Reliability vs. Validity

- Unreliable & Unvalid
- Unreliable, But Valid
- Reliable, Not Valid
- Both Reliable & Valid
Reliability

- Reliability is a measure of precision and is a function of both hospital exposure volume (i.e., sample size which determines “noise” variation) and the amount of true variation across hospitals (“signal”)

\[
\text{Reliability} = \frac{\sigma^2_{\text{signal}}}{\sigma^2_{\text{signal}} + \sigma^2_{\text{noise}}} = \frac{\sigma^2_{\text{between-hospital}}}{\sigma^2_{\text{between-hospital}} + \sigma^2_{\text{within-hospital}}}
\]

- For example, hospitals with low exposure volume will have lower reliability and need to be weighted towards the mean, whereas, hospitals with high exposure volume are more reliable and require less weighting towards the mean.
Secure web-based system operated by the Centers for Disease Control and Prevention (CDC)

Used by CDC and its healthcare and public partners for surveillance of HAIs

All 50 states participate

In 2011, the Centers for Medicare & Medicaid Services (CMS) Inpatient Quality Reporting program required hospitals to report CLABSI incidence data from their intensive care units
Public Reporting & CDC Goals

- CMS Inpatient Quality Reporting is a pay-for-reporting program
- CLABSI incidence data are publicly reported on CMS’ Hospital Compare website as of January 2012
- Healthcare quality metrics suitable for public reporting should
  - Account for variability in patient case-mix
  - Adjust for measured and unmeasured risk factors
  - Account for differences due to exposure volume
CMS Hospital Compare Site

Central-Line-Associated Blood Stream Infections (CLABSI)
Why is this important?

Lower Numbers are Better

<table>
<thead>
<tr>
<th>Hospital</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital A</td>
<td>2.22</td>
</tr>
<tr>
<td>Hospital B</td>
<td>1.30</td>
</tr>
<tr>
<td>Center C</td>
<td>1.10</td>
</tr>
<tr>
<td>Georgia</td>
<td>0.71</td>
</tr>
</tbody>
</table>

National Benchmark = 1

http://www.hospitalcompare.hhs.gov/
Objective

- Develop an improved metric that summarizes infection experience and provides more meaningful ranking among hospitals using advanced methods
Methods

- 2011 NHSN CLABSI incidence data
- Modeling
  - Univariate analysis
  - Log linear marginal modeling using a Negative Binomial distribution
  - Bayesian hierarchical random effects model with diffuse priors estimated using Markov chain Monte Carlo sampling methods
- Calculate crude and reliability-adjusted SIRs
- Compare variation across these two distributions
### NHSN CLABSI Data for 2011

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of hospitals</td>
<td>3,348</td>
</tr>
<tr>
<td>Number of CLABSI&lt;es&gt;</td>
<td>11,936</td>
</tr>
<tr>
<td>Number of Central Line-Days</td>
<td>10,588,922</td>
</tr>
<tr>
<td>CLABSI Incidence Density Rate (per 1000 CL Days)</td>
<td>1.13</td>
</tr>
</tbody>
</table>
# Potential Model Factors

<table>
<thead>
<tr>
<th>Description</th>
<th>Value Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICU location type</td>
<td>Burn, Coronary, Medical, Medical/Surgical, Pediatric, Surgical, etc.</td>
</tr>
<tr>
<td>Major medical school affiliation</td>
<td>Y / N</td>
</tr>
<tr>
<td>Hospital bed size</td>
<td>12-1523</td>
</tr>
<tr>
<td>Central line device utilization</td>
<td>0 ≤ d ≤ 1</td>
</tr>
</tbody>
</table>
## Negative Binomial Model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>Rate Ratio</th>
<th>Chi-square P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-6.9990</td>
<td>.</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>ICU location: Burn vs. Med-Surg</td>
<td>1.2450</td>
<td>3.47</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>ICU location: Ped vs. Med-Surg</td>
<td>0.3726</td>
<td>1.45</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Major teaching status</td>
<td>0.2078</td>
<td>1.23</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Central line device utilization ratio &lt; 0.50</td>
<td>0.0492</td>
<td>1.05</td>
<td>0.0177</td>
</tr>
</tbody>
</table>
Standardized Infection Ratio (SIR)

\[ SIR = \frac{\text{Observed CLABSI}_i(O_i)}{\text{Predicted CLABSI}_i(E_i)}, \]

\[ O_i = \sum_{j=1}^{L} \sum_{k=1}^{M} \text{Observed CLABSI}_{i,j,k} \]

\[ E_i = \sum_{j=1}^{L} \sum_{k=1}^{M} \hat{Y}_{i,j,k} \]

where

\[
\log \left[ Y_{i,j,k} \mid x_{n,i,j,k} \right] = \beta_0 + \beta_1 x_{1,i,j,k} + \ldots + \beta_n x_{n,i,j,k} + \log(D_{i,j,k})
\]
Standardized Infection Ratio (SIR)

SIR Distribution

Need to differentiate zero SIRs
### Zero SIRs

<table>
<thead>
<tr>
<th>Hospital #1</th>
<th>Hospital #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>107 Central line-days</td>
<td>1503 Central line-days</td>
</tr>
<tr>
<td>SIR(_1) = \frac{0}{0.10}</td>
<td>SIR(_2) = \frac{0}{1.42}</td>
</tr>
<tr>
<td>Upper 95% CI Bound = 29.96</td>
<td>Upper 95% CI Bound = 2.11</td>
</tr>
</tbody>
</table>

**Concept**

| SIR\(_1\)' = \frac{0}{0.10} * 0.05 + 1.0 * 0.95 | SIR\(_2\)' = \frac{0}{1.42} * 0.8 + 1.0 * 0.2 |
| SIR | Exposure | Mean | Mean | SIR | Exposure | Mean | Mean |
| Volume weight | weight | weight | weight |
Reliability-Adjusted SIR'

\[ SIR' = \frac{\text{Adjusted CLABSI}(O_i')}{\text{Predicted CLABSI}(E_i)'} \]

\[ O_i' = \sum_{j=1}^{L} \sum_{k=1}^{M} \hat{Y}_{i,j,k} \]

where \( Y_{i,j,k} \) was estimated using a Bayesian Random Effects model.
Reliability-Adjusted SIR’

SIR’ Distribution

Number of Hospitals

SIR’
SIR and SIR' Distributions

**SIR Distribution**
- CV = 137.4
- CQV = 1.0
- 95%CI = (0.999, 1.001)

**SIR' Distribution**
- CV = 42.6
- CQV = 0.19
- 95%CI = (0.181, 0.0204)
SIR or SIR' vs. Log CL DAYS

A

B

C

Log_{10}(Central Line-Days)
Conclusions

- Reliability-adjusted SIRs account for
  - Patient case-mix
  - Differences due to exposure volume
  - Unmeasured factors associated with CLABSI incidence

- This improved measure will allow for more meaningful ranking among hospitals

- New measures will be developed for other events (SSI, CAUTI, LAB ID events, etc.)

- CDC plans to implement these in future performance measurement conducted by CMS
Thank You!

For more information, please contact Centers for Disease Control and Prevention

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E-mail: cdcinfo@cdc.gov  Web: www.cdc.gov

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.