Estimating the Cost of Healthcare-Associated MRSA Infections in the VA

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• Collaborators
  – Michael A. Rubin, MD, PhD (VA SLC)
  – Matthew H. Samore, MD (VA SLC)
  – Makoto Jones, MD (VA SLC)
  – Vanessa Stevens, PhD (VA SLC)
  – Karim Khader, PhD (VA SLC)
  – Martin E. Evans, MD (VA Lexington)
  – Chuan-Fen Liu, PhD, MPH (VA Puget Sound)
  – Nicholas Graves, PhD (University of Queensland)
Poll

• Are you an infectious disease researcher or clinician?
  – Yes
  – No
Whiteboard Exercise

• How are estimates of the healthcare cost of a particular illness useful?
HAI and MRSA

• Healthcare-associated infections (HAI)
  – Infections that result from encounters with healthcare system
  – About 440,000 in US adults per year\textsuperscript{1}
  – NHSN definition = identified after 1\textsuperscript{st} 48 hours during hospital stay

• Methicillin-resistant \textit{Staphylococcus aureus} (MRSA)
  – Bacteria resistant to many antibiotics
  – One of the leading causes of invasive infections in healthcare settings\textsuperscript{2}
    • Bloodstream, pneumonia, and surgical site infections

\textsuperscript{1} Zimlichman \textit{JAMA Int Med} 2013
\textsuperscript{2} Hidron \textit{Infect Control Hosp Epidemiol} 2008
Original Investigation

National Burden of Invasive Methicillin-Resistant Staphylococcus aureus Infections, United States, 2011

Raymund Dantes, MD, MPH; Yi Mu, PhD; Ruth Belflower, RN, MPH; Deborah Aragon, MSPH; Ghinwa Dmyati, MD; Lee H. Harrison, MD; Fernanda C. Lessa, MD; Ruth Lynfield, MD; Joelle Nadle, MPH; Susan Petit, MPH; Susan M. Ray, MD; William Schaffner, MD; John Townes, MD; Scott Fridkin, MD; for the Emerging Infections Program-Active Bacterial Core Surveillance MRSA Surveillance Investigators

Veterans Affairs
MRSA Prevention Initiative

• Began October 2007
• Consisted of a “bundle” of prevention strategies
  – Universal nasal surveillance for MRSA
  – Contact precautions for patients colonized or infected with MRSA
  – Hand hygiene
  – Institutional change
    • HAI prevention is everyone’s responsibility
Veterans Affairs Initiative to Prevent Methicillin-Resistant Staphylococcus aureus Infections

Rajiv Jain, M.D., Stephen M. Kralovic, M.D., M.P.H., Martin E. Evans, M.D., Meredith Ambrose, M.H.A., Loretta A. Simbartl, M.S., D. Scott Obrosky, M.S., Marta L. Render, M.D., Ron W. Freyberg, M.S., John A. Jernigan, M.D., Robert R. Muder, M.D., LaToya J. Miller, M.P.H., and Gary A. Roselle, M.D.
Veterans Affairs methicillin-resistant *Staphylococcus aureus* prevention initiative associated with a sustained reduction in transmissions and health care-associated infections

Martin E. Evans MD\(^{a,b,*}\), Stephen M. Kralovic MD, MPH\(^{c,d}\), Loretta A. Simbartl MS\(^c\), Ron W. Freyberg MS\(^e\), D. Scott Obrosky MS\(^f\), Gary A. Roselle MD\(^{c,d}\), Rajiv Jain MD\(^g\)
Long-Term Research Question

• What was budget impact of MRSA Prevention Initiative in VA?
  – Key component: cost of MRSA HAI in VA
## Conceptual model

<table>
<thead>
<tr>
<th>Admission date</th>
<th>HAI date</th>
<th>Discharge date</th>
</tr>
</thead>
</table>
| Healthcare services attributable to HAI | • More inpatient days  
• More services on each day | • Number of outpatient visits  
• Number of prescriptions  
• Risk of readmission  
• More inpatient days on readmission |
| Healthcare costs attributable to HAI | • Cost per inpatient day | • Cost of outpatient visit  
• Cost per prescription  
• Cost of readmission |
|                           | Pre-discharge | Post-discharge |
| Index hospitalization |
Components of accurate cost of HAIs

1. Pre-discharge costs
   – Incorrect methods (overestimation)

2. Post-discharge costs
   – Often neglected in cost of HAI estimates (underestimation)
Which Costs Can be Avoided?

Cost of HAI

- Staff
- Buildings
- Equipment

Fixed Cost

Variable Cost
Estimating cost of MRSA HAI in VA

• Need way of identifying healthcare costs
  – VA DSS data
    • Activity-based accounting system in VA
    • Extracts information from general ledger and VA payroll system
    • Specific job categories, supplies or equipment
    • Costs are allocated to cost centers
      – Primary care clinics
      – Intensive care units
      – Administration
      – Environmental services
    • Costs are allocated based on employee activities
Estimating cost of MRSA HAI in VA

• Need way of identifying MRSA infections
  – ICD-9 code (V09) is not good for MRSA HAIs
    • V09 = infection with drug-resistant microorganisms
  – Microbiology data
    • Unstructured

Schweizer et al *ICHE* 2011
Identification of methicillin-resistant *Staphylococcus aureus* within the Nation’s Veterans Affairs Medical Centers using natural language processing

Makoto Jones¹,²*, Scott L DuVall¹,²*, Joshua Spuhl¹, Matthew H Samore¹,², Christopher Nielson³,⁴ and Michael Rubin¹,²
Aside: Impact of HAI on Excess LOS

• Important because each extra bed-day taken up by a patient with HAI represents opportunity cost for hospital

• Many studies compare total LOS between patients with HAI and those without

Patient 1

[Diagram showing HAI during admission]

Patient 2

[Diagram showing no HAI during admission]

• But not all of the days are attributable to the HAI

• This leads to “time-dependent bias”

Barnett AJE (2009)
Barnett Value in Health (2011)
Aside: Impact of HAI on Excess LOS

- Multi-state models

\[ \lambda_{ij} = \frac{\text{number of } i \rightarrow j \text{ transitions}}{\text{person-time in state } i} \]

- Match patients with HAI with those without HAI on timing of infection
Estimates of the Magnitude of Time-Dependent Bias

### Multistate model

<table>
<thead>
<tr>
<th>Study</th>
<th>HAI type</th>
<th>Excess LOS (HAI non-time-varying)</th>
<th>Excess LOS (HAI time-varying)</th>
<th>Absolute difference (days)</th>
<th>Relative difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schulgen (2000) - Study I</td>
<td>Postoperative wound</td>
<td>18.8</td>
<td>9.8</td>
<td>9.0</td>
<td>91.8%</td>
</tr>
<tr>
<td>Schulgen (2000) - Study II</td>
<td>Pneumonia</td>
<td>13.4</td>
<td>3.4</td>
<td>10.0</td>
<td>292.6%</td>
</tr>
<tr>
<td>Roberts (2010)</td>
<td>Many</td>
<td>8.1</td>
<td>5.9</td>
<td>2.2</td>
<td>37.3%</td>
</tr>
<tr>
<td>Barnett (2011)</td>
<td>CLABSI, CAUTI, VAP</td>
<td>11.2</td>
<td>1.4</td>
<td>9.9</td>
<td>731.9%</td>
</tr>
<tr>
<td>Schumacher (2013)</td>
<td>Pneumonia</td>
<td>21.9</td>
<td>6.2</td>
<td>15.7</td>
<td>253.2%</td>
</tr>
<tr>
<td>Wolkewitz (2013)</td>
<td>MRSA</td>
<td>24.5</td>
<td>6.0</td>
<td>18.6</td>
<td>312.3%</td>
</tr>
</tbody>
</table>

**Mean** 10.9 286.5%

### Matching on timing of infection

<table>
<thead>
<tr>
<th>Study</th>
<th>HAI type</th>
<th>Excess LOS (HAI non-time-varying)</th>
<th>Excess LOS (HAI time-varying)</th>
<th>Absolute difference (days)</th>
<th>Relative difference</th>
</tr>
</thead>
</table>

**Mean** 8.7 96.1%
Impact of HAI on Pre-Discharge Costs

• All previous studies compare total inpatient costs between patients with HAI and those without

• But not all of the costs are attributable to the HAI

• This leads to “time-dependent bias”
Impact of HAI on Pre-Discharge Costs

- Can we differentiate between costs that occur before and after HAI with VA data?

- DSS Daily Cost Resource (DCR)
  - Daily inpatient costs

- DSS Production-Level Data
Impact of HAI on Pre-Discharge Costs

- Can we differentiate between costs that occur before and after HAI with VA data?
  - Separate observations for each patient-treating specialty-calendar month

<table>
<thead>
<tr>
<th>admitday</th>
<th>txspsd</th>
<th>txsped</th>
<th>txsp</th>
<th>fy</th>
<th>fp</th>
<th>TotFD</th>
<th>TotFI</th>
<th>TotVD</th>
<th>TotCost</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009-10-29</td>
<td>2009-10-29</td>
<td>2009-10-31</td>
<td>63</td>
<td>2010</td>
<td>1</td>
<td>$1270.52</td>
<td>$17,767.53</td>
<td>$38,508.67</td>
<td>$57,546.72</td>
</tr>
<tr>
<td>2009-10-29</td>
<td>2009-10-31</td>
<td>2009-10-31</td>
<td>52</td>
<td>2010</td>
<td>1</td>
<td>$13.83</td>
<td>$195.31</td>
<td>$282.38</td>
<td>$491.52</td>
</tr>
<tr>
<td>2009-10-29</td>
<td>2009-11-01</td>
<td>2009-11-04</td>
<td>52</td>
<td>2010</td>
<td>2</td>
<td>$63.47</td>
<td>$1560.92</td>
<td>$1966.30</td>
<td>$3590.69</td>
</tr>
<tr>
<td>2009-10-29</td>
<td>2009-11-04</td>
<td>2009-11-05</td>
<td>63</td>
<td>2010</td>
<td>2</td>
<td>$225.60</td>
<td>$1882.73</td>
<td>$2480.43</td>
<td>$4588.76</td>
</tr>
<tr>
<td>2009-10-29</td>
<td>2009-11-05</td>
<td>2009-11-12</td>
<td>52</td>
<td>2010</td>
<td>2</td>
<td>$401.53</td>
<td>$7290.23</td>
<td>$9183.70</td>
<td>$16,875.45</td>
</tr>
<tr>
<td>2009-10-29</td>
<td>2009-11-12</td>
<td>2009-11-21</td>
<td>22</td>
<td>2010</td>
<td>2</td>
<td>$1089.92</td>
<td>$12,469.61</td>
<td>$15,273.73</td>
<td>$28,833.26</td>
</tr>
</tbody>
</table>

6 observations
Impact of HAI on Pre-Discharge Costs

• Conventional analysis
  – Compare cost over entire LOS for patients with and without MRSA HAI

• Improved analysis
  – Utilize the quirk of the DSS TRT file to identify costs occurring after MRSA HAI
Patient 1
HAI on 1st day of month

Patient 2
HAI in 1st month

Patient 3
HAI in 2nd month

Patient 4
No HAI

Patient 5
HAI, 1 month

Patient 6
No HAI, 1 month

X = HAI
The diagram illustrates the time window for capturing costs in conventional and improved analysis.

- **Patient 1**: HAI on 1st day of month.
- **Patient 2**: HAI in 1st month.
- **Patient 3**: HAI in 2nd month.
- **Patient 4**: No HAI.
- **Patient 5**: HAI, 1 month.
- **Patient 6**: No HAI, 1 month.

**Time window for capturing costs in conventional analysis**:
- Calendar month 1: Admit X Discharge
- Calendar month 2: Admit Discharge

**Time window for capturing costs in improved analysis**:
- Calendar month 1: Admit X Discharge
- Calendar month 2: Admit Discharge

The symbol X represents an HAI event.
Patient 1
- HAI on 1st day of month

Patient 2
- Exclude
- HAI in 1st month

Patient 3
- No HAI
- HAI in 2nd month

Patient 4
- No HAI
- No HAI

Patient 5
- Exclude
- HAI

Patient 6
- Exclude
- No HAI

Time window for capturing costs in conventional analysis

Calendar month 1
- Admit
- Month 1 costs
- Discharge

Calendar month 2
- Admit
- Month 2 costs
- Discharge

X = HAI
Patient 1: HAI on 1st day of month
Patient 2: HAI in 1st month
Patient 3: HAI in 2nd month
Patient 4: No HAI
Patient 5: HAI, 1 month
Patient 6: No HAI, 1 month

Time window for capturing costs in conventional analysis
- Calendar month 1: Admit, Month 1 costs, Discharge
- Calendar month 2: X

Time window for capturing costs in improved analysis
- Calendar month 1: Admit, Month 1 costs, Discharge
- Calendar month 2: X
Impact of HAI on Pre-Discharge Costs

- Patient selection
  - Inclusion criteria
    - Patients admitted to 1 of 123 VA hospitals nationwide
      - 1\textsuperscript{st} hospitalization
    - Between Oct 1, 2007 – Sept 30, 2010
    - 365 days prior to admission
  - Exclusion criteria
    - Patients with inpatient stays < 48 hours
    - Patients with MRSA positive culture in 365 days prior to admission
    - Patients with MRSA positive surveillance test on index admission
Conventional Analysis

Include all patients who survived initial inclusion exclusion criteria

Patients meeting inclusion/exclusion criteria
N = 386,794

No MRSA HAI
N = 382,812

MRSA HAI
N = 3,982 (1.04%)

Improved Analysis

Exclude patients with < 2 calendar months and with MRSA HAI during month 1

Patients meeting inclusion/exclusion criteria
N = 121,520

No MRSA HAI
N = 121,428

MRSA HAI
N = 92 (0.08%)
Impact of HAI on Pre-Discharge Costs

• Approximation of improved method on data more widely available
  – “Almost as good” method
  – If have date of HAI but not cost data that separates cost by calendar month
  – Propensity score match 4 non-MRSA HAI patients for every MRSA HAI patient
    • For each MRSA HAI patient, the potential matches were those still at risk for MRSA HAI on the day that the infected patient was infected
    • Did separate PS matching for HAIs occurring on days 3-40
Conventional Analysis
Include all patients who survived initial inclusion exclusion criteria

Patients meeting incl/excl criteria
N = 386,794

No MRSA HAI
N = 382,812
MRSA HAI
N = 3,982

Almost as Good Analysis
PS match MRSA HAI patients with 4 controls without MRSA HAI up to that point

Patients meeting incl/excl criteria
N = 13,374

No MRSA HAI
N = 10,457
MRSA HAI
N = 2,917

Improved Analysis
Exclude patients with < 2 calendar months and with MRSA HAI during month 1

Patients meeting incl/excl criteria
N = 121,520

No MRSA HAI
N = 121,428
MRSA HAI
N = 92
Impact of HAI on Pre-Discharge Costs

• Methods
  – Dependent variables
    • Total cost
    • Variable cost
    • LOS
  – Generalized linear model (GLM)
    • Gamma distribution for costs
    • Poisson distribution for LOS
Impact of HAI on Pre-Discharge Costs

• Methods
  – Independent variables
    • Improved method
      – MSRA HAI
      – Demographics
      – Comorbid conditions
        » Principle ICD-9
        » CCI/Elixhauser comorbidity index
      – Prior healthcare utilization
        » Surgery within 1st 48 hours
        » Outpatient costs in 365 days prior to admission
        » LOS during 1st calendar month
      – Facility
Impact of HAI on Pre-Discharge Costs

• Methods
  – Independent variables
    • Conventional method
      – MSRA HAI
      – Demographics
      – Comorbid conditions
        » Principle ICD-9
        » CCI/Elixhauser comorbidity index
      – Prior healthcare utilization
        » Surgery within 1st 48 hours
        » Outpatient costs in 365 days prior to admission
      – Facility
Mean per-patient unadjusted inpatient costs

<table>
<thead>
<tr>
<th>Method</th>
<th>Total Cost</th>
<th>Variable Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>$98,758</td>
<td>$60,739</td>
</tr>
<tr>
<td>Almost as good</td>
<td>$90,735</td>
<td>$31,165</td>
</tr>
<tr>
<td>Improved</td>
<td>$88,652</td>
<td>$14,238</td>
</tr>
<tr>
<td>No MRSA HAI</td>
<td>$51,798</td>
<td>$32,209</td>
</tr>
<tr>
<td>Conventional</td>
<td>$48,323</td>
<td>$15,889</td>
</tr>
<tr>
<td>Almost as good</td>
<td>$45,832</td>
<td></td>
</tr>
<tr>
<td>Improved</td>
<td>$45,832</td>
<td></td>
</tr>
</tbody>
</table>

Bar chart showing cost breakdown for different methods and MRSA HAI status.
# Impact of HAI on Pre-Discharge Costs

## Results: Multivariable Cost Regressions

- **Model = GLM, gamma/Poisson distribution, log link**
- **Dependent variable = inpatient cost, LOS**
- **Key independent variable = MRSA HAI**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Improved method$^a$ N=121,520</th>
<th>Almost as good method$^a$ N=13,374</th>
<th>Conventional method$^b$ N=443,856</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Effect</td>
<td>95% CI</td>
<td>Effect</td>
</tr>
<tr>
<td>Variable</td>
<td>$12,272</td>
<td>$5,501</td>
<td>$13,816</td>
</tr>
<tr>
<td>Total</td>
<td>$23,733</td>
<td>$10,497</td>
<td>$25,517</td>
</tr>
<tr>
<td>LOS</td>
<td>12.85</td>
<td>11.86</td>
<td>12.10</td>
</tr>
</tbody>
</table>

$^a$Improved method regressions controlled for the following variables: demographic characteristics, comorbid conditions, surgery during 1st 48 hours, primary ICD-9 code, length of stay during 1st calendar month, and facility

$^b$Almost as good method regressions controlled for the following variables: demographic characteristics, comorbid conditions, surgery during 1st 48 hours, primary ICD-9 code, and facility

$^c$Conventional method regressions controlled for the following variables: demographic characteristics, comorbid conditions, primary ICD-9 code, and facility
Impact of HAI on Pre-Discharge Costs

- "Conventional" method
  - 46.7% higher than "improved" method
  - $18,003 vs. $12,272

- "Almost as good" method
  - 4.8% higher than "improved" method
  - $13,816 vs. $12,272
Impact of HAI on post-discharge costs

• Patient selection
  – Inclusion criteria
    • Patients admitted to 1 of 123 VA hospitals nationwide
      – 1st hospitalization
    • Between Oct 1, 2007 – Sept 30, 2010
    • 365 days prior to admission
  – Exclusion criteria
    • Patients with inpatient stays < 48 hours
    • Patients with MRSA positive culture in 365 days prior to admission
    • Patients with MRSA positive surveillance test on index admission
Impact of HAI on post-discharge costs

• Exposure
  – MRSA HAI
    • MRSA positive clinical culture between 48 hours after admission and 48 hours after discharge
Impact of HAI on post-discharge costs

• Post-discharge outcomes
  – Inpatient costs
    • Variable costs
    • Total costs
  – Outpatient costs
  – Pharmacy costs

Inpatient LOS
365 days post-discharge
Post-discharge outcomes time window
Impact of HAI on post-discharge costs

Patients meeting inclusion/exclusion criteria
N = 369,743

- No MRSA HAI
  N = 366,144
- MRSA HAI
  N = 3,599
Unadjusted post-discharge costs

Total inpatient: $36,030
Variable inpatient: $18,815
Outpatient: $13,427
Pharmacy: $4,146

MRSA HAI
No MRSA HAI
## Results – Multivariable Cost Regressions

- **Model** = GLM, gamma distribution, log link
- **Dependent variable** = cost in 365 days post-discharge
- **Key independent variable** = MRSA HAI

<table>
<thead>
<tr>
<th></th>
<th>Full cohort (N=369,743)</th>
<th>Propensity score matched subgroup (N=7,184)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outpatient</strong></td>
<td>Effect: -$465</td>
<td>Effect: -$395</td>
</tr>
<tr>
<td></td>
<td>95% CI: -$972</td>
<td>95% CI: -$1,191</td>
</tr>
<tr>
<td></td>
<td>$42</td>
<td>$401</td>
</tr>
<tr>
<td><strong>Pharmacy</strong></td>
<td>Effect: $563</td>
<td>Effect: $710</td>
</tr>
<tr>
<td></td>
<td>95% CI: $24</td>
<td>95% CI: $407</td>
</tr>
<tr>
<td></td>
<td>$1,102</td>
<td>$1,013</td>
</tr>
<tr>
<td><strong>Total inpatient</strong></td>
<td>Effect: $7,179</td>
<td>Effect: $11,044</td>
</tr>
<tr>
<td></td>
<td>95% CI: $5,533</td>
<td>95% CI: $8,298</td>
</tr>
<tr>
<td></td>
<td>$8,825</td>
<td>$13,790</td>
</tr>
<tr>
<td><strong>Variable inpatient</strong></td>
<td>Effect: $3,735</td>
<td>Effect: $5,826</td>
</tr>
<tr>
<td></td>
<td>95% CI: $2,882</td>
<td>95% CI: $4,380</td>
</tr>
<tr>
<td></td>
<td>$4,588</td>
<td>$7,273</td>
</tr>
</tbody>
</table>

*Note: Regression controlled for the following variables: demographic characteristics, comorbid conditions, LOS during index hospitalization, primary ICD-9 code for index hospitalization*
Limitations

• MRSA positive cultures
  – Could be colonization rather than infection
• We don’t see post-discharge healthcare resource utilization that occurred outside the VA
Conclusions

• Conventional methods lead to different estimates of economic burden of MRSA HAIs

<table>
<thead>
<tr>
<th></th>
<th>Conventional methods</th>
<th>Improved methods</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre-discharge</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>$33,885</td>
<td>$23,733</td>
</tr>
<tr>
<td>Variable</td>
<td>$18,003</td>
<td>$12,272</td>
</tr>
<tr>
<td><strong>Post-discharge</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pharmacy</td>
<td>-</td>
<td>$710</td>
</tr>
<tr>
<td>Total inpatient</td>
<td>-</td>
<td>$11,044</td>
</tr>
<tr>
<td>Variable inpatient</td>
<td>-</td>
<td>$5,826</td>
</tr>
<tr>
<td><strong>Total total costs</strong></td>
<td>$33,885</td>
<td>$35,487</td>
</tr>
<tr>
<td><strong>Total variable costs</strong></td>
<td>$18,003</td>
<td>$18,808</td>
</tr>
</tbody>
</table>
Thank you

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