Electronic Surveillance of Healthcare-Associated Infections – Is it worth it?

Walter Koller\(^a\), Alexander Blacky\(^a\), Harald Mandl\(^b\), Klaus-Peter Adlassnig\(^b,c\)

\(^a\) Clinical Institute of Hospital Hygiene, Medical University of Vienna (MUV) and Vienna General Hospital (VGH), Austria
\(^b\) Medexter Healthcare GmbH, Vienna, Austria
\(^c\) Section for Medical Expert and Knowledge-Based Systems, Center for Medical Statistics, Informatics, and Intelligent Systems, MUV, Austria

SF2H Congress Lille, 6 June 2012
**Background**

For good reasons, healthcare authorities demand installation and regular application of HAI surveillance as part of quality management in hospitals.

Dilemma of conventional surveillance of HAIs: HAI surveillance is a time-consuming task for highly trained experts. Unavailability of a suitable workforce meets with increasing financial constraints.

**Challenge:** Obtain reliable surveillance results without urging or relying on doctor’s or nurse’s sparse time resources for documentation of surveillance data.
Multiple infection risks in intensive care: Impaired immunity and exposure* to pathogens (MRSA, VRE, ESBL etc.)

*multiple entry sites

3SF2H Congress Lille, 6 June 2012  Kolle
In ICUs specific features support IT-based HAI surveillance:

Electronic patient data management systems (PDMS):
- are installed and in use in many ICUs,
- receive continuous automated input from monitoring equipment (vital parameters) and from laboratories (incl. microbiology).
- ICU caregivers are familiar with documentation of patient-related clinical information into PDMS

- PDMS hold structured clinical data relevant for infection surveillance
Our target:

Develop and implement intelligent software which can extract and analyze HAI-related surveillance information from structured clinical data held in PDMS.
(Our) main challenges when starting and propagating intelligent IT surveillance:

- **Bridge the gap** between international **standard HAI case definitions** and the **clinicians perception** of his/her actual “case”
  - Reliability and accuracy in clinical terms and
  - Timeliness of surveillance results
- Achieve full **technical** and **organizational feasibility of IT surveillance**
- Get independent from day to day data input of clinical specialists and documentation staff
  ➔ ➔ Reduce infection rates and costs by (almost) real-time IT monitoring
MONI-ICU

Knowledge-based recognition and automated monitoring of nosocomial infections for adult ICUs at

Medical University of Vienna and Vienna General Hospital
MONI-ICU components in terms of METHOD and PRACTICE

(1) **Electronic data sources** providing **structured medical data**;

(2) **Medical knowledge base** with computerized knowledge about all relevant clinical entities;

(3) **Processing algorithm** that evaluates, aggregates, and interprets medical data in a stepwise manner until it can be mapped into the given HAI definitions (ECDC/HELICS or NHSN*)

* NHSN = National Healthcare Safety Network, former NNIS of CDC, Atlanta, USA
CareVue/ICIP™ (Philips Medical Systems) acting as **PDMS and structured data source for MONI**

### Table

<table>
<thead>
<tr>
<th>GRAFIK</th>
<th>ATTIK</th>
<th>TFATI</th>
<th>TFAMO</th>
<th>ATTIK</th>
<th>TFATI</th>
<th>TFAMO</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRAPIK</td>
<td>ATTIK</td>
<td>TFATI</td>
<td>TFAMO</td>
<td>ATTIK</td>
<td>TFATI</td>
<td>TFAMO</td>
</tr>
<tr>
<td>GRAPIK</td>
<td>ATTIK</td>
<td>TFATI</td>
<td>TFAMO</td>
<td>ATTIK</td>
<td>TFATI</td>
<td>TFAMO</td>
</tr>
<tr>
<td>GRAPIK</td>
<td>ATTIK</td>
<td>TFATI</td>
<td>TFAMO</td>
<td>ATTIK</td>
<td>TFATI</td>
<td>TFAMO</td>
</tr>
<tr>
<td>GRAPIK</td>
<td>ATTIK</td>
<td>TFATI</td>
<td>TFAMO</td>
<td>ATTIK</td>
<td>TFATI</td>
<td>TFAMO</td>
</tr>
</tbody>
</table>

### Diagram

SF2H Congress Lille, 6 June 2012  Koller
Medical Knowledge Base and data processing

Constituents of HAI case definitions

- **Clinical signs/symptoms** (e.g., fever, chills, cough, rales, pain, ...)

- **Laboratory** findings (e.g., elevated WBC-counts, elevated CRP)

- **Microbiology** findings

- **Radiology** findings (e.g., positive chest-RX)
Constituents of HAI case definitions — one example

**Source:** ECDC HAIICU protocol v 1.01, 2010; [http://www.ecdc.europa.eu](http://www.ecdc.europa.eu)

### Pneumonia (PN1-PN5)

Two or more serial chest X-rays or CT-scans with a suggestive image of pneumonia for patients with underlying cardiac or pulmonary disease. In patients without underlying cardiac or pulmonary disease one definitive chest X-ray or CT-scan is sufficient.

And at least one of the following:

- Fever > 38 °C with no other cause
- Leukopenia (<4000 WBC/mm³) or leucytosis (≥ 12 000 WBC/mm³)

And at least one of the following:

(or at least two if clinical pneumonia only = PN4 and PN5)

- New onset of purulent sputum, or change in character of sputum (color, odor, quantity, consistency)
- Cough or dyspnea or tachypnea
- Suggestive auscultation (rales or bronchial breath sounds), ronchi, wheezing
- Worsening gas exchange (e.g., O₂ desaturation or increased oxygen requirements or increased ventilation demand)
Constituents of HAI case definitions — example contin.

and according to the used diagnostic method

a - Bacteriologic diagnostic performed by:

- Positive quantitative culture from minimally contaminated LRT specimen (PN1)
  - Broncho-alveolar lavage (BAL) with a threshold of $\geq 10^4$ colony forming units (CFU)/ml or $\geq 5\%$ of BAL obtained cells contain intracellular bacteria on direct microscopic exam (classified on the diagnostic category BAL).
  - Protected brush (PB Wimberley) with a threshold of $\geq 10^3$ CFU/ml
  - Distal protected aspirate (DPA) with a threshold of $\geq 10^4$ CFU/ml

- Positive quantitative culture from possibly contaminated LRT specimen (PN2)
  - Quantitative culture of LRT specimen (e.g. endotracheal aspirate) with a threshold of $10^9$ CFU/ml

b - Alternative microbiology methods (PN3)

- Positive blood culture not related to another source of infection
- Positive growth in culture of pleural fluid
- Pleural or pulmonary abscess with positive needle aspiration
- Histologic pulmonary exam shows evidence of pneumonia
- Positive exams for pneumonia with virus or particular germs (Legionella, Aspergillus, mycobacteria, mycoplasma, Pneumocystis carinii)
  - Positive detection of viral antigen or antibody from respiratory secretions (e.g., EIA, FAMA, shell vial assay, PCR)
  - Positive direct exam or positive culture from bronchial secretions or tissue
  - Seroconversion (e.g.: influenza viruses, Legionella, Chlamydia)
  - Detection of antigens in urine (Legionella)

c - Others

Positive sputum culture or non-quantitative LRT specimen culture (PN4)

- No positive microbiology (PN5)

Note: PN1 and PN2 criteria were validated without previous antimicrobial therapy
Translation of HAI definitions into IT terminology

Example bloodstream infections (BSI)

**Source:** HELICS-protocol for Surveillance of HAI in ICU, ver. 6.1, Sep. 2004

<table>
<thead>
<tr>
<th>CODE: BSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSI-A:</td>
</tr>
<tr>
<td>▪ 1 positive blood culture for a <strong>recognised pathogen</strong></td>
</tr>
<tr>
<td>or</td>
</tr>
<tr>
<td>▪ Patient has at least one of the following signs or symptoms: fever (&gt;38°C), chills, or hypotension and 2 positive blood cultures for a common skin contaminant (from 2 separate blood samples drawn within 48 hours).</td>
</tr>
<tr>
<td>skin contaminants = coagulase-negative staphylococci, <em>Micrococcus sp.</em>, <em>Propionibacterium acnes</em>, <em>Bacillus sp.</em>, <em>Corynebacterium sp.</em></td>
</tr>
</tbody>
</table>

**BSI-B:** Patient has at least one of the following signs or symptoms: fever (>38°C), chills, or hypotension

And either

| ▪ 1 positive blood culture with a **skin contaminant** in patient with an intravascular line in place and in whom the physician instituted appropriate antimicrobial therapy. |

or

| ▪ positive blood Antigen test (e.g. *H.influenzae*, *S.pneumoniae*, *N. meningitidis* or Group B *Streptococcus*) |

**Comment:**
BSI-A is the definition used by the majority of NI surveillance networks in Europe. BSI-B extends this definition to the CDC definition of laboratory-confirmed bloodstream infection. Networks should specify in the network data (table ICU_net, see 6.3.1) whether only BSI A or both BSI B and BSI A are included in the surveillance (i.e. networks using CDC definition of laboratory confirmed bloodstream infection [CDC_cst=BSI-A+B]). If this is the case, then BSI A and BSI B categories should be specified in the data collection.
Decomposition and time allocation of clinical signs

clinical_signs_of_BSI \( (t-1d, t, t+1d) \) [yesterday, today, tomorrow]

\[
\begin{align*}
\text{clinical_signs_of_BSI} \ (t-1d) &= \\
&= \text{fever} \ (t-1d) \\
&\quad \lor \\
&\quad \text{hypotension} \ (t-1d) \\
&\quad \lor \\
&\quad \text{leucopenia} \ (t-1d) \\
&\quad \lor \\
&\quad \text{leucocytosis} \ (t-1d) \\
&\quad \lor \\
&\quad \text{CRP increased} \ (t-1d)
\end{align*}
\]

\[
\begin{align*}
\text{clinical_signs_of_BSI} \ (t) &= \\
&= \text{fever} \ (t) \\
&\quad \lor \\
&\quad \text{hypotension} \ (t) \\
&\quad \lor \\
&\quad \text{leucopenia} \ (t) \\
&\quad \lor \\
&\quad \text{leucocytosis} \ (t) \\
&\quad \lor \\
&\quad \text{CRP increased} \ (t)
\end{align*}
\]

\[
\begin{align*}
\text{clinical_signs_of_BSI} \ (t+1d) &= \\
&= \text{fever} \ (t+1d) \\
&\quad \lor \\
&\quad \text{hypotension} \ (t+1d) \\
&\quad \lor \\
&\quad \text{leucopenia} \ (t+1d) \\
&\quad \lor \\
&\quad \text{leucocytosis} \ (t+1d) \\
&\quad \lor \\
&\quad \text{CRP increased} \ (t+1d)
\end{align*}
\]

SF2H Congress Lille, 6 June 2012. Koller
Fuzzification of clinical signs — example: fever

fever (t-1d) ⇐ ...

\[ \begin{cases} \text{body temperature} \uparrow \\ \text{thermoregulation applied} \end{cases} \]

fever (t) ⇐ ∨

fever (t+1d) ⇐ ...

Data import

Intensive care unit

Maximum value of the day e.g., 38.5 °C
MONI-ICU components in terms of OUTPUT

a) Standard Reporting Tool: aggregates results in tables and graphs for periodic epidemiology reporting

b) Advanced Reporting Tool: Graphical user interfaces display daily “infection pattern” and allow for deep insight at the level of vital parameters and basic clinical indicators

c) Option: automated reminders (alerts) for HAI-related conditions may be installed
a) MONI-ICU “standard” reporting

Preformatted tables and graphs:

- **Overview of 12 ICUs** for the Institute of Hospital Hygiene
- Separate report for each ICU

MONI-ICU data are exported into a specially designed EXCEL tool which displays tables and graphs
MONI surveillance standard report

Denominator data:

- Admissions

- Patient days

- mean LOS (days)
MONI surveillance standard report

Device use:

- Urine catheter days
- CVC days
- Respirator days
MONI surveillance standard report

Infections:

CRI by type

CVC-associated CRI-rate
(n/1000 device days)
MONI surveillance standard report

**UTI by type**
(k = with, nk = without catheter)

<table>
<thead>
<tr>
<th>UTI</th>
<th>ICU 1</th>
<th>ICU 2</th>
<th>ICU 3</th>
<th>ICU 4</th>
<th>ICU 5</th>
<th>ICU 6</th>
<th>ICU 7</th>
<th>ICU 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>UTI-A-k</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>UTI-A-nk</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>UTI-B-k</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>UTI-B-nk</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>UTI-C-k</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>UTI-C-nk</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

**Urine catheter assoc. UTI-rate**
(n/1000 device days)

**Urine catheter use rate**
(n/1000 patient days)

**UTI incidence rate**
(n/1000 patient days)
b) MONI-ICU “advanced” tool for detailed analyses

- Detailed insight into day-to-day patient data
- Tool for infection control staff and for ICU staff
MONI surveillance overview - one month and one ward selected

Colors indicate patient days with infection and % fuzziness degree of compliance with case definitions for HAI.

Each line in graph is one patient stay.

One patient stay selected and line listed.

One day exploded.

HAI rules which fired and % fuzzy degree of compliance.

Underlying clinical, lab and RX findings.
COMPARATIVE CLINICAL STUDY with MONI ICU


Comparison of:

- **Surveillance results** generated automatically by MONI-ICU with conventionally generated - in parallel by trained surveillance staff and attending clinical experts using patient chart reviews and other available information (“gold standard”)

- **Time expenditure** for manual analysis of patient charts vs. time expenditure when applying MONI-ICU for presentation and analysis of surveillance results
### Table 1: Patient data

<table>
<thead>
<tr>
<th></th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td># admissions &gt;48h</td>
<td>99</td>
</tr>
<tr>
<td>average duration of stay (days)</td>
<td>10.2</td>
</tr>
<tr>
<td>patient days cumulative</td>
<td>1007</td>
</tr>
</tbody>
</table>
Table 2: HAI conditions correctly / falsely identified or missed by MONI-ICU

<table>
<thead>
<tr>
<th></th>
<th>condition present “gold standard” (n = 31)</th>
<th>condition absent “gold standard” (n = 68)</th>
</tr>
</thead>
<tbody>
<tr>
<td>condition present “MONI-ICU”</td>
<td>28 (90.3%) *</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>condition absent “MONI-ICU”</td>
<td>3 (9.7%)</td>
<td>68 (100%) **</td>
</tr>
</tbody>
</table>

* sensitivity  ** specificity  overall accuracy 97%
### Table 3: Time expenditures for both surveillance techniques

<table>
<thead>
<tr>
<th></th>
<th>MONI-ICU surveillance</th>
<th>Conventional surveillance</th>
</tr>
</thead>
<tbody>
<tr>
<td>time spent</td>
<td><strong>12.5 h</strong> * (100%)</td>
<td><strong>82.5 h</strong> ** (660%)**</td>
</tr>
</tbody>
</table>

* time spent by our HAI expert at the MONI terminal  
** 52 ward visits of our HAI expert
### Manual versus automated surveillance of HAIs

<table>
<thead>
<tr>
<th></th>
<th>Manual</th>
<th>Automated</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IC expert time expenditure</strong></td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td><strong>IT system manager time exp.</strong></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td><strong>Data collection tools</strong></td>
<td>Human hands and feet + pencil or notebook</td>
<td>Interfaces to electronic PDMS and laboratory data bases (LIS)</td>
</tr>
</tbody>
</table>
| **Reasons for malfunction**    | Mainly attributable to deficiencies in manpower:  
  - Work time for surveillance  
  - Interest in surveillance  
  - Qualification  
  - Skill  
  - Scrutiny, fitness | Technical and human factors:  
  - Interface compatibility  
  - Non-communication of changes in IT systems  
  - Lack of IT competence or funding  
  - Disinterest of end-users in IT requirements |
| **Precision and speed of output when PDMS and LIS is functioning and qualified IC-surveillance staff is scarce** | Low | High |
CONCLUSIONS

• **High specificity** (= no “false alarms”) with MONI surveillance; cases missed in MONI-ICU surveillance due to rectifiable technical errors

• **85% of doctors’ and nurses’ time saved** with MONI-ICU compared to manual/conventional surveillance

• When PDMS and LIS provide an accessible and up-to-date collection of clinical and denominator data, *intelligent IT can provide valuable surveillance reports on demand and quickly*

• MONI-ICU is also suited for day-to-day follow-up of infections and may – in conjunction with the modules MOAB and MOMO – support clinical decisions in ICUs

• **MONI-ICU enhances transparency of infection matters and supports scientific work-up of unresolved questions**
Electronic Surveillance of HAI – Is it worth it?

- Intelligent software helps to ask relevant questions and to get reliable answers from abundant clinical data without a need for time consuming (and often redundant!) manual data management.

- Facing a growing lack of skilled manpower, health care institutions are under increasing pressure to comply with quality assurance and patient safety regulations.

- We believe that electronic surveillance of HAI with intelligent IT in near future will be indispensible in health care institutions.
Co-workers:

Prof. Peter ADLASSNIG
Dr. Alexander BLACKY
Dr. Harald MANDL

Dr. Claudia HONSIG-BAUER

Thank you for attention!