Reduction in Medication Errors due to Adoption of Computerized Provider Order Entry Systems

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Modified from a Panel Presentation at Academy Health’s Annual Research Meeting, Boston, MA June 2010
Funding: PSC Contract # 233020088, T.O. HHSP233200700008T#
Team Effort

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\(^{(1)}\) Abt Associates Inc.
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Funder
- AHRQ

Other Acknowledgements
- Robert Mays
- Ashish Jha
- Catherine Desroches
- Eric Campbell
- William Rhodes
- K P Srinath

UCSD Health Informatics Journal Club Webinar. May 2, 2013
Background

- Health IT a core theme of health reform
  - Incentives for physician adoption
  - Efficiency and quality gains?

- Impact of many Health IT initiatives unknown

- Difficult to quantify Health IT’s impact nationally
Evaluation Approach

**Context**

**Settings/ Units of Analysis**
- Hospital Inpatient

**Techniology of Interest**
- Computerized Provider Order Entry

**Adoption**

**Operational definition**
Adoption of any CDS functionality/ in hospitals, full implementation in at least 1 unit

**Data Sources**
- AHA EHR Supplement
- Physician EHR Survey

**Analysis Method**
Sample proportions adjusted for sampling weights and non-response

**Use/ Meaningful Use**

**Operational definition**
Use of CDS at least some of the time/ by CDS type

**Data Sources**
- Adoption data plus additional Physician EHR Survey items
- No use data available from hospitals

**Analysis Method**
Averages adjusted for non-response plus simple arithmetic

**Outcomes**

**Operational definition**
Reduction of medication errors due to CPOE

**Data Sources**
- CPOE Adoption and use data from AHA plus Effect estimates from the literature

**Analysis Method**
Meta-analysis plus simple arithmetic
Objectives

• Computerized Provider Order Entry (CPOE)
  - Medication Errors: Potentially Harmful & Costly
  - CPOE believed help avoid errors
    - Transcription, dosing, adverse interactions, etc.…
  - CPOE can be a new source of errors
    - e.g. Wrong drug choice from pull-down menu

• Derive a nationally representative estimate of medication error reduction (if any) in acute hospital settings attributable to the use of CPOE

• Percent [%] reduction \((R_p)\) in this presentation

• Absolute [#] reduction \((R_a)\) in this presentation
Construct Clarification

- **Medication error**: A mistake in the prescribing or dispensing process.

- **Computerized Provider Order Entry (CPOE)**: A system allowing providers to electronically write orders for diagnostic tests, therapy (e.g. medications, nursing orders) or consultations (e.g. consult to a specialist for input).

- **Adoption**: Presence of a CPOE system within an inpatient acute-care setting that has the ability to process prescription drug orders electronically.

- **Implementation**: The degree to which prescription drug orders made within an inpatient acute healthcare facility are processed through a CPOE system.

- **Medication Order**: A written order by a healthcare provider (with prescribing authority) for a medication to be dispensed by a pharmacy for administration to a patient.
# Study Approach

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<th>Effect of CPOE on medication error frequency</th>
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Step 1: Effect of CPOE medication error frequency

Methods

- Literature review
  - No randomized studies
  - Relied on high quality observational studies
- 9 pre/post studies of medication error frequency in hospitals and units that implemented a CPOE system (hospitals serve as their own control facilities)
- Comparison was CPOE vs. ‘traditional’ hand written Rx Orders
- Error rates standardized to number of errors per month before/after CPOE
- Data pooled using DerSimonian & Laird weights to account for within- and between-study heterogeneity

\[
M = \sum (w_k \cdot \left( \frac{M_{C_k} - M_{n_k}}{M_{n_k}} \right))
\]

\[
M = \frac{\sum w_k (M_{C_k} - M_{n_k})}{\sum w_k}
\]

- \(M\) = Percent reduction in medication error rates associated with adoption of CPOE
- \(k\) = Denotes the study
- \(M_{C}\) = Medication error rate in settings with CPOE
- \(M_{n}\) = Medication error rate in settings without CPOE
- \(w\) = Meta analytic study weight, defined using the DerSimonian method
Step 1: Effect of CPOE medication error frequency
Findings (literature review)

Percent (%) Reduction in Medication Error Rate
Associated with CPOE in Reviewed Studies

- 2008: Taylor
- 2007: Mahoney
- 2006: Kim
- 2004: Cordero
- 2003: Igboechi
- 2002: Bizovi
- 1999: Bates
- 1998: Evans

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Step 2: Proportion of Rx Orders Processed by CPOE Methods

- Nationally representative
- Accounts for CPOE adoption and implementation
- Data from hospital surveys:
  - AHA Annual Survey (2007): hospital size, bed days & other characteristics
  - EHR Adoption Supplement (2007): CPOE adoption & implementation
  - ASHP Annual Survey: Medication Order Volume
- Non-Response mediated using a regression imputation

\[ Pc = \frac{\sum_{j=1}^{4} \sum_{i=1}^{N_j} B_j A_i C_i D_i}{\sum_{j=1}^{4} \sum_{i=1}^{N_j} B_j A_i} \]

- \( Pc \) = Proportion of total medication orders processed through a CPOE system
- \( i \) = denotes the study
- \( j \) = denotes the study
- \( B \) = Estimated medication orders per bed-day from ASHP survey
- \( A \) = Reported bed days in hospitals from AHA survey
- \( C \) = Probability that a hospital has adopted CPOE
- \( D \) = CPOE implementation - the percent of medication orders in facilities with CPOE that are processed through the CPOE system
### Step 2: Proportion of Rx Orders Processed by CPOE

**Findings – CPOE Adoption**

Hospitals with CPOE ≈ 34% (1,589 of 4,701)

<table>
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<tr>
<th>CPOE Adoption by select Hospital Characteristics</th>
<th>CPOE % With / Without</th>
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<tr>
<td><strong>Characteristic</strong></td>
<td></td>
</tr>
<tr>
<td>Children's Hospital</td>
<td>100 / 0</td>
</tr>
<tr>
<td>Bed Size: Small (&lt;100)</td>
<td>30 / 70</td>
</tr>
<tr>
<td>Medium (100-399)</td>
<td>35 / 65</td>
</tr>
<tr>
<td>Large (&gt;=400)</td>
<td>56 / 44</td>
</tr>
<tr>
<td>Location: Rural</td>
<td>28 / 72</td>
</tr>
<tr>
<td>Urban</td>
<td>41 / 59</td>
</tr>
<tr>
<td>Teaching: ≤ 20 residents</td>
<td>32 / 68</td>
</tr>
<tr>
<td>&gt; 20 residents</td>
<td>53 / 47</td>
</tr>
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</table>

Other factors: Region of the Country (NE is highest), Ownership Type (not for profit is highest), Part of a System (not significant)
Step 2: Proportion of Rx Orders Processed by CPOE
Findings – CPOE Implementation

Mean implementation = 58%

Source: EHR Adoption Supplement Survey. Only includes EHR supplement responders
## Step 2: Proportion of Rx Orders Processed by CPOE Findings – Total CPOE Exposure

<table>
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<th>Total Inpatient Medication Orders ($O_t$)</th>
<th>1,757 Million</th>
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<tr>
<td>Inpatient Medication Orders made using CPOE ($O_c$)</td>
<td>459 Million</td>
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CPOE Exposure: **26%** *(estimate bounds: 16-53%)*
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**Steps 3 & 4: National Estimates of Medication Error Reduction Methods**

- **Step 3:** Percentage reduction in medication error frequency resulting from using CPOE to process medication orders

\[ Rp = M \cdot Pc \]

\[ Rp = \text{Percent reduction in medication errors due to CPOE} \]
\[ M = \text{Percent reduction in medication error rates associated with adoption of CPOE (step 1)} \]
\[ Pc = \text{Proportion of total medication orders processed through a CPOE system (step 2)} \]

- **Step 4:** Absolute reduction in medication error frequency resulting from using CPOE to process medication orders

\[ Ra = Ot \cdot Mn \cdot Rp \]

\[ Ra = \text{Absolute reduction in medication errors due to CPOE} \]
\[ Ot = \text{Total number of medication orders processed annually in U.S. hospitals (step 2)} \]
\[ Rp = \text{Percent reduction in medication errors due to CPOE (step 3)} \]
\[ Mn = \text{Medication error rate in settings without CPOE (step 1)} \]

- Probability-based bounds not realistic
- Based on logical assumptions about variability in underlying statistics
- Bounds set as follows:
  - Rx orders: reported sampling variance from ASHP survey
  - CPOE Adoption
    - Lower: set to 0 for all non-reporting hospitals
    - Upper: set to 1 for all non-reporting hospitals
- CPOE Implementation
  - Lower: set to 0 for non-responders and lower value of reported range for responders
  - Upper: set to mean for non-responders and upper value of reported range for responders
- Summary statistics re-calculated using upper and lower estimates
Steps 3 & 4: National Estimates of Medication Error Reduction

Findings

**Step 3**

*Percentage* reduction in medication error frequency resulting from using CPOE to process medication orders

- **12.5%**
- Estimate Bounds: 10.6% to 14.4%
- **17.4 Million**
  - Estimate Bounds: 88K to 27M

**Step 4**

*Absolute* reduction in medication error frequency resulting from using CPOE to process medication orders

- 879 million orders
- 1.76 billion orders

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## Summary

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<th>Point Estimate</th>
<th>Estimate Bound</th>
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<tr>
<td>Step 1</td>
<td>Average percent (%) reduction in medication error rates conditional on using CPOE to prescribe the order</td>
<td>-48%</td>
<td>(-55% to -41%)</td>
</tr>
<tr>
<td>Step 2</td>
<td>Proportion of medication orders that are ordered using a CPOE system</td>
<td>26.1%</td>
<td>(16.0% to 53.6%)</td>
</tr>
<tr>
<td>Step 3</td>
<td>Percentage reduction in medication error frequency</td>
<td>-12.5%</td>
<td>(-14.6% to -10.6%)</td>
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<td>Absolute reduction in medication error frequency</td>
<td>17,390,443</td>
<td>(88,058 to 27,094,038)</td>
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Findings: What if…?

- $21\%$ of Hospitals that have adopted CPOE

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Limitations

- Authors’ definition of medication error varies between studies
- No risk-adjustment
- Unobservable factors could explain study-specific effect
- Estimate bounds are wide
  - Conservative estimation approach
  - Weights on pooled data from literature review
  - Extreme bounds for CPOE adoption and implementation
Conclusions

- CPOE appears to be an effective strategy for reducing medication errors in hospitals
- The use of CPOE in hospitals for ordering prescription drugs is modest
- Opportunities exist to increase CPOE use that may result in fewer medication errors
- Medication errors is an important, but intermediate outcome. Additional attention should be given to assessing costs and patient health outcomes
- Effective strategy for measuring outcomes associated w/ Health IT in the absence of comprehensive data