



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

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## 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.)



## 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



# 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 HAICU protocol v 1.01, 2010; <http://www.ecdc.europa.eu>

## Pneumonia (PN1-PN5)

X-ray

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/mm<sup>3</sup>) or leucocytosis (≥ 12 000 WBC/mm<sup>3</sup>)

Symptoms

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., O<sub>2</sub> 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  $\geq 10^3$  CFU/ml

*Positive quantitative culture from possibly contaminated LRT specimen* (PN2)

- Quantitative culture of LRT specimen (e.g. endotracheal aspirate) with a threshold of  $10^6$  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 (ex : 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

Microbiology

# 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

### CODE: BSI

#### **BSI-A:**

- 1 positive blood culture for a recognised pathogen

or

- Patient has at least one of the following signs or symptoms: fever (>38°C.), chills, or hypotension and 2 positive blood cultures for a common skin contaminant (from 2 separate blood samples drawn within 48 hours).

skin contaminants = coagulase-negative staphylococci, *Micrococcus sp.*, *Propionibacterium acnes*, *Bacillus sp.*, *Corynebacterium sp.*

**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<sub>LCBI</sub>=BSI-A+B]). If this is the case, then BSI A and BSI B categories should be specified in the data collection.

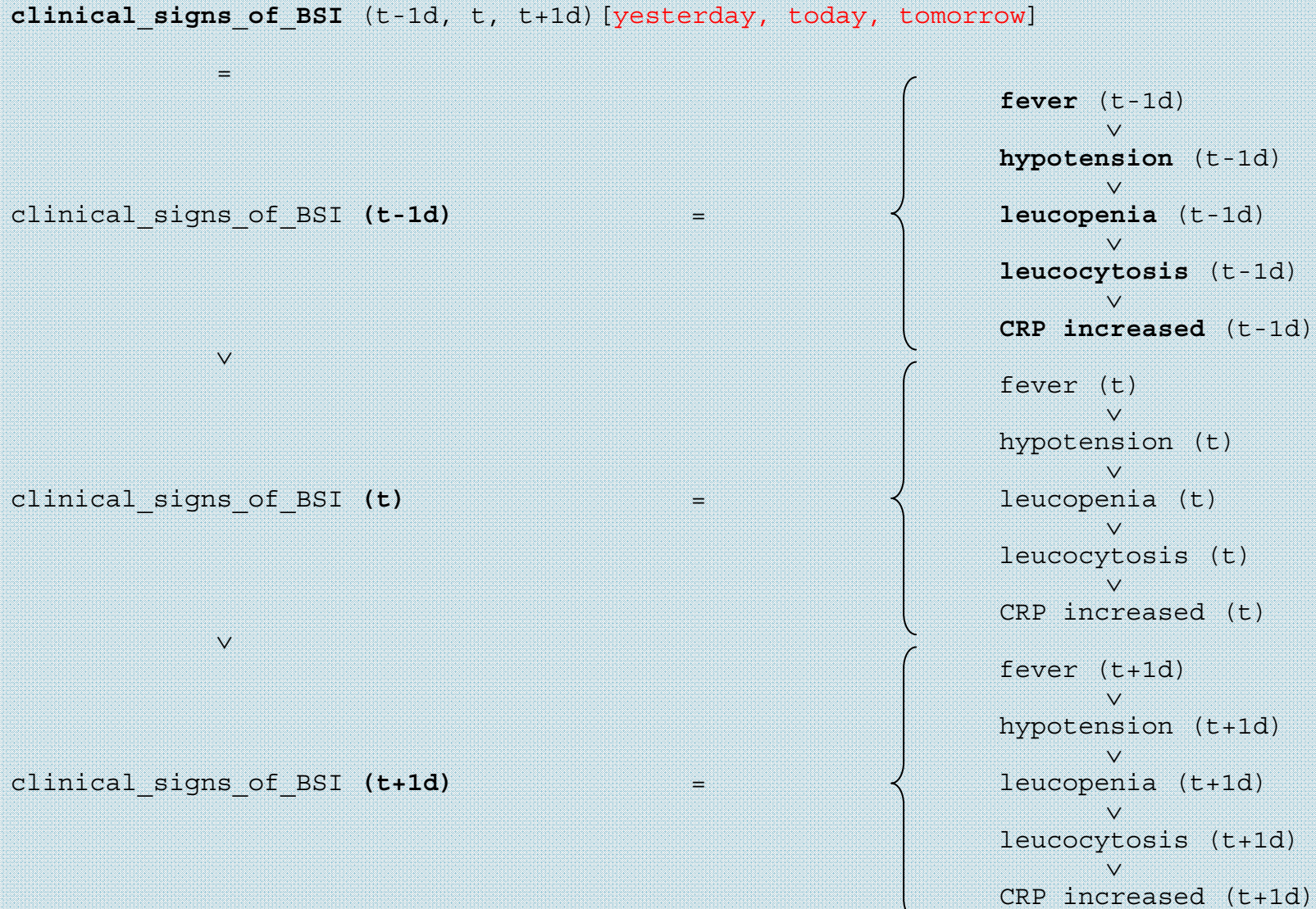
**Recognized pathogen**

**OR clinical signs and growth of same skin contaminant from two separate blood samples**

**OR clinical signs and growth of same skin contaminant from blood and intravascular line**

**OR clinical signs and positive antigen test from blood**

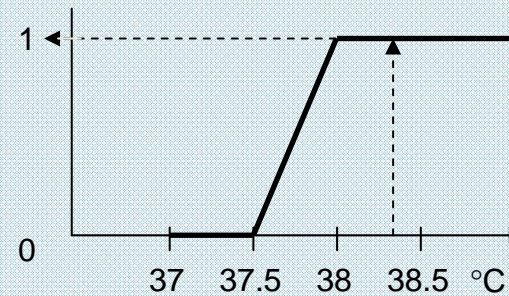
# Decomposition and time allocation of clinical signs



# Fuzzification of clinical signs — example: fever

fever (t-1d)  $\leftarrow$  ...

fever (t)  $\leftarrow$  {  
body temperature  $\uparrow$   
v  
thermoregulation applied



data import  
 $\leftarrow$   
intensive care unit  
[ maximum value  
of the day  
e.g., 38.5 °C ]

fever (t+1d)  $\leftarrow$  ...

## 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

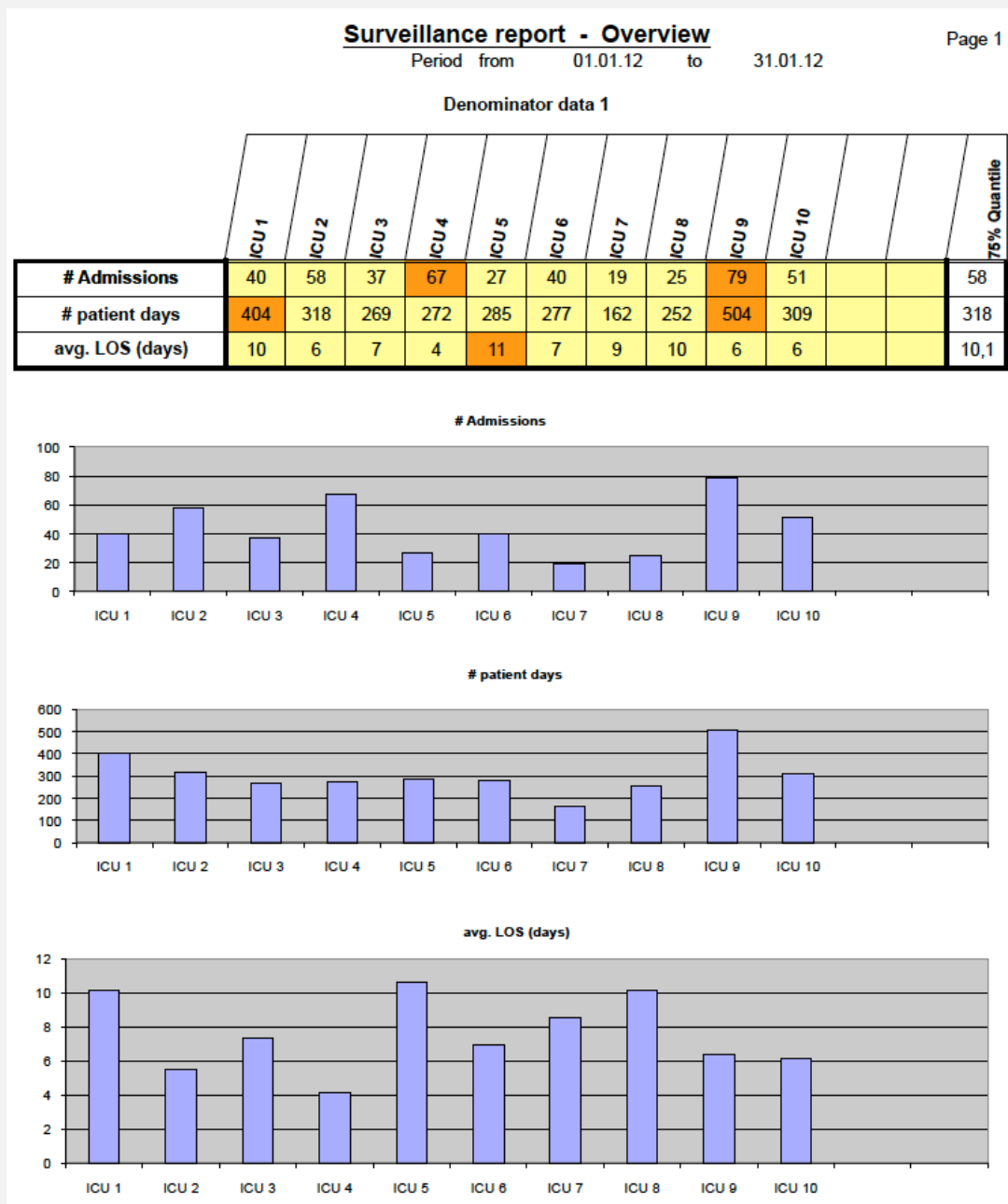
# MONI surveillance standard report

## Denominator data:

–Admissions

–Patient days

–mean LOS (days)



# MONI surveillance standard report

## Device use:

–Urine catheter days

–CVC days

–Respirator days

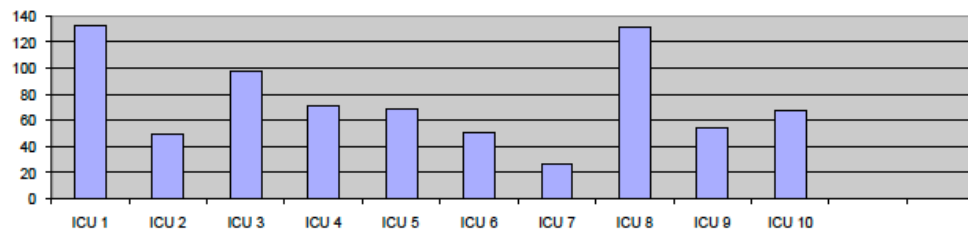
### Surveillance report - Overview

Period from 01.01.12 to 31.01.12

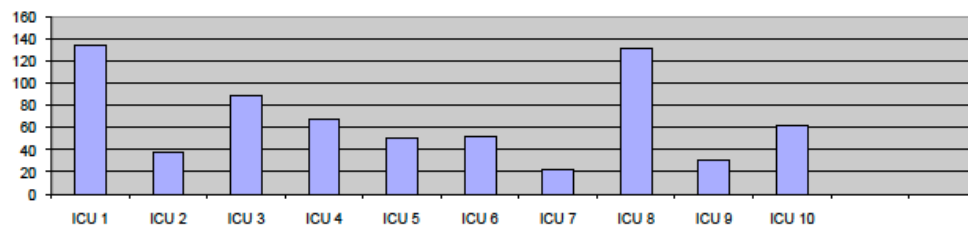
Denominator data 2

	ICU 1	ICU 2	ICU 3	ICU 4	ICU 5	ICU 6	ICU 7	ICU 8	ICU 9	ICU 10		75% Quantile
Urine catheter days	133	49	98	71	69	51	26	131	54	68		98
CVC-days	134	37	89	67	50	52	22	131	31	62		89
Respirator days	135	52	113	80	72	63	27	133	56	71		113

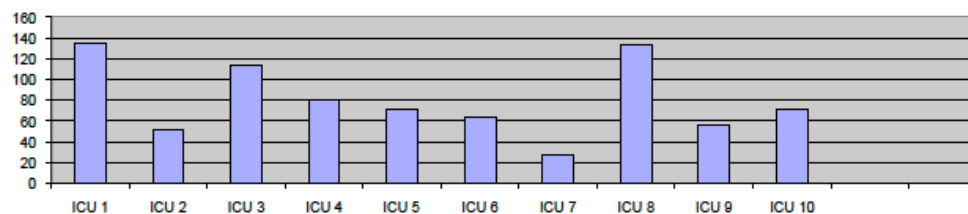
Urine catheter days



CVC-days



Respirator days



# MONI surveillance standard report

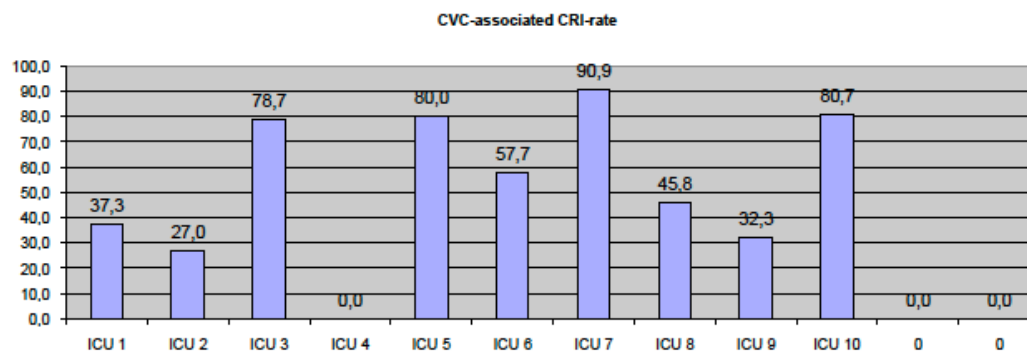
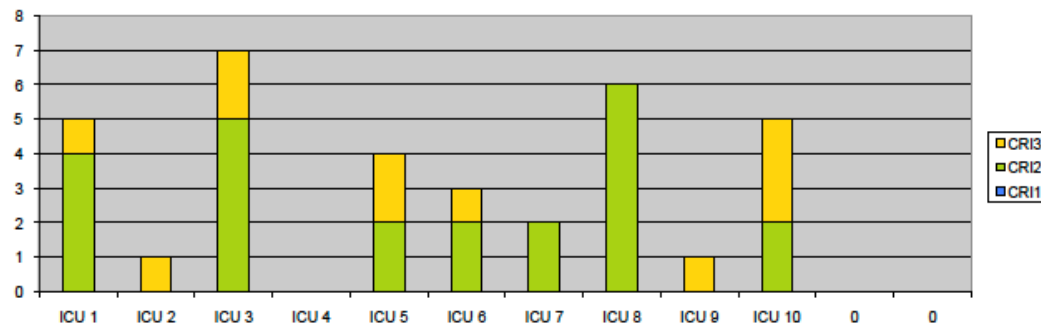
Infections:

CRI by type

CVC-associated CRI-rate  
(n/1000 device days)

CVC-associated infections

	ICU 1	ICU 2	ICU 3	ICU 4	ICU 5	ICU 6	ICU 7	ICU 8	ICU 9	ICU 10		
CRI1												
CRI2	4		5		2	2	2	6		2		
CRI3	1	1	2		2	1			1	3		
<b>total CRI</b>	<b>5</b>	<b>1</b>	<b>7</b>		<b>4</b>	<b>3</b>	<b>2</b>	<b>6</b>	<b>1</b>	<b>5</b>		



# MONI surveillance standard report

## UTI by type

(k = with, nk = without catheter)

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

Urine catheter use rate  
(n/1000 patient days)

UTI incidence rate  
(n/1000 patient days)

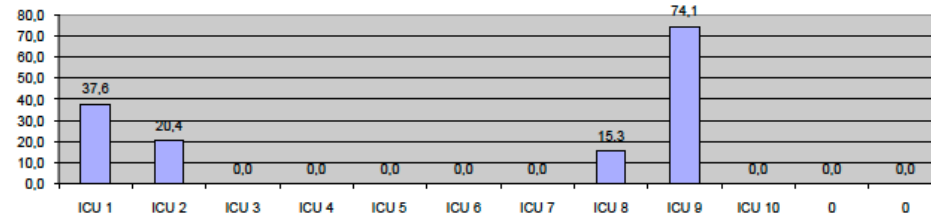
### Surveillance report - Overview

Period from 01.01.12 to 31.01.12

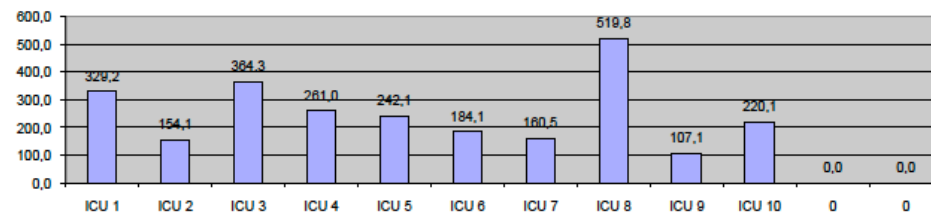
#### Urinary tract infections

	ICU 1	ICU 2	ICU 3	ICU 4	ICU 5	ICU 6	ICU 7	ICU 8	ICU 9	ICU 10		
UTI-A-k	5	1						2	3			
UTI-A-nk	2									3		
UTI-B-k									1			
UTI-B-nk									1			
UTI-C-k												
UTI-C-nk												
<b>HWI - k</b>	<b>5</b>	<b>1</b>						<b>2</b>	<b>4</b>			
<b>HWI</b>	<b>7</b>	<b>1</b>						<b>2</b>	<b>5</b>	<b>3</b>		

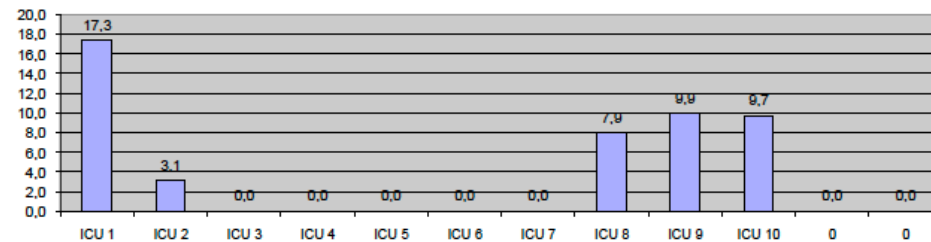
#### Urine catheter associated UTI-rate



#### Urine catheter use rate



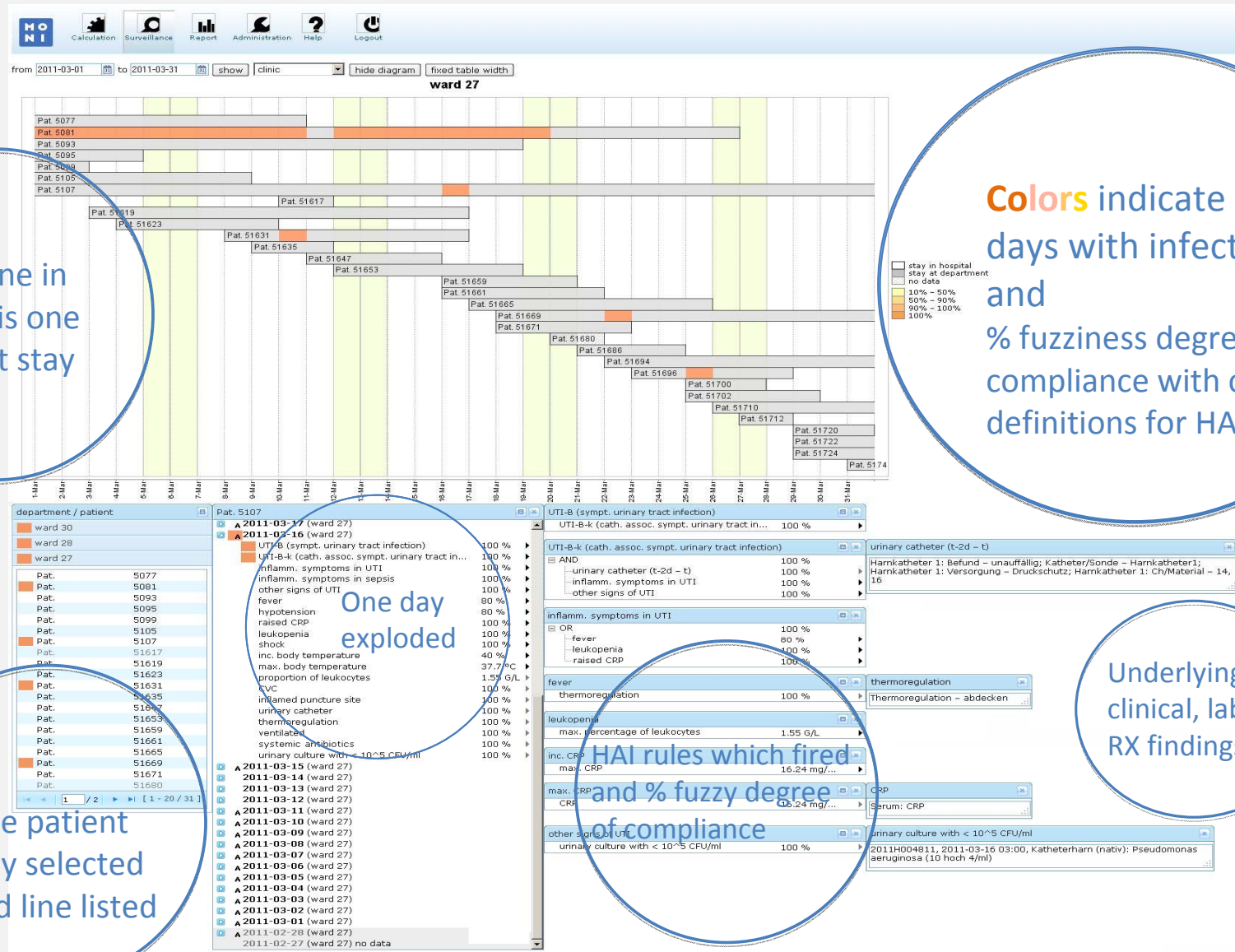
#### UTI incidence rate



## **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



Each line in graph is one patient stay

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

One day exploded

One patient stay selected and line listed

HAI rules which fired and % fuzzy degree of compliance

Underlying clinical, lab and RX findings

## COMPARATIVE CLINICAL STUDY with MONI ICU

Blacky A, Mandl H, Adlassnig K-P, Koller W. Fully automated surveillance of healthcare-associated infections with MONI-ICU – A breakthrough in clinical infection surveillance. **Appl Clin Inf 2011; 2: 365–372**

### 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*

	n
# admissions >48h	99
average duration of stay (days)	10,2
patient days cumulative	1007

*Table 2: HAI conditions correctly / falsely identified or missed by MONI-ICU*

	condition present “gold standard” (n = 31)	condition absent “gold standard” (n = 68)
condition present “MONI-ICU”	28 <b>(90.3%) *</b>	0 (0%)
condition absent “MONI-ICU”	3 (9.7%)	68 <b>(100%) **</b>

\* sensitivity    \*\* specificity    **overall accuracy 97%**

*Table 3: Time expenditures for both surveillance techniques*

	<b>MONI-ICU surveillance</b>	<b>Conventional surveillance</b>
time spent	<b>12.5 h *</b> (100%)	<b>82.5 h **</b> (660%)

- \* time spent by our HAI expert at the MONI terminal
- \*\* 52 ward visits of our HAI expert

## Manual versus automated surveillance of HAIs

	Manual	Automated
<b>IC expert time</b> expenditure	High	Low
<b>IT system manager time</b> exp.	Low	High
<b>Data collection tools</b>	Human hands and feet + pencil or notebook	Interfaces to electronic PDMS and laboratory data bases (LIS)
<b>Reasons for malfunction</b>	<u>Mainly attributable to deficiencies in manpower:</u> <ul style="list-style-type: none"> <li>• Work time for surveillance</li> <li>• Interest in surveillance</li> <li>• Qualification</li> <li>• Skill</li> <li>• Scrutiny, fitness</li> </ul>	<u>Technical and human factors:</u> <ul style="list-style-type: none"> <li>• Interface compatibility</li> <li>• Non-communication of changes in IT systems</li> <li>• Lack of IT competence or funding</li> <li>• Disinterest of end-users in IT requirements</li> </ul>
<b>Precision and speed of output</b> 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 indispensable in health care institutions**.



Co-workers:

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**Thank you for attention!**