within 24 hours. Failure to co-sign orders in a timely manner is an indication of poor compliance with accepted hospital policy.

- **Percentage of all active in-patients with orders for medications for which the specified dose exceeds recommended dose ranges.** A high percentage of patients with doses that are too high or low may indicate a quality of care issue.

- **Percentage of all active in-patients with orders for medications to which an allergy has been documented** or an allergy to another drug in the same category exists [6]. A high percentage indicates that either the clinicians do not believe the allergy information provided or that clinicians are ignoring the warnings.

- **Percentage of all active in-patients with orders for medications that pose a known dangerous interaction** (i.e., a black box warning as defined by the Food and Drug Administration) when administered via the same route concurrently [6]. A high percentage here indicates that efforts to improve the quality of care may not be working as expected.

**Potential e-Iatrogenesis (Outcome)** – Indicators of potential hazards caused by or resulting from use of the CPOE system or other aspects of the clinical information system.

- **Ratio of user-initiated system logouts to total system logouts** (includes automatic timeouts or aborted sessions). This metric helps the organization learn whether clinicians are properly securing the workstations when they are unattended. Failure to log off represents both a patient confidentiality problem as well as the potential for users “poaching” or illegally using the system with another user’s login credentials.

- **Percentage of each progress note that is copied from the previous progress note** [7]. A high percentage indicates that clinicians may be over utilizing a system feature that leads to redundant and difficult to read clinical progress notes.

- **Percentage of (pop-up) alerts ignored/overridden.** A high percentage indicates a problem with the clinical decision support system or with the clinicians’ belief in the rules that have been implemented. Either way something must be fixed because over alerting can affect clinicians’ ability to concentrate on their work and potentially cause them to ignore all alerts.

- **Percentage of daily system interface efficiency** (i.e., number of successful transmissions / total number of transmissions attempted) for the top 5 (by volume) clinical interfaces to the CPOE system (e.g., pharmacy, laboratory, ADT, radiology, nutrition). This percentage should be very close to 100% and ALL system-to-system interface problems should be quickly investigated and fixed.

- **Percentage of all orders that are entered as “miscellaneous” or using free text** should be monitored and reviewed periodically (quarterly, semi-annually, annually). Free text entry of orders eliminates the possibility that the computer can provide any clinical decision support to clinicians.

**Methods**

**Survey Development**

Following Institutional Review Board approval from Kaiser Permanente Northwest and Oregon Health & Science University, we created an email-based CPOE measurement survey (available upon request) based on our previous work with a small group of CPOE experts [2]. This survey contained descriptions of each of the 18 measures previously identified and listed in the Background section of this manuscript. For each measure we asked our experts to rate how important this measure would be in determining the success of your CPOE project using the following Likert scale:

1–Unimportant; we don’t need this measure at all
2–Of little importance; there is a small possibility that this measure would affect our decisions
3–Moderately important; e.g., nice to have, but certainly not necessary
4–Important; has the potential to be a valuable indicator of project success
5–Very important, e.g., we must have this measure to properly manage the project

In addition we asked each expert to rate the difficulty in making the measurement: “How much effort, expense, time, etc. would be required to make this measure on a quarterly basis using your existing system and tools?” using the following scale:

1 – Very difficult, e.g., would require modifications to a) our CPOE system or b) the data that is currently recorded with each transaction;
2 – Difficult, e.g., would require a skilled analyst working several days, but the data exists;
3 – Relatively easy, e.g., would require an analyst, but less than an hour of work.
4 – Easy, e.g., the data exists and it would be easy to collect and analyze.
5 – No problem, e.g., we currently are making and monitoring this measure on a regular basis.

Finally we asked each expert to estimate the expected numerical result if they were to make each measure based on their experience with a functioning CPOE system.

The Modified Delphi Survey [8]

We identified 20 clinical informaticists with extensive experience in implementing CPOE systems based on their participation on the Association of Medical Directors of Information Systems (AMDIS.org) listserv. We sent each of them a copy of our survey.

We tabulated the results from these 20 respondents and sent each of them a short report of our findings and our recommendations for future work. We asked each of them to comment on our analysis and conclusions. The responses to this second round of the survey indicated that we had achieved the consensus we originally sought so we stopped the Delphi process.

Results

Figure 1 shows a graph of the perceived importance rating of each of the measures along with the perceived difficulty rating for each measurement. In all but one case (i.e., % note copied) the mean importance rating was greater than 3 (Moderately important). Interestingly, the mean perceived difficulty in making each measure only reached 4 (Easy) for one measure (i.e., % orders re: co-sign).

Table 1 shows the estimated (i.e., very few respondents had reliable measurements for any of these measures) mean value for each measurement. Interestingly, no respondent was willing to even venture a guess as to the percentage of user initiated system (timeouts) logouts. Using these quantitative results along with the qualitative comments from respondents, we were able to select eight (8) measures that most respondents agreed would be a good starting point for future data collection. The 8 measures are marked with asterisks in Figure 1 and Table 1.

Discussion

CPOE, while often put forth as one of the key solutions to many of the challenges facing the modern healthcare delivery system [9], has not been widely adopted [10]. And, of those institutions that are leading the way, the lack of easily accessible, seemingly critical to success, measures is astonishing. While we realize that implementing CPOE system availability, performance, and outcome measures is both difficult and time consuming, we believe that until we create and utilize robust, repeatable, and transferable (across institutions and vendors) measures to appropriately evaluate CPOE systems,
we can make only educated guesses as to actual overall healthcare quality improvement. This list of preliminary measures is provided as a starting point.

Table 1. Estimated value of each measure. Asterisks (*) designate the 8 measures identified as most important to measure. They are also relatively easy to measure and well-defined.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>% system uptime</td>
<td>99.4%</td>
</tr>
<tr>
<td>Mean response time</td>
<td>2.9 secs</td>
</tr>
<tr>
<td>Ratio of workstations to beds</td>
<td>2.4 : 1</td>
</tr>
<tr>
<td>% units live with CPOE</td>
<td>97 %</td>
</tr>
<tr>
<td>% active users login</td>
<td>94 %</td>
</tr>
<tr>
<td>% all orders entered</td>
<td>87.3 %</td>
</tr>
<tr>
<td>% order sets used</td>
<td>56.3 %</td>
</tr>
<tr>
<td>% default values changed</td>
<td>23.3 %</td>
</tr>
<tr>
<td>% alert(s) that fire</td>
<td>70 %</td>
</tr>
<tr>
<td>% orders re: co-sign</td>
<td>12.5 %</td>
</tr>
<tr>
<td>% doses outside normal ranges</td>
<td>2.5 %</td>
</tr>
<tr>
<td>% orders for meds w doc. allergy</td>
<td>10 %</td>
</tr>
<tr>
<td>Interaction</td>
<td>4 %</td>
</tr>
<tr>
<td>Ratio user to system logouts</td>
<td>NA</td>
</tr>
<tr>
<td>% progress note copied</td>
<td>20 %</td>
</tr>
<tr>
<td>% alerts overridden</td>
<td>52.8 %</td>
</tr>
<tr>
<td>System interface efficiency</td>
<td>99.7 %</td>
</tr>
<tr>
<td>“Miscellaneous” orders</td>
<td>2.3 %</td>
</tr>
</tbody>
</table>

Study Limitations
The modified Delphi approach we used to both select the initial CPOE experts and to identify the 20 additional experts may have resulted in a biased sample. On the other hand, with so few hospitals actually having implemented CPOE [10], we believe that our experts’ opinions represent the best currently available estimates.

Conclusion
We have identified eight CPOE-related measures that cover the categories of system availability, use, benefits, and e-Iatrogenesis that we must begin collecting on a widespread/national basis. Failure to establish reliable national benchmarks against which new implementations and existing systems can be compared will prevent organizations from being able to effectively manage and hence to realize the full benefits of their CPOE implementations.

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