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Decision Support for infectious diseases - a working prototype

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Abstract. This paper presents a decision support system for nosocomial infections and its integration in the large HIS of the University Hospital of Giessen. The model comprises five different engines and a data dictionary. It is designed to detect hospital aquired infections even in a situation where only a restricted amount of clinical data is available (the data is split up in different information systems). Furthermore the model prevents time consuming manual data entry.
The five engines split the main task into 1) a preselection, which sort out patients who definitely do not have a nosocomial infection; 2) a rule based reasoning process which detects patients likely to have such an infection; 3) an alarm process which is responsible for the presentation of the alert; 4) an explanation process to follow up the reasoning and 5) statistic tools to answer specific hygienic questions.
A data dictionary supplies the controlled vocabulary, but it is also required to understand datastructures used in the different clinical subsystems.

1. Introduction

Nowadays it has become necessary for large hospitals to work with a hospital information system (HIS) which includes patient records. On the bases of this requirement, the need for additional information arises. So, monitoring systems for different tasks are integrated in the Giessener HIS [1-4], which generate alarms, if certain parameters get out of range. A typical example is a warning sign, if a patient is allergic to a specific drug and this drug is prescribed. However, decision support functions are more difficult to implement, because they have to give advice before an actual decision is made. In order to provide such functions, much more additional data is needed. This article presents such a decision support application concerning hospital aquired infections which is integrated in the HIS.
The idea of computer surveillance of nosocomial infections is not new. Some systems exist both in Germany and in the USA [5-7]. Most of them are used in hospitals which have enough personnel for the necessary input. Without this input the systems do not deliver any results. The idea in Giessen is to integrate the system in the existing HIS, so that manual data entry can be avoided.
This paper presents a system which provides not only a list of the most likely infected patients, but also all relevant data for the patient and an easy way to gain access all kinds of information about the patient. Furthermore the system provides data from an explanation machanism, which is generated during the analysis process. For documentation purpose, there is a statistic tool.

2. Environment

At present the University Hospital of Giessen has 1.300 beds, 40.000 stationary and 80.000 ambulatory patients per year. More than 4.000 persons are currently working in the medical, technical and administrative areas. [1].
Since 1989 the hospital information system WING (knowledge-based information network Giessen) has been used. The central components of WING are implemented on a tandem Himalaya mainframe with four processors. It uses a large central patient database and is connected via network (TCP/IP) with a variety of commercial, departmental subsystems with their own databases.

In 1994, Giessen introduced the commercial laboratory system LDS C-BAK in the medical microbiology. The microbiology system C-BAK is an implementation on a SUN Sparc 20. It is accessed by 20 terminals. All bacteriologic and serologic data are entered at these terminals. Additionally, it does the complete storage of the laboratory data and all administrative work. Originally, it was used as a departmental system only, with limited ability to receive ADT data and no data transfer to other systems.

3. Tasks

To build a successful decision support system, much clinical data is needed. Most data is organised in the electronic patient record inside the HIS. So the logical conclusion was to integrate the infectious disease advisor in the hospital information system. However, there are much more requirements to be fulfilled.

1. Development of a reliable HL7 interface from the microbiology lab system to the hospital information system
2. A concept for a system-independent mechanism to display data on a variety of different clinical workstations.
3. Integration of other datasources and databases (e.g. diagnosis, OP reports, laboratory results from the clinical chemistry)
4. Definition of a standard vocabulary (MDD) to describe the semantics and meaning of the data
5. Definition of the medical knowledge for the infectious disease advisor.

4. Methods

The first step in our development was to make microbiology results data available inside the HIS. Due to the restricted capacity on the SUN it was necessary to transfer the data to a more efficient system. This meant that we had to design a reliable HL7 interface from LDS to our central mainframe Tandem. The data is transferred every day. It is inserted into a database on the Tandem mainframe, where it can be accessed efficiently by other programms. For distributing the data throughout the hospital a system-independent concept for data presentation had to be found, since inside the Giessener HIS very heterogeneous workstations are used like: Apple Macintosh and DOS workstations accessing WING and NT Workstations with the newly developed hospital information system KAOS. A possible solution represents the intranet approach. It uses an intranet webserver (currently Jigsaw 2.0.3) and conventional browsers, which are already available on each workstation. So in all three different systems the data can be shown in the same way and there is only one version to support and maintain.
As an interim result we built an additional tool just for the display of microbiology results. This result reporting application uses logon procedure and access restrictions of the HIS because of its integration. After a short introduction period, it is well accepted throughout the hospital.
After the integration of the microbiology results, additional data was needed to decide, whether a patient had developed a hospital acquired infection or not. In the daily routine there is no time to insert a large amount of additional data manually. Therefore all relevant and electronically available data must be included in the analysis process, in order to obtain as high a recognition accuracy as possible. The integration of other data sources and databases e.g. diagnosis, surgical reports, laboratory results from the clinical chemistry is necessary.
To interpret the information content of the data according to the original context, in addition to the raw data vocabulary and semantic information is required which is provided by the dictionary MDD GIPHARM [8]. Within a semantic net the descriptive knowledge about data is stored, which incorporates information from the clinical information systems. We developed automated tools to insert all new data into the semantic network, so it can be used according to their original context. To do this task, more than 4.000 vocabulary objects and 10.000 new relationships have been added to MDD-GIPHARM.

There is a special interface for each database, which is designed to retrieve the data and the necessary semantic information. Therefore, data dependencies from the subsystems (microbiology, laboratory) are stored in the semantic net of the data dictionary MDD-GIPHARM as follows: In dependence on the latest changes of the microbiology tests, the MDD-GIPHARM has to be updated. On the basis of this information an appropriate semantic net was defined. Old data structures (e.g. hierarchies from a filesystem) have been completely restructured in an automatic process and loaded into the dictionary. So, all data becomes available within their semantic context, regardless of their former structure. The procedures can be triggered event-driven or time-driven.
The next step was to implement the medical knowledge. We defined formal rules to detect nosocomial infections, similar to ARDEN medical logic modules [9]. We started with a set of rules based on the recommendations of the American Center of Disease Control (CDC) in Atlanta [10,11]. These medical rules will be analysed with the help of an interpreter.
Due to the great amount of microbiology data, a pre-sorting routine was established: the preselection. The purpose of the preselection engine is to sort out patients who definitely do not have a nosocomial infection. In the preselection engine all patients are analysed by using a small set of exclusion criteria specified in XML (extensible markup language) [12]. The preselection engine stores its results in an XML format in order to use it for further analysis.

```
<INFEKTION>Harnweginfektion
        <Med-Intensiv>3
                        <KRITERIUM>Leukozyten im Urin
                        <NEGATIVER-TEXT>keine Leukozyten im Urin</NEGATIVER-TEXT>
                        <MDD>H</MDD>
                        <MIKROBIOLOGIE>PMN</MIKROBIOLOGIE>
                        <FKT>LH</FKT>
                        <QUE>LEER</QUE>
                </KRITERIUM>
                <KRITERIUM>Dauerkatheter
                        <NEGATIVER-TEXT>es liegt kein Dauerkatheter</NEGATIVER-TEXT>
                        <TISS>getBlasenDauerKatheter</TISS>
                        <FKT>DK</FKT>
                        <QUE>LEER</QUE>
                </KRITERIUM>
                <KRITERIUM>Mikrobiologischer Befund
                        <NEGATIVER-TEXT>kein mikrobiologischer Befund</NEGATIVER-TEXT>
                        <MDD>H</MDD>
                        <MIKROBIOLOGIE>KEIM</MIKROBIOLOGIE>
                        <MIKROBIOLOGIE>PILZ</MIKROBIOLOGIE>
                        <FKT>MH</FKT>
                        <QUE>Harnweg</QUE>
                </KRITERIUM>
        </Med-Intensiv>
        <FEHLEND-Med-Intensiv>2
                <FDAT>Fieber über 38°C</FDAT>
                <FDAT>suprapubischer Wund- oder Flankenschmerz</FDAT>
        </FEHLEND-Med-Intensiv>
</INFEKTION>
```

Fig 1: An example of rule definitions in XML

Each ward may have its own special adapted set of decision-rules. These depend on the different kinds of data available and the different requirements of the units. The rules are derived from the CDC criteria, and divided into different kinds of nosocomial infections. They are treated independently in the rule engine. Updating the rules is easy, because of the use of XML.
The main rule engine includes the rule-interpreter. It decides on the correct set of rules (also specified in XML) and interprets them on the basis of the patient's data. The main rule engine and its interpreter is implemented in Java to support the portability to different platforms.
The last step is the design of the user interface. It includes a statistical engine and an explanation engine. The statistical engine is implemented as a set of servlets and provides the possibility for the hygienic personnel and responsible physicians to discover weak points

which might favour an infection or a spread of infections. The spreading of certain resistant bacteria in problem areas can be reconstructed accordingly. In addition time-dependent trends and the effect of new hygienic measures (e.g. change of filters in operation theatres) can be investigated. Discovering weak points is the first step to initiate effective measures [13]. In the context of quality assurance it is important to log and analyse the frequency and distribution of hospital acquired infections, in order to assess the efficiency of hygienic prevention measures.
This application is conceived as a system-independent program, which makes use of the programming language Java and the browser technology within the local intranet. It can be accessed from all workstations inside the HIS.

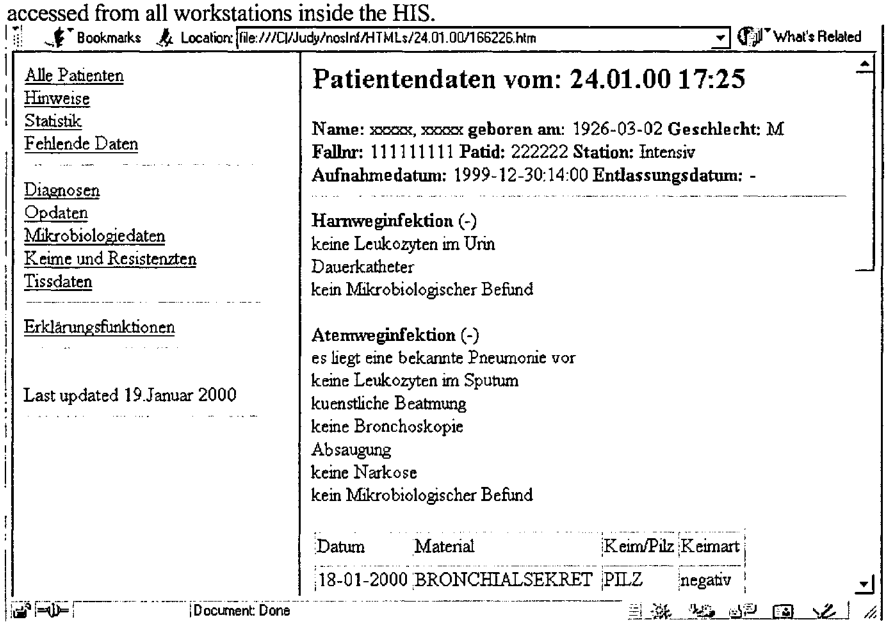

Figure 2 shows the screen with a patient, who is considered to have a hospital aquired infection. By initiating the links on the left, you can get additional data. In this figure the output of the explanation-engine is shown, which describes the analysis process.

5. Discussion

Our main intention was to develop a decision support system for nosocomial infections. Currently the system runs in a prototype stage for finetuning purposes on the intensive care unit since the beginning of December 1999. It is designed to give advice about which patients should be closely monitored to clinicians in the microbiology, the hygienic as well as in the clinical departments. To make this possible, the system provides access to all available patient data. In addition it can show the complete reasoning process with the help of integrated explanation functions. For documentation purpose, a statistical tool has been added. The whole system is integrated in the HIS, so that it can be accessed throughout the hospital, on the condition that required permissions are given.
Now the fine-tuning of the set of rules for further units takes place. Since January 2000 the system has been introduced in the orthopaedic unit. As there is completely different data, the medical rule set has to be adapted to the new conditions. Because of the condensed view on all stored clinical data of a patient, the acceptance is very high and further use in other units is planned.
Infectious diseases pose a major threat on hospital patients. Discovering weak points in patient care is the first step to initiate effective measures for avoiding nosocomial infections[14]. In the context of quality assurance it is required to assess the actual frequency and distribution of

infections acquired in the hospital. We think that our decision support system will enable the responsible clinicians to perform this task more effectively. It ensures a concentration on those patients who were marked by the system. Furthermore, once the statistical engine is extended, it may enable us to assess the efficiency of hygienic prevention measures. Having used a modular and adaptable design, we should be able to adapt the system for all wards in the hospital in the long term.
Our integrated decision support systems can use all available clinical data of a patient. This may enable us to achieve what standalone expert systems - such as Iliad or Internist - have not yet achieved: Putting effective decision support on a large scale into clinical routine use without the need of additional manual data entry.

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