National Web-Based Teleconference on Health IT and Safety

Using Health IT to Prevent Adverse Events

July 13, 2010

Moderator:
Amy Helwig
Agency for Healthcare Research and Quality

Presenters:
George Hripcsak
Tejal Gandhi
Kevin B. Johnson
Mining electronic health records for patient safety research

George Hripcsak, MD, MS
Department of Biomedical Informatics
Columbia University
Meaningful Use Incentives

One Hundred Eleventh Congress
of the
United States of America

AT THE FIRST SESSION

Began and hold at the City of Washington on Tuesday,
the sixth day of January, two thousand and nine

An Act

Making supplemental appropriations for job preservation and creation, infrastructure
investment, energy efficiency and science, assistance to the unemployed, and
State and local fiscal stabilization, for the fiscal year ending September 30,
2009, and for other purposes.

Be it enacted by the Senate and House of Representatives of
the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the “American Recovery and Reinvestment
Act of 2009”.

SEC. 2. TABLE OF CONTENTS.
Potential US Annual EHR data

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000,000,000</td>
<td>visit notes</td>
</tr>
<tr>
<td>35,000,000</td>
<td>admit notes, discharge sum.</td>
</tr>
<tr>
<td>46,000,000</td>
<td>procedure notes</td>
</tr>
<tr>
<td>3,000,000,000</td>
<td>prescriptions</td>
</tr>
<tr>
<td>1,000,000,000</td>
<td>laboratory tests</td>
</tr>
<tr>
<td>&gt;50,000,000,000</td>
<td>facts</td>
</tr>
</tbody>
</table>
Benefits of EHR data

• symptoms, signs, and detailed treatments
• detailed temporal course
• clinician’s reasoning
• good redundancy

Much is in the narrative notes
Event detection

- Bates (JAMIA 2003) review
  - Rocha, Evans, Dessau, Pittet, … each on nosocomial infection using microbiology and pharm data
  - Honignman, Brown, Classen, Payne, Jha, … each on adverse drug events using lab, pharm, admin data
  - Benson, … each on adverse events using vitals and pharm data
- Melton (JAMIA 2005) on adverse events using discharge summaries
- Handler (AMIA 2008) on adverse drug events using a clinical event monitor
- Hinrichsen (JAMIA 2007) on vaccine adverse events using alert-driven reports
Framework
Event detection

1. Select target events
2. Analyze clinical data repository
3. Data preparation (including NLP)
4. Queries, rules
5. Verification of events
6. Classification
7. Feedback to improve queries
Target errors

• Explicit voluntary error reporting
  – “error,” “unexpected,” “inadvertent”
• Learning from reported errors
  – New York State event definitions
• Conflicts in the record
  – Evidence of errors and adverse outcomes
• Literature
  – Candidate set of events from existing literature
Data sources

- Administrative data
  - Ubiquitous, coded
  - May not reflect truth: errors, lack of temporal information, code creep, coded after discharge, adverse events poorly represented

- Laboratory, medication data
  - Direct evidence for laboratory and medication related errors
  - Indirect evidence: Medications to rescue or treat adverse events, evidence for a diagnosis

- Narrative data
  - Visit notes, discharge summary, admission notes, progress notes, operative reports, resident signout, ancillary reports

- Work flow information
  - Order entry, coded documentation
  - Opportunity for timely intervention
Terminology challenges

• Terminology and data model
  – Different sources use different coding
  – Cannot easily share detection rules with others
    • ICD9-CM is one exception

• Often only a limited view of the clinical state and process
Natural language processing

• Generate coded information
  – Defined structure
  – Defined vocabulary
  – Handle negation, distribute modifiers, etc.

• Keyword searching
  – Find documents with relevant words
  – Negation, ambiguous terms, spelling
  – Stemming prefixes and suffixes
  – Mapping to a thesaurus (UMLS)
  – Best for less common conditions
Deep Natural Language Processing

“Slight increase of pulmonary vascular congestion with new left pleural effusion, question mild congestive changes”

- pulmonary vascular congestion
  - change: increase
  - degree: low

- pleural effusion
  - region: left
  - status: new

- congestive changes
  - certainty: moderate
  - degree: low
NLP at Columbia

```
```
Demography of CXRs

- 10 years; 889,921 reports; 250,000 pts.
- Side of lesions
  - Side of lung mass
    - right:left 1.49 (1.40-1.58) or 3:2
    - volume 1.14
    - weight 1.2
    - inhaled aerosol 1.28
- Bullet and stab wounds
  - Dropped 46% over 10 years
  - Consistent with FBI rates
    - violent 52%; aggravated assault 41% (NS)
    - murder 67% (p<.001)

Calibration via falls
Falls

- Calibrate database to literature
- Look for evidence of a fall
  - severe enough to warrant a radiology report
- Look for “s/p fall,” …
- But not “fallopian tube,” “no fall”
- Not related to the admission
  - at least two days after admission
Falls

• Results
  – 1447 inpt. visits with a fall out of 553,011
  – 2.6 per 1000
  – by age
    • 16-44 = 0.95 per 1000
    • 45-64 = 2.1 per 1000
    • 15-64 = 1.4 per 1000
    • 65+ = 6.5 per 1000
  – 0.35 per 1000 (14%) had a fracture

• Literature
  – estimate 6.6 per 1000
  – age 16-64
    • 0.1 per 1000
    • 0.19 to 0.30 per 1000
  – age 65+
    • 1 per 1000
    • 3.19 per 1000
    • 19 per 1000 (elderly)
  – 0.4 per 1000 injury
Conflicts in the EHR
Identifying AEs using conflicts in EHR

• Increase predictive value of AE detection using NLP
• Find —conflicts”
  • e.g., mismatch between admit and discharge diagnoses
• Design
  – 150 cases from each of 5 target areas
  – 2 internal medicine reviewers
Conflicts in the EHR: "Digital Clues"

- Admitted for DVT
- Elevated INR
- Head CT: "Midline shift"
- Protamine Given
- Discharge Dx: CVA

(time)
## Conflicts in the EHR: 1990-1999

<table>
<thead>
<tr>
<th>Target</th>
<th>Total Cases</th>
<th>Matches (%)</th>
<th>P True Conflict</th>
<th>Mis-Matches (%)</th>
<th>P True Conflict†</th>
</tr>
</thead>
<tbody>
<tr>
<td>MI</td>
<td>7901</td>
<td>5850 (74)</td>
<td>0.012</td>
<td>2051 (26)</td>
<td>0.18</td>
</tr>
<tr>
<td>Stroke</td>
<td>11356</td>
<td>8270 (73)</td>
<td>0.014</td>
<td>3086 (27)</td>
<td>0.16</td>
</tr>
<tr>
<td>Aspiration Pneumonia</td>
<td>4615</td>
<td>701 (15)</td>
<td>0.0625</td>
<td>3914 (85)</td>
<td>0.18</td>
</tr>
<tr>
<td>PE</td>
<td>1923</td>
<td>486 (25)</td>
<td>0.0</td>
<td>1437 (75)</td>
<td>0.39</td>
</tr>
<tr>
<td>Catheter – related Infections</td>
<td>2138</td>
<td>436 (20)</td>
<td>0.0</td>
<td>1702 (80)</td>
<td>0.25</td>
</tr>
</tbody>
</table>

† Estimated from manual review of random subset (~150 cases for each diagnosis)
Self reporting in the EHR
Self reporting in the EHR

• Do clinicians report errors in the record?
• Narrative
  – discharge summary
  – outpatient notes
  – signout notes

Self reporting in the EHR

- Accident
- Active Error
- Adverse
- Adverse Drug Event
- Adverse Drug Reaction
- Adverse Event
- Adverse Medical Event
- Adverse Outcome
- Allergic Reaction
- Bad Outcome

- Complication
- Diagnostic Error
- Drug Toxicity
- Error
- Error of Commission
- Error of Omission
- Harm
- Human Error
- Iatrogenic
- Iatrogenic Injury
- ...

Agency for Healthcare Research and Quality
Advancing Excellence in Health Care  •  www.ahrq.gov
Self reporting in the EHR

• He did not take the antibiotics because I mistakenly prescribed augmentin when he has a penicillin allergy. Luckily, his pharmacist caught the error.
  – (near miss)

• It was noted that pt had been given albuterol inhaler instead of vancenase for intranasal use! pt alerted to mistake made by pharmacy
## Self reporting in the EHR: PPV

<table>
<thead>
<tr>
<th></th>
<th>Discharge sum</th>
<th>Signout note</th>
<th>Visit note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mistake</td>
<td>10%</td>
<td>36%</td>
<td>16%</td>
</tr>
<tr>
<td>Error</td>
<td>3%</td>
<td>11%</td>
<td>1%</td>
</tr>
<tr>
<td>Inadvertent</td>
<td>24%</td>
<td>20%</td>
<td>22%</td>
</tr>
<tr>
<td>Incorrect</td>
<td>12%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Iatrogenic</td>
<td>14%</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>8%</strong></td>
<td><strong>15%</strong></td>
<td><strong>5%</strong></td>
</tr>
</tbody>
</table>

Discharge sum hospital course section PPV 15%

>1000 actual instances of error in ten years
## Self reporting in the EHR

<table>
<thead>
<tr>
<th>Role</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physicians</td>
<td>36%</td>
</tr>
<tr>
<td>Nurses</td>
<td>14%</td>
</tr>
<tr>
<td>Pharmacy</td>
<td>8%</td>
</tr>
<tr>
<td>Radiologists</td>
<td>4%</td>
</tr>
<tr>
<td>Administration</td>
<td>3%</td>
</tr>
<tr>
<td>Unknown</td>
<td>34%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside institution</td>
<td>81%</td>
</tr>
<tr>
<td>- self</td>
<td>4%</td>
</tr>
<tr>
<td>- others</td>
<td>39%</td>
</tr>
<tr>
<td>- unknown</td>
<td>57%</td>
</tr>
<tr>
<td>Outside institution</td>
<td>12%</td>
</tr>
<tr>
<td>Unknown</td>
<td>6%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>With adverse outcome</td>
<td>41%</td>
</tr>
<tr>
<td>Without adverse outcome</td>
<td>58%</td>
</tr>
<tr>
<td>Near miss with recovery</td>
<td>1%</td>
</tr>
</tbody>
</table>
Large scale event reporting
New York State events

- 45 events defined by New York State
  - hemorrhage during procedure
  - new DVT
  - post-op infection
  - pulmonary edema related to volume overload
  - new pulmonary ebolism
  - equipment malfunction with serious injury
  - etc.

Event reporting

• Use NLP and 45 rules to detect errors in discharge summaries
• Review 1000 randomly chosen charts
• Review all 1461 positives detected from 57,452 DSUMs
Event reporting

• By case
  – prevalence .053
  – manual review sensitivity .09

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>.28 (.17-.42)</td>
<td></td>
</tr>
<tr>
<td>Specificity</td>
<td>.985 (.984-.986)</td>
<td></td>
</tr>
<tr>
<td>Positive predictive value</td>
<td>.45 (.42-.47)</td>
<td></td>
</tr>
<tr>
<td>Negative predictive value</td>
<td>.96 (.95-.97)</td>
<td></td>
</tr>
</tbody>
</table>

• By event type

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>.25 (.15-.37)</td>
<td></td>
</tr>
<tr>
<td>Specificity</td>
<td>.9996 (.9996-.9997)</td>
<td></td>
</tr>
<tr>
<td>Positive predictive value</td>
<td>.44 (.42-.47)</td>
<td></td>
</tr>
<tr>
<td>Negative predictive value</td>
<td>.9989 (.9986-.9992)</td>
<td></td>
</tr>
</tbody>
</table>
Next-generation detection
Challenges

• Solvable
  – Lack of penetration of EHRs
  – Distributed systems
  – Inconsistent formats
  – Privacy

• Hard
  – Quality of data
    • accuracy, completeness, complexity
  – Bias
Data quality

- All medical record information should be regarded as suspect; much of it is fiction.
  - Burnum JF ... Ann Intern Med 1989
Truth → Concept → Record → Concept

Truth: Health status of the patient
Concept: Clinician or patient’s conception
Record: EHR/PHR
Concept: 2nd clinician’s conception of the patient (or self, lawyer, compliance, ...)

Model: Computable representation
Learning from the Data

Deviation by stated unit

Proportional deviation
Number of occurrences
day
week
month
year

3 days ago

now

Hripcsak ... JAMIA 2009
Physics of medical records

• Study the EHR as an object of interest in itself
  – the EHR as a natural system
  – understand and correct for or avoid biases

• Apply methods from nonlinear time series analysis

\[ I(X; Y) = \mathbb{E}_{X,Y}[SI(x, y)] = \sum_{x,y} p(x, y) \log \frac{p(x, y)}{p(x)p(y)} \]
Illness, sampling & predictability

Patient state:
- Patient stable
- Patient ill
- Patient stable
- Lapse in visits
- Patient stable

Theoretical predictability w.r.t. time (delta-t):

Clinician sampling:

Predictability w.r.t. sequence (tau):
Conclusions
Conclusions

- EHR can be useful in patient safety research
  - you need an EHR
- Imperfect sources and imperfect processing
  - reports collected for different purposes, although redundancy helps
  - complex reports (DSUM) require complex processing (NLP)
    - can exploit simpler keyword techniques effectively
- Performance depends mainly on what is available in the clinical repository
Thank You!
Bar-coding and Medication Safety

Tejal Gandhi, MD, MPH

Director of Patient Safety
Partners Healthcare
Associate Professor of Medicine
Harvard Medical School

Funded by a grant from AHRQ
Medication Safety

• The typical hospital medication process has multiple stages:
  – Ordering--MD orders medication
  – Transcribing--nurse copies order onto a paper medication administration record (MAR)
  – Dispensing--pharmacy sends medication to the floor
  – Administering--nurse gives medication to patient and documents this on the MAR
  – Monitoring—assessing whether or not the patient had an adverse effect

• Medication errors in hospitals are common and can have serious consequences
  – Errors can occur at any stage
IT Solutions by Stage

- **Ordering errors**
  - Computerized physician order entry (CPOE)
- **Transcription errors**
  - Electronic medication administration records (eMAR)
- **Dispensing errors**
  - Bar-coding
  - Robots
- **Administration errors**
  - Bar-coding
  - Electronic medication administration records (eMAR)
  - Smart pumps
Barcode/eMAR at the Bedside

• Orders flow electronically from CPOE to an electronic medication administration record (eMAR)
  – Eliminates transcription entirely
  – Nurses have laptops with eMAR and use this to track what medications need to be given (administered)
• Nurses use barcode scanning of the medication and the patient to verify that the drug they are administering matches the physicians’ orders
  – Right drug, right patient, right dose, right time
  – eMAR alerts if any of these is incorrect
  – Potentially reduces administration errors
Barcode Medication Scanning at the Bedside: Components that make it work
Wrong Medication
Medication is not part of patient's active medication profile.

Product Scanned:
SODIUM BICARB 650 MG TABLET

Please zoom the order to verify Pharmacy approved packages
Real Time Alerts to Nurse

Wrong Patient

The scanned wristband is either the wrong patient's or the wristband was unreadable. Please check to see if this is the correct patient's wristband and re-scan. If this is the correct patient and this continues then select "Manual Patient Entry" on the To Do Screen to record the administrations.

Patient Scanned:
EMARTEST, MAGGIE MRN: 18919027
Evaluating the Impact of Barcode-eMAR on medication Administration Errors

• Study Design
  – Non-randomized, controlled observational study comparing error rates on units with and without bedside barcode scanning

• Primary Study Outcomes
  – Directly-observed medication administration errors
  – Directly-observed potential adverse drug events (ADEs) due to medication administration errors

• Data Collection
  – Direct observations of medication administrations by trained research nurses
  – All errors detected adjudicated by 2 members of a multi-disciplinary panel
Impact of Barcode Scanning Technology on Administration Errors and Potential Adverse Drug Events

<table>
<thead>
<tr>
<th></th>
<th>No Barcode Scanning (n=6712)</th>
<th>Barcode Scanning (n=7314)</th>
<th>Relative Reduction (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medication Administration Errors</td>
<td>11.5%</td>
<td>6.8%</td>
<td>41% (p&lt;0.001)</td>
</tr>
<tr>
<td>Potential Adverse Drug Events</td>
<td>3.1%</td>
<td>1.6%</td>
<td>50.8% (p&lt;0.001)</td>
</tr>
</tbody>
</table>

Poon et al, NEJM 2010
Impact on Potential Adverse Drug Events of Various Severity

<table>
<thead>
<tr>
<th>Potential Adverse Drug Events</th>
<th>No Barcode Scanning (n=6712)</th>
<th>Barcode Scanning (n=7314)</th>
<th>Relative Reduction (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.1%</td>
<td>1.6%</td>
<td>51% (p&lt;0.001)</td>
</tr>
<tr>
<td>Significant</td>
<td>1.82%</td>
<td>0.94%</td>
<td>48% (p&lt;0.001)</td>
</tr>
<tr>
<td>Serious</td>
<td>1.30%</td>
<td>0.60%</td>
<td>54% (p&lt;0.001)</td>
</tr>
<tr>
<td>Life-threatening</td>
<td>0.03%</td>
<td>0.01%</td>
<td>54% (p=0.52)</td>
</tr>
</tbody>
</table>

Poon et al, NEJM 2010
# Impact of Barcode eMAR on transcription errors

<table>
<thead>
<tr>
<th>Manual Transcription (n=1799)</th>
<th>Automatic Transcription (n=1283)</th>
<th>Relative Reduction (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transcription Errors</td>
<td>6.1%</td>
<td>0%</td>
</tr>
<tr>
<td>Potential Adverse Drug Events due to transcription Errors</td>
<td>3.0%</td>
<td>0%</td>
</tr>
<tr>
<td>Significant</td>
<td>1.6%</td>
<td>0%</td>
</tr>
<tr>
<td>Serious</td>
<td>1.3%</td>
<td>0%</td>
</tr>
<tr>
<td>Life Threatening</td>
<td>0.06%</td>
<td>0%</td>
</tr>
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</table>

Poon et al, NEJM 2010
Admin and Transcription Error Study - Conclusions

• Barcode scanning technology can significantly reduce the incidence of medication administration and transcription errors and associated potential adverse drug events

• Significant impact on medication safety at study hospital
  – ~90,000 potential ADEs prevented per year during administration stage
  – ~50,000 potential ADEs prevented per year during transcription stage

• Errors not completely eliminated
  – Still on learning curve at time of study
  – Possibility of new errors being introduced
  – Incomplete compliance with scanning
  – Need for ongoing monitoring and improvements
Impact of eMAR on Nurse Satisfaction

• Pre and post surveys
• Main Results: Nurses feel medication administration is safer and more efficient after implementation of barcode technology

Impact on Nurse Workflow

• 232 2-hour observation sessions before and after barcode/eMAR implementation

• Primary Result: Proportion of time spent on medication administration did not change after barcode/eMAR implementation

• Secondary Result: Proportion of time spent in presence of patient increased

Summary: Impact on Serious Medication Errors

- **Order Entry & decision support**: 55% reduction
- **Pharmacy decision support**: EMar/Barcoding: 67% reduction
- **-EMAR/barcoding at bedside**: 51% reduction

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**Medication on Wards**

- **Medication Admin Record**: eMAR-100% reduction
- **Transcription**: Transcription Errors (11%)
- **Dispensing**: Dispensing Errors (14%)
- **Administration**: Administration Errors (26%)

**Pharmacist**

- **Med Ordering**: Ordering Errors (49%)

**MD**

**RN**

**Patient**
Implementation Factors

• Software developed by Partner’s Healthcare Information Systems analysts
  – Customized to BWH medication administration with ability to provide real time enhancements
  – Networked with existing CPOE and Pharmacy systems
  – 10 year project
Implementation

- Initial Trial March 2004
- Intermediate Care Unit and Neuro ICU for 2 weeks each
- Supports
  - Computer based training
  - 4 hour Class
  - RN Super User
  - IS Analysts
Implementation

• 45 Enhancements to software prior to incremental hospital wide roll out
• 3 Mother Baby Units
• 27 Intermediate Care Units
• 8 ICU’s
• Second Phase
  – 8 Hematology Oncology Units
• Planned
  – Specialty Units – L&D, PACU, OR, ED
Super User

• Available to all staff nurses to assist with medication administration until proficient.
Information System Analyst

- Trouble shoots issues with the application and hardware and acts as a resource for the super users.
Hardware

- Small footprint required
- eMAR cart = Workbench
- No writing surface
- Beverages and computers don’t mix well!
Scanners

- Need scanning flexibility at bedside

- Pros
  - Fit work flow
  - Light, easy to use
  - Allowed proximity to patient

- Cons
  - Can lay down anywhere
  - Can drop anywhere
  - Storage location not used
What Have We Discovered?
Bar Coding Inconsistencies

- Where is it?
- Which one do I scan?
- Why won’t it scan?
Bar Code Solutions

• Data base management
• Display of bar codes
Physician Workflow

- Inability to quickly assess medication administration data
Solutions

- Dedicated devices for physicians
- Different hardware solutions for different disciplines
- Improve log-on time
- Create user friendly screens
Over Reliance

• Technology driving the work flow
  – —The computer told me to give the med”
  – —The scanner beeped - it must be the right patient”
  – —The eMAR set me up to make the mistake”
• Replaces critical thinking skills
• Expect application & equipment to be perfect
• Weakening vigilance
Technology is a Tool

- Emphasize technology intended to double-check the clinician
- Review safety data regularly
- Share stories with clinicians
- Avoid over engineering functionality
  - Keep it Simple
  - Make it Easy to Do the Right Thing
- Continually seek user feedback for improvements
  - Electronic
  - Face-to-face
Continued Feedback

Partners Healthcare System Application Feedback Form

Application: eMAR
Suggestion/Comment:

Your Name: Anne Bane
Telephone: 617-686-7785
Email Address: abane@partners.org

Please enter a phone number or an email address if your comment requires a response.

Please note: Feedback is for submitting non-urgent issues only. For urgent issues, please call your Help Desk.
eMAR Lessons Learned

• Training is most successful when clinicians teach clinicians.
• Expect extreme variances in staff acceptance.
• Be ready to uncover unknown processes that have been supporting the existing MAS now.
• End user feedback is essential to design, implement and maintain technology
• Technology can never replace the critical thinking of clinicians
In Summary

• Barcode technology significantly reduces transcription and administration errors
• A well-designed and fully-supported system did not increase the proportion of time nurses spend on medication administration
• Nurses using the system had higher satisfaction with the medication process
• Key is involvement of end users from the beginning in design, hardware selection, and piloting
Thank You!
Improving The Safety of Pediatric ePrescribing

Kevin B. Johnson, MD, MS
Professor Biomedical Informatics
Showing Your Work

e-prescribing annotations project

Funded by AHRQ R03 HS016261-01

• Adverse events are often mitigated by pharmacists (Cotter, BMJ, 1995)

• Callbacks are the primary mechanism of communication (Isetts, Arch Intern Med 2003)

• E-prescribing provides cognitive support to prescribers, but this process and resulting decisions are not communicated to pharmacists.
The use of a method to automatically annotate prescriptions may improve communication and reduce the risk of adverse drug events.
Show Your Work

- Single site study using internally-developed e-prescribing system (RxStar)
- Randomized trial examining callbacks in three local pharmacies
  - Reason for callback
  - Date and time
  - Type of prescription generating callback
- 7-item survey distributed to 50 high volume local pharmacies:
  - Likert questions about impact of SYW
  - Free text explanations

Fig. 1. Example of Show Your Work annotations below an electronically generated prescription.
Show Your Work Results

No impact on volume of callbacks

Table 4
Callback reasons with and without Show Your Work on.

<table>
<thead>
<tr>
<th>Callback reason</th>
<th>SYW off (%)</th>
<th>SYW on (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error-related</td>
<td>19 (55.9)</td>
<td>20 (60.6)</td>
</tr>
<tr>
<td>Insurance</td>
<td>12 (35.4)</td>
<td>11 (33.3)</td>
</tr>
<tr>
<td>Stock issue</td>
<td>2 (5.8)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>Rule violations</td>
<td>1 (2.9)</td>
<td>2 (6.1)</td>
</tr>
<tr>
<td>Total</td>
<td>34 (100)</td>
<td>33 (100)</td>
</tr>
</tbody>
</table>

Chi-sq(4) = 2.388, p = 0.665 (Fisher’s exact test, p ≈ 1).

- Allergy Overrides 1368
- Severe dose alert overrides 8
- Information-only dose alerts 9894
- Dose calculation formula 3757
- Dose manually calculated alert 302
SYW Pharmacist Perceptions

Table 5
Show Your Work pharmacists perception survey results (n = 33).

<table>
<thead>
<tr>
<th>SYW…</th>
<th>Strongly disagree (%)</th>
<th>Disagree (%)</th>
<th>Neutral (%)</th>
<th>Agree (%)</th>
<th>Strongly agree (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Helped me avoid callbacks</td>
<td>0</td>
<td>1 (3.0)</td>
<td>9 (27)</td>
<td>16 (48)</td>
<td>7 (21)</td>
</tr>
<tr>
<td>2. Helped me check for potential errors</td>
<td>0</td>
<td>0</td>
<td>4 (13)</td>
<td>20 (63)</td>
<td>8 (25)</td>
</tr>
<tr>
<td>3. Caused me to call the prescriber back</td>
<td>1 (3)</td>
<td>20 (61)</td>
<td>9 (27)</td>
<td>2 (6)</td>
<td>1 (3)</td>
</tr>
<tr>
<td>4. Was helpful in pediatric cases</td>
<td>1 (3)</td>
<td>0</td>
<td>5 (16)</td>
<td>18 (55)</td>
<td>9 (27)</td>
</tr>
<tr>
<td>5. Was helpful with insurance eligibility</td>
<td>2 (7)</td>
<td>10 (31)</td>
<td>13 (41)</td>
<td>5 (17)</td>
<td>2 (6)</td>
</tr>
<tr>
<td>6. Was helpful with avoiding callbacks due to patient-reported allergies</td>
<td>0</td>
<td>3 (9)</td>
<td>7 (21)</td>
<td>17 (52)</td>
<td>6 (18)</td>
</tr>
<tr>
<td>7. Was helpful avoiding callbacks due to low or high doses</td>
<td>0</td>
<td>1 (3)</td>
<td>10 (32)</td>
<td>18 (55)</td>
<td>4 (12)</td>
</tr>
</tbody>
</table>

Table 6
Show Your Work pharmacists perception survey comment themes.

<table>
<thead>
<tr>
<th>Theme</th>
<th>No. of comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improving communication between prescribers and dispensers</td>
<td>8</td>
</tr>
<tr>
<td>Decreases callbacks in some cases</td>
<td>3</td>
</tr>
<tr>
<td>Pediatric dosing information helps check for potential errors</td>
<td>16</td>
</tr>
<tr>
<td>Increases callbacks in some cases</td>
<td>2</td>
</tr>
<tr>
<td>Need more information to be included in annotations</td>
<td>2</td>
</tr>
<tr>
<td>New Show Your Work feature request</td>
<td>5</td>
</tr>
</tbody>
</table>
Show Your Work--Impact

- No change in volume of callbacks
- Comments suggest some impact on the reasons for callbacks and the quality of the callbacks.
- Structured sig/e-prescribing should support note fields that can be used to expose results of clinical decision-support.
- Additional studies should more carefully examine quantity and quality of pharmacist communication resulting from e-prescribing.
pediatric dose rounding and compounding

Funded by AHRQ R 18 HSO17216
Ramifications

• Mismatches between formulation recommended by e-prescribing tools and what should be prescribed

• Incorrect dosing recommendations that must be overridden in e-prescribing situations.

Killelea B. Pediatrics 2007
Johnson KB, Pediatrics 1996
The Problem

Data needed to improve pediatric e-prescribing do not exist in a form that is usable by the pharmacists and vendors. How can we construct and disseminate this knowledge nationally?
Goal – to improve the safety and usability of e-prescribing in pediatrics

- Develop a knowledgebase of rounding tolerances for commonly-prescribed medications
- Develop an algorithm to round computer-calculated medication doses safely.
- Develop tools using this knowledgebase and algorithm that can be integrated into disparate e-prescribing systems
- Evaluate the impact on dosing acceptability and pharmacy callbacks
Methods

• Literature review
• Prescriber interviews
• Advisory group survey

• Literature review
• Drug rounding category (digoxin vs. amoxicillin?)
• Knowledge validation-SWAG

Rounding algorithm and philosophies
Rounding tolerance knowledgebase
Data Collection/ Literature Review

• Discovered 115 medications to round, representing 90% of the most commonly prescribed pediatric drugs at Vanderbilt, Cincinnati, CHOP.

• Drug Literature review references:
  – Weight-based dosing guidelines
  – Minimum and maximum dosing
  – Drug toxicity and side effects

  – The Harriet Lane Handbook, 18th Edition
  – Lexi-Comp’s Pediatric Dosage Handbook, 14th Edition
  – Basic and Clinical Pharmacology, 7th Edition
  – Thomson Reuters Healthcare database
Dosing Implements

- Many allow dosing in 0.1 ml increments
- Most designate fractional teaspoon dosing
1) Avoiding Unintentional Consequences
   • Dose-dependent side effects (ex. clindamycin)

2) Controlling Intended Effects
   • Impact of dose-dependent effects (ex. Lasix)

3) Toxicity
   • Narrow therapeutic index (ex. digoxin)

4) No pediatric dosing
   • Safety and Efficacy unknown (ex. Lyrica)
Rounding Percentages

15 percent, 29
10 percent, 24
5 percent, 31
0 percent, 24
1 percent, 2
Web Service for Distributed Use of Rounding Knowledge

Users

E-Prescribing System Server

HTTP XML messages

STEPSTools Server
Values Expected To Come From E-Prescribing System To Web Service

- Patient’s weight in Kg
- Patient’s age in months
- Medication Name
- Medication Encoding
- Mg/Kg Dosing Formula
Medication Mapping

* Attempt to map based on medication encoding first. If mapping fails, attempt to parse medication name (brand or generic) for recognizable match to medication in STEPSTools knowledge base.

**Medication Name**
- Medication Encoding
- Vocabulary
- Code

Recognized Medication In STEPSTools Knowledge Base

(ie. Amoxicillin)
Recognized Medication In STEPSTools Knowledge Base (ie. Amoxicillin)

STEPSTools Knowledge Base Query*

Known Frequencies Simplified as Times Per Day (ie. 2x per day, etc.)

*What are the known commonly-used frequencies for this medication?
Calculate an exact dose

For each known frequency…

Patient Weight In Kilograms from received values (ie. 30 kg)

Mg/Kg Dosing Formula from received values (ie. 40 mg/kg/day)

Known Frequency from knowledge base (ie. 2x per day)

Exact Calculated Dose Which Needs Rounding (ie. 600 mg/dose)
Recognized Medication In STEPSTools Knowledge Base
(ie. Amoxicillin)

Patient Weight in Kilograms
(ie. 30 kg)

Patient Age in Months
(ie. 114 mos)

Minimum and Maximum Recommendations
(ie. 8.3 mg/kg/dose low and 1500 mg/kg/dose high for Amoxicillin, not to exceed 3000 mg/day)

* Find the concatenation of age-based and weight-based absolute minimum and maximum recommendations for this medication as well as absolute maximum per day where applicable.
Recognized Medication In STEPSTools Knowledge Base (ie. Amoxicillin)

STEPSTools Knowledge Base Query

STEPSTools Recommended Rounding Percentage*

Calculate range above and below exact dose by rounding percentage.

ie. 600 mg/dose * 1.15 = 690 mg/dose as high
600 mg/dose * .85 = 510 mg/dose as low

* Recommended percentages based on results from panel discussion of American Academy of Pediatrics and American Medical Informatics Association experts
Generate a List of Possible Doses Within the Working Range

Formulations of Medication*

Amox 125 mg tab
Amox 250 mg/5 ml liquid
Amox 400 mg/5 ml liquid

Working Range (510 – 690 mg/dose)

Formulation Specific Dose Ranges

4.08 - 5.52 tabs
10.2 – 13.8 ml
6.375 - 8.625 ml

Possible Dose Generator

Collection of Possible Doses

*List of formulations for the medication are retrieved from a table in the STEPSTools knowledge base which was derived from data in RxNorm.
Possible Dose Generator Explanation

For each dose range...

Formulation
Specific Dose Range

6.375 - 8.625 ml

Collection of Possible Doses

STEPSTools uses real-life increments appropriate to the form and dose range.

Possible Dose Generator
Score Possible Doses

Collection of Possible Doses → Scoring* → Collection of Possible Doses Sorted By Score

*Each dose scored based on a set of business rules.
Examples of Business Rules for Scoring Possible Doses

• If the age of the patient is less than 7 years, boost the score on doses in liquid or suppository form.

• If the form is liquid, boost the score of doses that are whole milliliter amounts.

• If the form is liquid, boost the score of doses that are greater than 1 milliliter but less than 10 milliliters.
Response Returned To E-Prescribing Server From Web Service

- Frequencies, Calculated Doses
- Working Range
- Possible Ranges
- Possible Doses Scored
Next Steps

• Implementation in two vendor systems
• Evaluation of log files to assess
  – Frequency of use
  – Differences between high scoring doses and final orders
• Site visits to assess
  – Overall prescriber and prescriber agent perception of impact on e-prescribing
  – Pharmacy callbacks and perception of impact
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  – Eugenia Watson, MD
Thank You!
Questions & Answers

Our Panel:

George Hripcsak, M.D., M.S., professor and chair of Columbia University's department of biomedical informatics

Tejal Gandhi, M.D., M.P.H., board certified internist and associate professor of medicine at Harvard Medical School

Kevin B. Johnson, M.D., M.S., professor and vice chair of biomedical informatics; joint appointment in the department of pediatrics at Vanderbilt University Medical Center
Coming Soon!
Our Next Event

A webinar examining health information technology and underserved and vulnerable populations

Stay tuned for exact date and time and information on how to register
Thank You for Attending

This event was brought to you by the AHRQ National Resource Center for Health IT

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http://healthit.ahrq.gov