Second: Connect surveillance data with clinical and radiological data

Maaike S.M. van Mourik
Connecting surveillance data

- Typical surveillance: manual chart review of specific groups of patients
  - Labor-intensive
  - ‘The more you look, the more you find’
  - Variable interpretation

- Connecting clinical data ↔ surveillance data
  - Adoption of electronic health records (EHR)
    1. Automated surveillance to increase quality & efficiency
    2. Collect data to drive and assess interventions
Data (re)sources

- Routine care data
  - collected during routine process of care
  - extracted through clinical data warehouses

- Availability in a standardized format differs
- Depends on clinical practice and documentation
- Additional registration by clinicians

<table>
<thead>
<tr>
<th>Clinical data</th>
<th>Medico-administrative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microbiology results</td>
<td>Medication use</td>
</tr>
<tr>
<td>Laboratory results</td>
<td>Procedures</td>
</tr>
<tr>
<td>Device use</td>
<td>Radiology interventions</td>
</tr>
<tr>
<td>Physician narratives*</td>
<td>Diagnosis codes</td>
</tr>
<tr>
<td>Radiology*</td>
<td>Billing data</td>
</tr>
</tbody>
</table>

*often free text

De Bruin *JAMIA* 2014, van Mourik *BMJ Open* 2015
Connecting surveillance and clinical data

- Automation to support surveillance
  - Measure outcomes (incidence): SSI, CLABSI, pneumonia, UTI, ...

- Automation to support interpretation
  - Case-mix correction: underlying disease, medications, ASA, BMI
  - SIR

- Automation to drive interventions -> modifiable risk factors?
  - Antibiotic prophylaxis, glucose control, normothermia, duration of central line
  - Process measures
Automated surveillance

- Replacing manual decision steps with automated process
  - ≠ Electronic registration

  ➢ More efficient by reducing workload

  ➢ Better standardization
    - Less subjective interpretation
    - Less effort-dependent
Semi-automated surveillance

- Select probable HAI cases for manual review

Performance:
- Sensitivity
- Efficiency

Figure by Meander Sips
Fully automated surveillance

- No manual confirmation of HAI status

Performance:
- Comparability
- Specificity

Woeltje *J Hosp Infect*, 2013, Figure by Meander Sips
Approaches to automated surveillance

Approaches to automated surveillance

• Classification models

• Regression models

• Machine-learning based algorithms
  – Classification trees, Bayesian frameworks, fuzzy logic

• Adapted definitions to support (full) automation
  – Simplifying definitions by removing clinical components
Classification algorithms for semi-automated surv.

- Good performance for SSI and other infections
- Multiple sources of information for case-finding
- Match clinical practice

Indicators of HAI

Demographics
Clinical chemistry
Signs & symptoms
Microbiology
Procedures
Diagnosis
Medication

Case-finding indicator(s) and/or refinement criteria

High probability
Patients assessed manually

Low probability
No chart review

+ HAI
- No HAI

No HAI

Van Mourik *Clin Infect Dis* 2013
Table 2. Characteristics and Performance of Selected Classification Algorithms for the Detection of Healthcare-Associated Infections

<table>
<thead>
<tr>
<th>Study</th>
<th>Targeted HAI</th>
<th>No. (% HAI)</th>
<th>Setting</th>
<th>Case Finding Based on</th>
<th>Refinement Steps</th>
<th>Sensitivity (%)</th>
<th>PPV (%)</th>
<th>NNS</th>
<th>Records to Review (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trick et al, 2004</td>
<td>CLABSI</td>
<td>135 (35.6)</td>
<td>Inpatient</td>
<td>Microbiology (blood culture)</td>
<td>Timing, other cultures, antibiotic use</td>
<td>81</td>
<td>62</td>
<td>1.3</td>
<td>47</td>
</tr>
<tr>
<td>Wielandtje et al, 2008</td>
<td>CLABSI</td>
<td>771 (8.7)</td>
<td>ICU</td>
<td>Microbiology (blood culture)</td>
<td>Timing, CVC presence, other culture, fever</td>
<td>94</td>
<td>20</td>
<td>5.0</td>
<td>43</td>
</tr>
<tr>
<td>Wielandtje et al, 2011</td>
<td>CLABSI</td>
<td>391 (22)</td>
<td>Inpatient (non-ICU)</td>
<td>Microbiology (blood culture)</td>
<td>Timing, CVC presence, other culture, fever</td>
<td>95</td>
<td>90</td>
<td>1.1</td>
<td>23</td>
</tr>
<tr>
<td>Pokorny et al, 2006</td>
<td>BSI, VAP, CAUTI</td>
<td>194 (18)</td>
<td>ICU</td>
<td>2 or more of: microbiology, antibiotics or discharge code</td>
<td>Timing</td>
<td>94</td>
<td>56</td>
<td>1.8</td>
<td>30</td>
</tr>
<tr>
<td>Stamm and Bettacchi, 2012</td>
<td>CLABSI, VAP, CAUTI</td>
<td>141 HAI</td>
<td>ICU</td>
<td>Microbiology (NIM)</td>
<td>Timing, ADT</td>
<td>67</td>
<td>39</td>
<td>2.6</td>
<td>Unclear</td>
</tr>
<tr>
<td>Leth et al, 2010</td>
<td>UTI</td>
<td>1513 (3.2)</td>
<td>Inpatient + postdischarge</td>
<td>Microbiology and/or antibiotic</td>
<td>Timing</td>
<td>77</td>
<td>93</td>
<td>1.1</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td>SSI</td>
<td>1513 (7.1)</td>
<td>Inpatient + postdischarge</td>
<td>Microbiology and/or antibiotic and/or discharge code and/or reoperation</td>
<td>Timing</td>
<td>72</td>
<td>71</td>
<td>1.4</td>
<td>14</td>
</tr>
<tr>
<td>Bolon et al, 2009</td>
<td>SSI</td>
<td>6322 (1.7)</td>
<td>Inpatient</td>
<td>Antimicrobial exposure, diagnosis codes (index + readmission)</td>
<td>Timing</td>
<td>~90</td>
<td>25-40</td>
<td>2.5-4</td>
<td>4.0-6.2</td>
</tr>
<tr>
<td>Yokoe et al, 2012</td>
<td>SSI</td>
<td>11159 (5.8)</td>
<td>Inpatient</td>
<td>Antimicrobial exposure, diagnosis codes (index + readmission)</td>
<td>Timing</td>
<td>89</td>
<td>18</td>
<td>5.6</td>
<td>18</td>
</tr>
<tr>
<td>Song et al, 2008</td>
<td>SSI</td>
<td>1226 (5.9)</td>
<td>Inpatient + outpatient</td>
<td>Antibiotic or readmission or discharge diagnosis (index, follow-up)</td>
<td>Timing</td>
<td>82</td>
<td>13</td>
<td>7.7</td>
<td>36</td>
</tr>
<tr>
<td>Hollenbeck et al, 2012</td>
<td>SSI</td>
<td>1066 (8.8)</td>
<td>Inpatient</td>
<td>Microbiology (NIM)</td>
<td>Timing, ADT</td>
<td>20</td>
<td>68</td>
<td>1.5</td>
<td>2.6</td>
</tr>
<tr>
<td>Gerber et al, 2012</td>
<td>SSI</td>
<td>446 (8.5)</td>
<td>Inpatient</td>
<td>Antimicrobial exposure</td>
<td>Timing</td>
<td>68</td>
<td>34</td>
<td>2.9</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Microbiology</td>
<td>Timing</td>
<td>63</td>
<td>55</td>
<td>1.8</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Discharge code</td>
<td>Timing</td>
<td>26</td>
<td>83</td>
<td>1.2</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Combination of above</td>
<td>Timing</td>
<td>87</td>
<td>36</td>
<td>2.8</td>
<td>21</td>
</tr>
</tbody>
</table>

Abbreviations: ADT, admission, discharge, and transfer database; BSI, bloodstream infection; CAUTI, catheter-associated urinary tract infection; CLABSI, central line-associated bloodstream infection; HAI, healthcare-associated infection; ICU, intensive care unit; NIM, national institute of medicine; PPV, positive predictive value; SSI, surgical site infection; VAP, ventilator-associated pneumonia.
Example: deep SSI after hip/knee arthroplasty

- Re-operations
- Prolonged antibiotics
- > 5 cultures taken or positive culture
- Length of stay & readmissions

Classification algorithm: ≥3 out of 4 present

- High probability
  - Chart review
  - Low probability, no SSI

<table>
<thead>
<tr>
<th></th>
<th>Deep SSI</th>
<th>No deep SSI</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>High probability</td>
<td>30</td>
<td>46</td>
<td>76</td>
</tr>
<tr>
<td>Low probability</td>
<td>0</td>
<td>1561</td>
<td>1561</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>1607</td>
<td>1637</td>
</tr>
</tbody>
</table>

Sensitivity: 100%
PPV: 39.5% → workload reduction ≈ 95%
Example: classification algorithm for CLABSI

Case-finding
Positive blood culture

Refinement criteria:
- Time of onset > 48hrs?
- Common skin contaminant?
- Repeat culture (other sites)?
- Central line in place? (fever?)

<table>
<thead>
<tr>
<th>CLABSI</th>
<th>Sensitivity (%)</th>
<th>Pos pred value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trick 2004, Inpatient</td>
<td>81</td>
<td>62</td>
</tr>
<tr>
<td>Snyders 2015, ICU</td>
<td>79, 82</td>
<td>44, 57</td>
</tr>
<tr>
<td>Snyders 2015, Non-ICU</td>
<td>79, 82</td>
<td>44, 57</td>
</tr>
<tr>
<td>Woeltje 2008, Non-ICU</td>
<td>94</td>
<td>90</td>
</tr>
<tr>
<td>Woeltje 2011, ICU</td>
<td>94</td>
<td>20</td>
</tr>
</tbody>
</table>
Example: fully automated surveillance using adapted definitions

- *Hospital-acquired infections database* (HAIBA) – DK

- **Aim:** Monitor trends at hospital or department level
  - National sharing of source data, daily update
  - Incidence data published on public website
  - Adapted definitions (bacteremia, SSI, UTI, *C. diff*)
HAIBA

Microbiology

National patient registry

Medication (regional)

HAIBA

Algorithm

Primary total hip arthroplasty (index-operation)

Elective index-operation

Acute index-operation

Follow-up period between 3-90 days and 91 to 730 days

Relevant re-operation and at least two out of at least three Karmme-biopsy cultures positive for the same microorganism

Facilitating surveillance by shifting definitions?

Table 2. Key Data Elements Necessary for Electronic Surveillance of Healthcare-Associated Infections

<table>
<thead>
<tr>
<th>NHSN surveillance metric</th>
<th>Key electronic data elements</th>
<th>Barriers to fully automated electronic surveillance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central line–associated line infection</td>
<td>Microbiology cultures (blood and non-blood sites), ADT, central venous catheter presence</td>
<td>Current definition requires judgment regarding the origin of the blood pathogen</td>
</tr>
<tr>
<td>Catheter-associated urinary tract infection</td>
<td>Microbiology cultures (urine only), urinalysis, ADT, vital signs (fever), urinary catheter presence</td>
<td>Current definition requires assessment of patient symptoms</td>
</tr>
<tr>
<td>Surgical site infection</td>
<td>Microbiology cultures (superficial or deep wound cultures), procedure billing codes (eg, CPT codes), hospital billing codes (eg, ICD-9), ADT (to detect readmissions), antibiotic administration (optional)</td>
<td>Current definition requires judgment as to whether infection occurred, since not all infections have a positive culture; designation of depth of infection is often very nuanced</td>
</tr>
<tr>
<td>Ventilator-associated event (VAC, IVAC)</td>
<td>Ventilator settings (PEEP, FiO₂), presence of endotracheal intubation device, ADT, antimicrobial use, vital signs (temperature), laboratory (white blood cell count), microbiology culture results</td>
<td>None</td>
</tr>
</tbody>
</table>
Shifting definitions?

- Facilitates manual and automated surveillance
  - Higher inter-rater reliability

- Changing surveillance definitions → measure something else
  - Broader scope of conditions
  - Preventable events
  - Clinician buy-in

- Automation does not guarantee comparability
- Impact depends on intended aim of surveillance

Ability to drive quality improvement?

# Semi- vs. fully automated surveillance?

<table>
<thead>
<tr>
<th>Semi-automated</th>
<th>Fully automated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source data standardization</td>
<td>Source data standardization</td>
</tr>
<tr>
<td><strong>Standardized definition</strong></td>
<td><strong>Adapt definitions as HAI metric</strong></td>
</tr>
<tr>
<td>Need for chart review</td>
<td>Less effort</td>
</tr>
<tr>
<td>Room for clinical nuance</td>
<td>Subjective interpretation impossible</td>
</tr>
<tr>
<td>Clinical acceptance</td>
<td>Clinical buy-in?</td>
</tr>
</tbody>
</table>

Most suitable?  
Probably depends on application & setting
Crucial steps for automated surveillance

• Availability of high-quality data
  – Current lack of standardization of clinical data, multiple EHR systems
  – Understanding data generation mechanisms

• Build toolbox of methods & adapt to different clinical settings

• Validation: development and implementation

• Investment in IT development and acceptance
  • IT knowledge infection control not widespread (and vice versa)

• Heterogeneous system development -> shared methodology
Ongoing studies

• Building a toolbox: Semi-automated surveillance pilot study (EpiNet)
  – Framework for automated surveillance development, 4 European hospitals
  – SSI after orthopedic, cardiac and colon surgery (CLABSI)
  – Feasibility, performance, clinical practice variation and one-size-fits-all?

• Providing a Roadmap for Automated Infection Surveillance in Europe (PRAISE)
  – JPIAMR funded network project with partners from 11 European countries
  – Bringing automated surveillance from research to implementation
Thank you!

Julius Center for Health Sciences and Primary Care
Stephanie van Rooden, Janneke Verberk, Meander Sips
Department of Microbiology & Infection Control
Annet Troelstra, Marc Bonten
Hetty Blok, Herman Wunderink
(Research) IT
Aafke Jongsma, Gythe Arends, Eva Hendriks, Astrid Roskes
And many others

Contact: M.S.M.vanMourik-2@umcutrecht.nl
Example: Local semi-automated surveillance

Aims:
- Document SSI status in medical record of each individual patient
- Increase efficiency: semi-automated surveillance using data warehouse
- Increase reliability: more systematic workflow

- Focus on deep SSI
- THA/TKA, spine, cardiac surgery, breast ...
- Definitions unchanged
- Maintain clinician acceptance
- Flexible: new incidence studies possible
Local semi-automated surveillance (at UMCU)

- Report can include risk factors if documented in structured field
  - Age, ASA, BMI, duration of surgery, donor-harvest site ...

Inclusion

- Selected surgery
  - Automated rule
  - Manual inclusion

Assessment

- HAI prob.
  - low
  - high
- Chart review
  - Validation
  - No SSI
  - SSI

Reporting

- Extraction
  - t = 0
  - t = 90
  - t = 120
  - t = 150 - 180

Days after procedure
<table>
<thead>
<tr>
<th>Variable</th>
<th>Deep SSI (n = 30)</th>
<th>Deep SSI (n = 1,607)</th>
<th>Chart Review (n = 1,637)</th>
<th>Sensitivity, %</th>
<th>PPV, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case-finding in routine surveillance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥1 relevant microbiological culture obtained</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1A ≥1 positive relevant culture</td>
<td>30</td>
<td>81</td>
<td>111</td>
<td>100.0</td>
<td>27.0</td>
</tr>
<tr>
<td>1B ≥5 relevant cultures obtained</td>
<td>30</td>
<td>58</td>
<td>88</td>
<td>100.0</td>
<td>34.1</td>
</tr>
<tr>
<td>1 Total: 1A or 1B</td>
<td>30</td>
<td>111</td>
<td>141</td>
<td>100.0</td>
<td>21.3</td>
</tr>
<tr>
<td>Diagnostic category 2: Antibiotics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 ≥14 d of antibiotic exposure</td>
<td>30</td>
<td>50</td>
<td>80</td>
<td>100.0</td>
<td>37.5</td>
</tr>
<tr>
<td>Diagnostic category 3: (Re)admissions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3A Primary admission ≥14 d</td>
<td>16</td>
<td>220</td>
<td>236</td>
<td>14.4</td>
<td>53.3</td>
</tr>
<tr>
<td>3B ≥1 readmission for a relevant specialty</td>
<td>23</td>
<td>90</td>
<td>113</td>
<td>6.9</td>
<td>76.7</td>
</tr>
<tr>
<td>3 Total: 3A or 3B</td>
<td>30</td>
<td>295</td>
<td>325</td>
<td>19.9</td>
<td>9.2</td>
</tr>
<tr>
<td>Diagnostic category 4: Surgery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 ≥1 orthopedic surgical procedure</td>
<td>30</td>
<td>90</td>
<td>120</td>
<td>7.3</td>
<td>25.0</td>
</tr>
<tr>
<td>Surveillance models</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>m4 Positive on 4 categories</td>
<td>30</td>
<td>14</td>
<td>44</td>
<td>100.0</td>
<td>68.2</td>
</tr>
</tbody>
</table>