

## **Use of web services for computerized medical decision support, including infection control and antibiotic management, in the intensive care unit**

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Running head: Web-based decision support

## **Summary**

The increasing complexity of procedures in the Intensive Care Unit (ICU) requires complex software services, to reduce improper use of antibiotics and inappropriate therapies, and to offer earlier and more accurate detection of infections and antibiotic resistance. We investigated whether web-based software can facilitate the computerization of complex medical processes in the ICU. The COSARA application contains the following modules: Infection overview, Thorax, Microbiology, Antibiotic therapy overview, Admission cause with comorbidity and admission diagnosis, Infection linking and registration, and Feedback. After the implementation and test phase, the COSARA software was installed on a physician's office PC and then on the bedside PCs of the patients. Initial evaluation indicated that the services had been integrated easily into the daily clinical workflow of the medical staff. The use of a service oriented architecture with web service technology for the development of advanced decision support in the ICU offers several advantages over classical software design approaches.

## **Introduction**

Every year more than 100,000 patients suffer from nosocomial infection in Belgium. Nosocomial infections are those which are not present before the patient's admission but are acquired in hospital. The symptoms usually appear after 48 hours in hospital. Patients who are particularly at risk are those who have mechanical ventilation or invasive procedures. Nosocomial infections produce significant morbidity and mortality in patients in the intensive care unit (ICU). European and Belgian reports state that the prevalence of nosocomial infection in ICU is 20-25%. [1] Studies have shown that 20-30% of these infections might be prevented. [2,3]

Ghent University Hospital is a tertiary care facility in Belgium. The ICU was founded in 1980 and has a total of 56 beds. The ICU admits about 4000 patients each year and consists of a surgical, medical, cardiac surgery, paediatric and burns unit. The ICU has been using an information system with computerized physician order entry (CPOE). Although this commercial Intensive Care Information System (ICIS) was able to replace the paper-based ICU patient record, the level of advanced ICU medical decision support is still moderate. Extending the ICIS with support for nosocomial infection studies and creating an efficient integration process of monitored, laboratory, and radiology data were major requirements of the medical staff. By combining and mapping available data sources, data can be exploited in advanced decision support services.

The aim of the present study was to enable Computer-based Surveillance and Alerting of Nosocomial Infections, Antimicrobial Resistance and Antibiotic Consumption (COSARA) in the ICU by providing computerized support at the point of care. The COSARA platform will be used in the daily follow up of infections and antibiotic therapies. It has the potential to improve the quality of care, time efficiency and cost-effectiveness of critical care infection control.

## **Methods**

The COSARA project started in April 2007. Both physicians and software developers were involved in the design and implementation of the computer-based infection control and antibiotic management system.

### *Multidisciplinary approach*

Despite the potential of information technology (IT) to support complex medical decision making, few IT applications have been adopted to assist medical staff. One of the reasons is poor communication between ICU users and software developers. At the start of the COSARA project we established regular discussions between physicians, data managers and software developers to identify their expectations about the infection control application. Based on their experiences and previous studies [4], the application was adopted by the medical staff. Physicians started to use the application routinely because it was integrated with their current tasks and it was designed for their specific needs. The involvement of physicians in the design phase was crucial.

### *Infection control and antibiotics services*

Physicians and nurses perform time-consuming, complex data analyses in order to make decisions based on the individual patient's data. Previously, information was only accessible through multiple, vendor-specific applications. Therefore, we developed a data collection process that collected and integrated the relevant infection data within a single software application (Figure 1). Monitor and therapeutic data are retrieved from the ICIS, while laboratory data is collected from the hospital laboratory system and the patients' chest X-ray images are identified in the Picture Archiving and Communication System (PACS). All these data sources have a specific structure which makes it difficult to integrate them. Some sources, such as the microbiology reports, are entirely text-based and have no structured format. By creating additional parsing techniques and a data model we were able to collect, integrate all clinical data automatically.

The COSARA application [5] contains the following modules: Infection overview, Thorax, Microbiology, Antibiotic therapy overview, Admission cause with comorbidity and admission diagnosis, Infection linking and registration, and Feedback. The infection overview, as shown in Figure 2, presents the important laboratory values and the current antibiotic therapy. Figure 3 shows the thorax module which gives an overview of the patient's latest chest X-ray images. Figure 4 shows the susceptibility reports (antibiogram) and microbiology data.

The infection linking module allows the physician to link all infections with microbiological resistance patterns and antibiotic orders. Prior to the COSARA study, this information was not present in the information system database. Furthermore, the reasoning for making an antibiotic prescription with associated therapy indications (such as empiric, prophylactic therapy), available microbiology data and the level of diagnostic certainty is registered in a new antibiotic pop-up screen. This captures the diagnosis and judgement of the physician while initiating or changing the antibiotic order.

By combining all these data with advice from antibiotic services (such as an antibiotic dose, antibiotic switch and Sequential Organ Failure Assessment (SOFA) service) we are able to modify the antibiotic prescriptions and create alerts. Both antibiotic services check whether the current antibiotic therapy complies with the standard clinical guidelines in the ICU. The SOFA service gives an indication of the organ failure of the individual patient.

The client (Figure 2) shows graphs of the patient's laboratory values, such as thrombocytes and fibrinogen (left), C-reactive protein and white blood cells count (middle). It also shows the SOFA score (right). The client presents a timeline with ordered antibiotics and occurring infections. The box at the right shows the details of a selected antibiotic with given start and

endtime (in this case we selected an antibiotic Glazidim, a switch from Tavanic. This antibiotic was prescribed for a respiratory infection).

### *Implementation*

We investigated whether web-based software can facilitate the computerization of complex medical processes in the ICU. Using a service oriented architecture, new medical services can be plugged in easily.[6] Service-orientation expresses an architectural style that defines the use of loosely coupled services, which serve as building blocks for distributed software applications. The services are plugged in to a service execution platform that offers data collection, event handling and medical service management. Thus the developer and physician can concentrate on the design of the decision support function itself.

After the implementation and test phase, the COSARA software was installed on a physician's office PC. At this stage, the multidisciplinary team met to discuss updates or changes. Subsequently the application was also installed on the bedside PCs of the patients.

### **Results**

Initial evaluation indicated that the services had been integrated easily into the daily clinical workflow of the medical staff. The involvement of medical experts in the development of the application probably helped to establish user-acceptance in the hospital.

The additional recording of the physician's reasoning when making antibiotic prescriptions was not seen as additional workload. In September 2009, 93% of the prescribed antibiotics were recorded using the new antibiotic pop-up screen. It is expected that this percentage will increase after configuration of all bedside PCs. The complete application is currently being evaluated in a clinical study.

Because of the service oriented approach, it was also possible to generate real-time alerts such as alerting for early kidney injury [7], to implement advanced Computerized Physician Order Entry (CPOE) such as advice for adapting the antibiotic dosage according to renal function and to set up an automated infection surveillance computerized system.

### **Discussion**

The initial clinical evaluation showed three main benefits:

- (1) the service platform allowed more accurate investigation of the impact of infection control programmes and antimicrobial exposure on the incidence of nosocomial infection and microbial ecology, taking into account potential confounders;
- (2) the services produced time savings because manual calculations (e.g. SOFA score service) are time-consuming and therefore expensive;
- (3) the client gave physicians accurate data for daily patient care using a simple graphical user interface with data from several data sources. Using only one application able to integrate all data sources also saved time.

The use of a service oriented architecture with web service technology for the development of advanced decision support in the ICU offers several advantages over classical software design approaches. For example, it was possible to offer a P/F service calculating the PaO<sub>2</sub>/FiO<sub>2</sub> ratio (based on partial pressure of oxygen in the arterial blood, PaO<sub>2</sub>, and the fraction of

inspired oxygen, FiO<sub>2</sub>, after checking mechanical ventilation). This is used as a building block in the composed SOFA and CPIS services. The efficient distribution of the web services over the available workstations spread the workload and thus avoided overload failures. Finally, the involvement of the physician in the software specification process improved communication between the physicians and the software developers.

### **Acknowledgements**

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## **Figure legends**

1. Collection and integration of data from the hospital's data sources
2. Overview of the client with modules for infection control and antibiotic management
3. The client shows a history of chest X-ray images and an evaluation form. The form on the right is used to calculate the Clinical Pulmonary Infection Score (CPIS) based on occurrence of infiltrate (and its evolution), indication of acute respiratory distress syndrome (ARDS) and other laboratory values
4. The microbiology module shows the patient's antibiotic susceptibility reports and a list of lab sample results. These reports (A-D) (below) can be compared by highlighting an antibiotic element

Figure 1

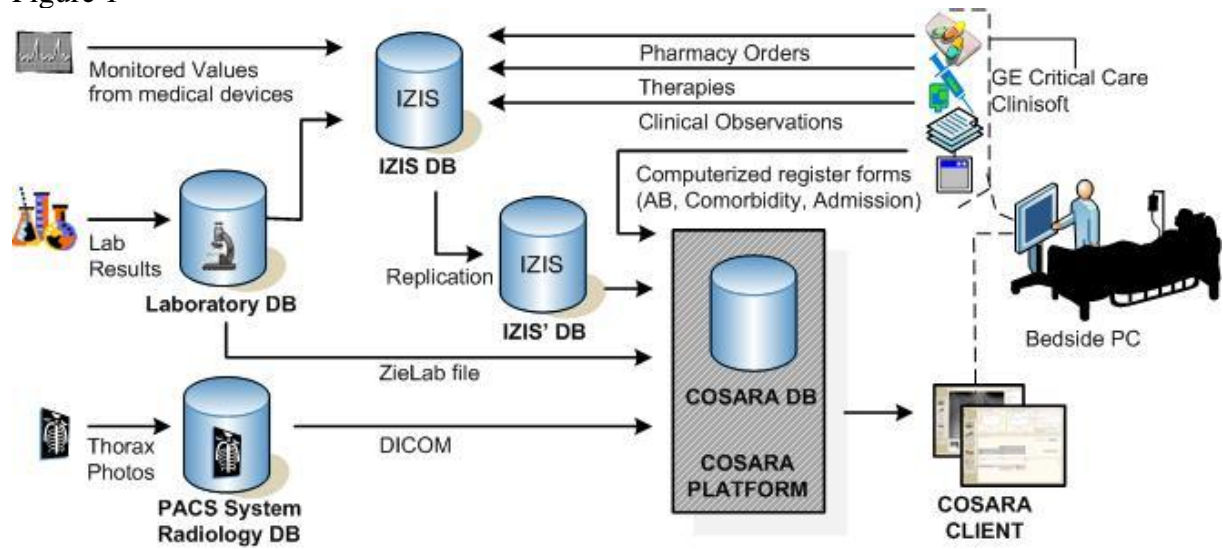


Figure 2

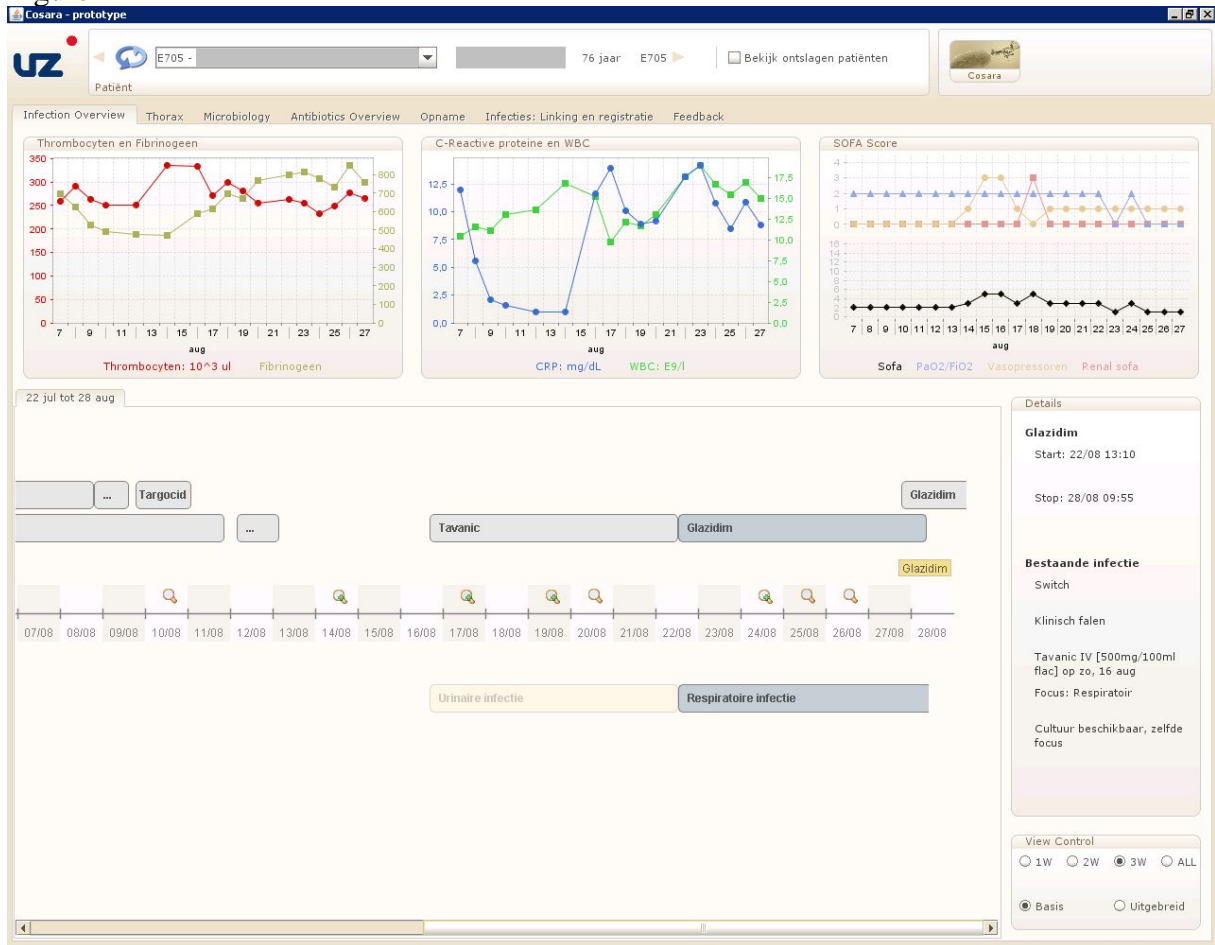




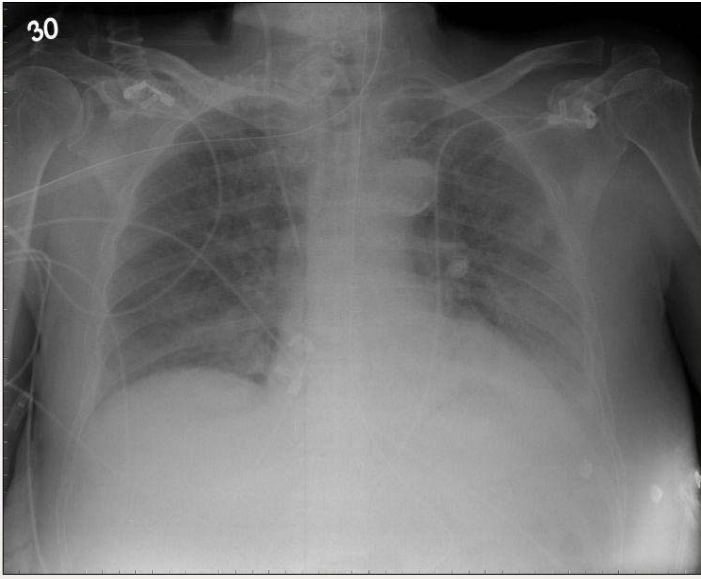
Figure 3

Cosara - prototype

UZ

Patiënt

Inflection Overview Thorax Microbiology Opname Feedback



30

Thorax Evaluatie

Tijd: 09:35:40 24/03/2009

Naam:


Beschrijving: Thoraxface (in bed genomen)

Infiltraat:  Ja  Nee

Evolve infiltraat:

- Nieuw
- Toegenomen
- Stabiel
- Afgenomen

ARDS:  Ja  Nee



19/03/2009 08:37:00 20/03/2009 08:49:29 21/03/2009 13:59:37 22/03/2009 12:37:52 23/03/2009 09:58:50 24/03/2009 09:35:40

Figure 4

Cosara - prototype

76 jaar E705  Bekijk ontslagen patiënten

Patient

Infection Overview Thorax Microbiology Antibiotics Overview Opname Infecties: Linking en registratie Feedback

Selecteer alle antibiogrammen  Enkel positieve culturen

26/08/2009 10:52:00	sputum	aspergillus fumigatus + commensalen +- aspergillus fumigatus +	
25/08/2009 20:52:00	aspiraaf bij geintubeerde	aspergillus fumigatus +	
24/08/2009 12:30:00	aspiraaf bij geintubeerde	aspergillus fumigatus +	
24/08/2009 12:30:00	keeluitstrijk	<input checked="" type="checkbox"/> serratia marcescens +- <b>Antibiogram</b>	
20/08/2009 23:02:00	aspiraaf bij geintubeerde	klebsiella oxytoca +- aspergillus fumigatus +- commensalen +- proteus mirabilis +- commensalen + klebsiella oxytoca +- <b>Antibiogram</b>	
19/08/2009 09:26:00	aspiraaf bij geintubeerde	commensalen + klebsiella oxytoca +- <b>Antibiogram</b>	

**Wis selectie**

A	B	C	D
3 keeluitstrijk SA: Negatief GN: Positief 1: enterobacter cloacae +- 1 R R S S S S S S S S I I I S S	30/07 13:56 Materiaal: aspiraaf bij geintubeerde Macroscopie staal: Bloederig Gramkleuring: WBC + gram-negatieve staven +++ Sputum kwaliteit: Goed (weinig plaveiselepitheel) .: Zie ook vorige / andere resultaten. : morganella morganii +++ Kweek: 1: citrobacter freundii ++ 1 ampicilline R cotrimoxazol R cefuroxim R gentamycine R gentamycine I colimycine S temocilline S ofloxacine/levofloxacine S amikacine S piperacilline/tazobactam R cefotaxim/ceftriaxone R ceftazidime R aztreonam R	29/07 09:23 Materiaal: aspiraaf bij geintubeerde Macroscopie staal: Bloederig Gramkleuring: WBC ++ gram-negatieve staven +++ Sputum kwaliteit: Goed (weinig plaveiselepitheel) Kweek: 1: morganella morganii +++ 1 ampicilline R cotrimoxazol S cefuroxim I gentamycine S colimycine R temocilline S ofloxacine/levofloxacine S amikacine S piperacilline/tazobactam S cefotaxim/ceftriaxone S ceftazidime S aztreonam S meropenem S	29/07 09:23 Materiaal: keeluitstrijk Opzoeken MRSA: Negatief Opzoeken MRGN: Positief Kweek: 1: citrobacter freundii ++ 1 ampicilline R cotrimoxazol R cefuroxim R gentamycine S colimycine S temocilline I ofloxacine/levofloxacine S amikacine S piperacilline/tazobactam R cefotaxim/ceftriaxone R ceftazidime R aztreonam R meropenem S ext spect-b-lactams R