A Knowledge-based Risk Assessment Tool for Alert-overridden High-risk IV Drug Infusions

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2017 REMEDI Spring Conference
Date: 04/20/2017
Problem

• Each alert-override IV infusion could potentially cause patient harm of various degrees

• Most analysis tools evaluate drug infusion performance by alert frequency:
  - Not consider that each alert-override infusion could cause patient harm of various degrees
  - No risk-based tool, considering likelihood of potential harm degrees, was developed

Source: https://catalyze-care.org/phi
Research Objectives and Importance

• Develop a quantitative risk assessment tool based on medical professionals’ knowledge

• This proposed tool can
  ➢ improve the existing analysis tools
  ➢ quantify the potential risk of IV harm by several commonly used, high-risk drug infusions

• Application
  ➢ help the medication safety teams efficiently highlight the clinical care areas and drugs with the highest risk of harm
Research Framework

**Goal:**
Develop a knowledge-based quantitative risk assessment tool

**Phase I:**
Create representative drug infusion scenarios
1. Obtain experts’ risk assessments
2. Create a model to predict risk of harm

**Phase II:**

**Phase III:**
1. Obtain expert’s paired-comparison assessments
2. Create AHP to calculate relative risk rankings
Explore and Classify Pump Alert Data

• Data:
  ➢ A large hospital system (REMEDI hospital member)
    ▪ Time frame: January 2010 – May 2015
    ▪ Overdose and overridden alerts

• Classification

<table>
<thead>
<tr>
<th>Factor</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_i$</td>
<td>Care Area (AICU, AMS)</td>
</tr>
<tr>
<td>$B_j$</td>
<td>Drug (Heparin, Insulin, Morphine, Propofol)</td>
</tr>
<tr>
<td>$C_k$</td>
<td>Drug Limit Type (Continuous, Bolus dose, BDAR)</td>
</tr>
<tr>
<td>$D_{ijk}$</td>
<td>Soft Max &amp; Hard Max Drug Limits</td>
</tr>
</tbody>
</table>

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**Phase I:** Scenario Design

**Phase II:** Experts’ Risk Assessment

**Phase III:** Experts’ Paired-Comparison Assessment
**Scenario Design Structure**

One set of A, B, C, D with 9 combinations of E & F

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**30 Scenario Types**
e.g. AICU – Propofol – Continuous – Drug Limit

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**9 Sub-scenarios**

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**Factors and Variables**

- Factor A<sub>i</sub>
- Factor B<sub>j</sub>
- Factor C<sub>k</sub>
- Factor D<sub>l</sub> (ijk)
- Factor E<sub>1</sub> (ijkl)
- Factor E<sub>2</sub> (ijkl)
- Factor E<sub>3</sub> (ijkl)
- Factor F<sub>1</sub> (ijkl)
- Factor F<sub>2</sub> (ijkl)
- Factor F<sub>3</sub> (ijkl)

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**Phase I:** Scenario Design

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**Phase III:** Experts’ Paired-Comparison Assessment

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**Care Area**

**Drug**

**Drug Limit Type**

**Soft Max & Hard Max Drug Limit**

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**Infusion Dose Rate/Ratio**

**Total Volume to be Infused (VTBI)**

**Scenario**
Example of Scenarios and Assessment Table

<table>
<thead>
<tr>
<th>Probability (%)</th>
<th>100</th>
<th>90</th>
<th>80</th>
<th>70</th>
<th>60</th>
<th>50</th>
<th>40</th>
<th>30</th>
<th>20</th>
<th>10</th>
<th>5</th>
<th>1</th>
<th>0</th>
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</thead>
<tbody>
<tr>
<td>Very Likely</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Unlikely</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Default when no probability selected/marked</td>
</tr>
</tbody>
</table>

Severity of Harm

- No Harm: (C)
- Minor Harm: (D)
- Moderate Harm: (E)
- Major Harm: (F, G)
- Extreme Harm: (H, I)

Patient Information
- a 35-year-old male
- Patient Weight: 70 kg

Scenario I - Infusion Information

- Dose (Dose Rate): 56 mcg/kg.min
- Ratio = \( \frac{Dose \ (Dose \ Rate)}{Soft \ Max \ (51 \ mcg/\ kg/min)} = 1.1 \)
- Volume Rate: 0.4 mL/min
- VTBI: 5 mL [A1]
- VTBI: 53 mL [A2]
- VTBI: 100 mL [A3]

AICU - Propofol

- Soft Max: 51 mcg/kg.min
- Hard Max: 80 mcg/kg.min

Field Limit Type: Continuous Dose

Total Volume to be Infused (VTBI)
## NCC MERP – Harm Degree Category

<table>
<thead>
<tr>
<th>NCC Category</th>
<th>Definition II (NCC, 2001)¹</th>
<th>Severity of Harm²</th>
</tr>
</thead>
</table>
| C            | A programming error occurred that reached the patient but did not cause patient harm  
*Harm is defined as “any physical injury or damage to the health of a person requiring additional medical care, including both temporary and permanent injury”* | No Harm |
| D            | A programming error occurred that reached the patient and required monitoring to confirm that it resulted in no harm to the patient and/or required intervention to preclude harm  
*Monitoring is defined as “to observe or record physiological or psychological signs”* | Minor Harm |
| E            | A programming error occurred that may have contributed to or resulted in temporary harm to the patient and required intervention  
*A significant intervention is defined as “an intervention intended to relieve symptoms that have the potential to be life-threatening if not addressed”* | Moderate Harm |
| F            | A programming error occurred that may have contributed to or resulted in temporary harm to the patient and required initial or prolonged hospitalization  
*A significant intervention is defined as “an intervention intended to relieve symptoms that have the potential to be life-threatening if not addressed”* | Major Harm |
| G            | A programming error occurred that may have contributed to or resulted in permanent patient harm  
*Permanent harm is defined as “harm lasting more than 6 months, or where end harm is not known (‘watchful waiting’)”* |  |
| H            | A programming error occurred that required intervention necessary to sustain life  
*An intervention necessary to sustain life is defined as including “cardiovascular and/or respiratory support (e.g., CPR, defibrillation, intubation)”* | Extreme Harm |
| I            | A programming error occurred that may have contributed to or resulted in the patient’s death |  |

Phase I: Scenario Design

Phase II: Experts' Risk Assessment

Phase III: Experts' Paired-Comparison Assessment

Preliminary Risk Assessment Results

Source: Chang et al. (2003). Categorization, Frequency, and Cost Impact of Medication Errors
Concept of Risk Assessment Model Development

**Knowledge-based Model (Compositional Data)**

\[
f(x_1, \ldots, x_K; \alpha_1, \ldots, \alpha_K) = \frac{1}{B(\alpha)} \prod_{i=1}^{K} x_i^{\alpha_i - 1},
\]

**Inputs**
- Risk Factor
  - $X_{1i}$
  - $X_{2i}$
  - $X_{ni}$

**Outputs**
- Harm Degree
  - No Harm
  - Minor
  - Moderate
  - Major
  - Extreme

**NCC Category**
- C
- D
- E
- F, G
- H, I

**Phase I:** Scenario Design
**Phase II:** Experts' Risk Assessment
**Phase III:** Experts' Paired-Comparison Assessment
AHP Risk Scores v.s. Experts’ Risk Assessments

Phase I: Scenario Design
Phase II: Experts’ Risk Assessment
Phase III: Experts’ Paired-Comparison Assessment

Relative Importance Variables

<table>
<thead>
<tr>
<th>factor A</th>
<th>Very Strongly</th>
<th>Strongly</th>
<th>Equally Important</th>
<th>Moderate</th>
<th>Strongly</th>
<th>Very Strongly</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X2i</td>
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</tr>
<tr>
<td>Xni</td>
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</tbody>
</table>

Analytic Hierarchy Process

Matrix-based Model (Paired Comparison Matrix)

AHP Outputs

Experts’ Risk Assessment

NCC Category

Scenario i1-i9

Inputs

Risk Factor

Option 1 | Option 2 | Option 3 | Option 4
---------|----------|----------|----------
Count    |          |          |          |
Weighted |          |          |          |
Rank     |          |          |          |

Option 1 | Option 2 | Option 3 | Option 4
---------|----------|----------|----------
Count    |          |          |          |
Weighted |          |          |          |
Rank     |          |          |          |
**Vision**

**Frequency-based Indicator**

- Alerts by Drug or Fluid
- Actions Taken by Drug or Fluid
- Alerts by Month
- Alerts Profile Pie Chart

**Risk-based Indicator**

\[ f \left( \sum_{i} x_i w_{i,j} \right) \]

**Alert Frequency**

- High Priority
- Low Priority

**Risk Score**

- High
- Low

Input Links

Output Links
Thank you!

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