Smart Alerts in Healthcare: Real as Never Before

Session 218, February 23, 2017

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Speaker Introduction

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Conflict of Interest


- AWARE and sepsis sniffer are licensed to Ambient Clinical Analytics Inc. Dr. Herasevich and Mayo Clinic have a financial conflict of interest relating to described technology.

- This research has been reviewed by the Mayo Clinic Conflict of Interest Review Board and is being conducted in compliance with Mayo Clinic Conflict of Interest Policies.
Conflict of Interest

Vitaly Herasevich, MD, PhD

Salary: Mayo Clinic
Royalty: Ambient Clinical Analytics
Receipt of Intellectual Property Rights/Patent Holder: Yes
Consulting Fees (e.g., advisory boards): Baxter, Philips
Fees for Non-CME Services Received Directly from a Commercial Interest or their Agents (e.g., speakers’ bureau): None
Contracted Research: Intensix
Ownership Interest (stocks, stock options or other ownership interest excluding diversified mutual funds): Ambient Clinical Analytics
Other: None
Agenda

1. Problems with alerts
2. Smart alerts
3. Sepsis sniffer example
4. Alerts evaluation methods
Learning Objectives

• Identify major problems with threshold-based alerts
• Define rule based-alerts or sniffers
• Summarize methods for alerts evaluation
An Introduction of How Benefits Were Realized for the Value of Health IT

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<th>Health IT Value STEPS&lt;sup&gt;tm&lt;/sup&gt;</th>
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Definition of alarms

• An alarm is an automatic warning that results from a measurement to indicate a relevant deviation from a normal state.
• Alarms improve patient safety and quality of care.
• Final goal of alarms could be to detect changes early and suggest appropriate action.
Problems persist over years
Why? Alarm-related problems

1. The rate of false alarms

2. Clinical perception of (mostly false) alarms

+ Patient can’t rest with the multitude of alarm signals going off in the room.
Rate of false alerts

• A 2014 study found that the physiologic monitors in an academic hospital's 66 adult intensive care unit beds generated more than 2 million alerts in one month, translating to 187 warnings per patient per day.

• According to another study, CPOE systems generate warnings for 3%–6% of all orders that are entered, meaning that a physician could easily receive dozens of warnings each day.


Isaac T; Weissman JS; Davis RB; et al. Overrides of medication alerts in ambulatory care. Arch Intern Med. 2009; 169: 305-311, PMID: 19204222
Rate of false alarms

Only eight out a total 1455 sounding indicated potentially life treating problems
Most subjects (about 90%) do not respond to all alarms but match their response rates to the expected probability of true alarms (probability matching).
Factors influencing alert acceptance

Table 6  Association of independent variables with providers’ alert acceptance in the stratum of interruptive alerts, analyzed by binary logistic regression

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds Ratio</th>
<th>95% CI</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose-dependent toxicity</td>
<td>1.13</td>
<td>1.07 to 1.21</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Frequency of the alert</td>
<td>1.30</td>
<td>1.23 to 1.38</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Level of the alert</td>
<td>1.74</td>
<td>1.63 to 1.86</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Prioritization has been found as a linear combination of other variables and is not reported.

However, if an alert did not require acknowledgment, it was only accepted in 1.4% of cases, indicating that alerts are overridden almost completely if no acknowledgment is required. Accordingly, the fact, that an alert was acknowledged, was a significant predictor of its acceptance.
Common causes for unnecessary alarms

• Inappropriate alarm settings,
• Electrode failure leading to poor signal quality,
• Alerts for non-actionable events
• Alerting about something that providers already know
What are ingredients of rule based alerts?
Rule based-alerts or sniffers

Key characteristics - recognition of the context

1. Who
2. When
3. Where
Why combination of data is essential?

• Brief answer: small tweak – big effect

- Introducing covariates significantly improve false alerts rate
- Data does not exist in single database
- Feedback loop is important to increase acceptance rate
Failure to Intervene
Failure to Intervene
Electronic surveillance

• Can do routine calculation
• Can notify provider
• Can analyze providers interventions
• **Should be smart to be not annoying**
Where is Artificial Intelligence?

• Brief answer: it is coming!

Problems to solve:
• Reliability
• Acceptance of “black box”
• Generalizability
Case study – Sepsis Sniffer
Real world problem – sepsis epidemic

• From 1979 to 2000, the incidence of sepsis in the US increased from 164,000 to 660,000 cases: 8.7% annually

• Worldwide, estimated 1400 deaths per day in the ICU as a result of sepsis

• Disproportionately impacts the elderly, individuals with special health care needs, and minorities

• Average costs per case in US: $22,100

• Aggregated cost in US of 2011 of $20.3 billion

Martin GS et al, 2003 (NEJM). PMID: 12700374
Poeze M et al, 2004 (Crit Care). PMID: 15566585
Iwashyna TJ et al, 2010 (JAMA). PMID: 20978258

Mayr FB et al, 2010 (JAMA). PMID: 20571016
DC Angus et al, 2001 (Crit Care Med). PMID: 11445675
The Potential Solution – Early Goal Directed Therapy

- Patients with severe sepsis or septic shock
- First six hours in ED: Critical “golden hours”
- Assigned to standard therapy or EGDT
- In-hospital mortality: Reduced from 46.5% to 30.5%

Rivers E et al, 2001 (NEJM). PMID: 11794169
Dellinger RP et al, 2013 (Crit Care Med). PMID: 15090974
RESULTS: An algorithm based on criteria for suspicion of infection, systemic inflammatory response syndrome, organ hypoperfusion and dysfunction, and shock had a sensitivity of 80% and a specificity of 96% when applied to the validation cohort.
How does the sepsis sniffer work?

- Pull data from source system
- Datamart storage
- Sepsis sniffer algorithm
- Clinician confirm or decline alert pop up
- Claim the patient function
- Decision support dashboard
- Alert in dashboard or email
**Algorithm**

ED

Patient has abnormal:
1) Lactate and/or
2) Hypotension

More sensitive: Do screening

ICU
How does the sepsis sniffer work?
No perfect algorithm!

Tests are never 100% accurate

<table>
<thead>
<tr>
<th>Test</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDA-approved Rapid HIV Tests</td>
<td>0.98 to 1.00</td>
<td>0.98 to 1.00</td>
</tr>
<tr>
<td>QuantiFERON-TB Gold</td>
<td>0.89</td>
<td>0.98</td>
</tr>
<tr>
<td>Tinel's sign</td>
<td>0.97</td>
<td>0.91</td>
</tr>
<tr>
<td>IgA antiendomysial antibodies</td>
<td>0.80 to 0.95</td>
<td>0.98 to 1.00</td>
</tr>
<tr>
<td>IgA anti-tTG antibodies</td>
<td>0.82 to 0.94</td>
<td>0.95 to 0.90</td>
</tr>
<tr>
<td>Video capsule endoscopy</td>
<td>0.82 to 0.94</td>
<td>0.89 to 0.98</td>
</tr>
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Needs to “claim” and confirm alert.

• Why claim the patient?
  – To route alert for appropriate caregiver
  – “Safety net” for sepsis conformation

• Why confirm?
  – No perfect algorithm
Decision support tool

• Why?
  – Lead toward achievement 4 elements of care
## Process monitoring

### Successful completion of bundle

<table>
<thead>
<tr>
<th>Lactate</th>
<th>Blood culture</th>
<th>Ab</th>
<th>Fluids</th>
<th>PASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.8 mmol/L</td>
<td>Ordered</td>
<td></td>
<td>80 ml/kg</td>
<td></td>
</tr>
</tbody>
</table>

### Failed completion of bundle

<table>
<thead>
<tr>
<th>Lactate</th>
<th>Blood culture</th>
<th>Ab</th>
<th>Fluids</th>
<th>FAIL</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.2 mmol/L</td>
<td>Ordered</td>
<td></td>
<td>20 ml/kg</td>
<td></td>
</tr>
</tbody>
</table>
Bundle compliance report

Percentage of patient out of rolling census experienced AWARE intervention

Monday, Dec 1, 2014
AWARE Intervention: 138 (73%) out of 190
Impact?

Time to alert reaction

- Sixty-two patients were identified by the sniffer during the two-week pilot trial. There were 24 providers who interacted with the tool.

- The median (IQR) time for the physician to take action to evaluate an identified patient was 3.8 min (1.1; 12.3).
## Bundle compliance in pilot trial

<table>
<thead>
<tr>
<th></th>
<th>BEFORE (N = 98)</th>
<th>AFTER (N = 60)</th>
<th>p-value</th>
</tr>
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<tbody>
<tr>
<td><strong>Percent completion (%)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-hour SSC Bundle overall compliance</td>
<td>25</td>
<td>55</td>
<td>0.001</td>
</tr>
<tr>
<td>Measure lactate level</td>
<td>64</td>
<td>95</td>
<td>0.001</td>
</tr>
<tr>
<td>Obtain blood cultures</td>
<td>81</td>
<td>88</td>
<td>0.204</td>
</tr>
<tr>
<td>Administer antibiotics</td>
<td>61</td>
<td>93</td>
<td>0.001</td>
</tr>
<tr>
<td>Administer 30 mL/kg fluids</td>
<td>46</td>
<td>62</td>
<td>0.055</td>
</tr>
<tr>
<td><strong>Average time to completion median value, mins (IRQ)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-hour SSC Bundle overall compliance</td>
<td>-4 (-137 to 148)</td>
<td>-126 (-159 to -18)</td>
<td>0.184</td>
</tr>
<tr>
<td>Measure lactate level</td>
<td>128 (0 to 374)</td>
<td>13 (-63 to 125)</td>
<td>0.002</td>
</tr>
<tr>
<td>Obtain blood cultures</td>
<td>416 (79 to 710)</td>
<td>153 (53 to 517)</td>
<td>0.019</td>
</tr>
<tr>
<td>Administer antibiotics</td>
<td>116 (8 to 398)</td>
<td>-31 (-84 to 85)</td>
<td>0.001</td>
</tr>
<tr>
<td>Administer 30 mL/kg fluids</td>
<td>-4 (-138 to 332)</td>
<td>-120 (-159 to 105)</td>
<td>0.380</td>
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Steps to develop intelligent alerts or “sniffers”

1. Patterns need to be recognized: machine learning techniques or by experienced clinicians in the field or from evidence-based literature.

2. Patterns need to be algorithmized.

3. Algorithms need to be tested on large databases.

4. EMRs need to be programmed to recognize these patterns by using tested algorithm.

5. Real-time testing then needs to be used to ensure that sensitivity and specificity is adequate for clinical usage.
Alerts evaluation

- Is it fast?
- Is it accurate?
- Is it user friendly?

- Does it work?
- Will they use it?

- What is cost/benefit?
- Is it reliable?

- Is it safe?
- Is it help me?

Adopted from: Friedman and Wyatt, 1997
Clinically meaningful outcomes to test in alerting systems

1) Sensitivity, Specificity, PPV, NPV
3) Mortality, LOS and other clinical metrics
2) Time to acknowledgment
4) Users satisfaction

PPV – positive predictive value
NPV – negative predictive value
LOS – length of the stay
Diagnostic accuracy study

Clinical metrics

- Before-after study
- Randomized trial

Example

Time to acknowledgment and user satisfaction


The System Usability Scale (SUS) provides a “quick and dirty”, reliable tool for measuring the usability.

Points to remember

• No perfect detection algorithm exist
• Manual alert conformation is a key
• Visual DST gives “something back” to clinicians
• Real time compliance report allows act quick
Medical informatics

Hunter JS. Enhancing Friedman’s “Fundamental Theorem of Biomedical Informatics”. J Am Med Inform Assoc 2010;17:112-113
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Questions

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PS. Please complete online session evaluation