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A web-based system for clinical decision support and knowledge maintenance for deterioration monitoring of hemato-oncological patients

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ABSTRACT

We introduce a web-based clinical decision support system (CDSS) and knowledge maintenance based on rules and a set covering method focusing on the problem of detecting serious comorbidities in hemato-oncological patients who are at high risk of developing serious infections and life threatening complications. We experienced that diagnostic problems which are characterized by fuzzy, uncertain knowledge and overlapping signs, still reveal some kind of patterns that can be transferred into a computer-based decision model. We applied a multi-stage evaluation process to assess the system's diagnostic performance. Depending on how system behavior was compared to presumably correct judgment of a case the correctness rate for closed cases with all data available varied between 58% and 71%, the overall rate after critical review was 84%. However, the real time behavior of our approach which data becoming available as time passes still has to be evaluated and observational studies need to be conducted.

1. Introduction

Patients with hematological malignancies, such as leukemia or lymphoma, frequently have to undergo extensive and prolonged medical treatments. Therapy options in this field have advanced enormously in the past years. Established strategies include high-dose chemotherapy, radiation and stem cell transplantation, which temporarily can result in a nearly complete suppression of the immune system. These patients are at high risk of developing serious infections and life threatening complications, such as sepsis. About 80% of these patients develop an infection during their in-patient stay [1]. Clinical studies have shown that the survival probability of patients with sepsis depends most essentially on the delay between detection and start of effective antibiotic treatment [2]. The

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failure to respond to patient deterioration promptly and appropriately thus leads to increased morbidity and mortality.

Making optimal clinical decisions requires timely and correct interpretation of relevant information. Time pressure, information overload, various data sources (lab values, microbiology findings, vital signs from monitors) and the diagnostic problem itself are shaping the clinical challenge. Further, the specifics of the hemato-oncological patients have to be considered: Normal signs of the underlying disease, signs of therapy side effects and serious signs of bacteremia, systemic inflammatory response syndrome (SIRS) and sepsis have to be identified in order to distinguish between certain disease patterns, like harmless fever as immunologic reaction, fever of unknown origin and fever caused by bacteremia or the onset of a severe sepsis. This is complicated by the fact that important information like blood cell counts is not usable due to the underlying disease. The physician's experience partly determines the treatment course and the outcome of the patient. We believe that a computer-based system, which intelligently filters and assesses relevant parameters, may foster a timely and correct diagnosis.

We introduce a clinical decision support system (CDSS) based on rules and a set covering method focusing on the problem of detecting serious comorbidities in hemato-oncological patients. It has been implemented as a web based system, which provides a generic knowledge module to construct, maintain and test individual knowledge models.

2. Background

2.1. *Project background*

It has been stated repeatedly that the introduction of new information technology and CDSS in particular, raises concerns about reliability and safety issues [3,4]. However, in a survey we conducted with the medical personnel at the Heidelberg University Clinic for Hematology and Oncology (response rate = 70.5%, n = 36 of 51) we found an encouraging openness toward CDSS. In general the staff was open-minded toward new Information Technology systems. About 88% indicated to be "rather open-minded" or "open-minded". Concerning CDSS, the potential benefit was assessed by the majority (72%) as "rather high" or "high" and 60% would "rather follow" the system's recommendations.

The work presented here was embedded in a joint project of academic research partners and two commercial clinical software manufacturers. The goal was the conception and development of system to generate patient data management systems that each map the specific needs of a clinical caregiver and its medical and organizational requirements. The ability to integrate decision support modules was among the requirements. Hematologic wards were selected as a challenging target environment for which a proof of concept should be provided. This proof of concept includes the decision support module described in this article. The decision support module is implemented as a stand-alone web application and able to communicate with a commercial patient data management system (PDMS) through an individually designed system interface. Currently, the CDSS can be started within the PDMS test environment via a button on the toolbar. Available patient data is passed to the CDSS and the results of the system are shown to the user in a modal dialog (Fig. 4).

2.2. *Related work*

Publications on computational methods and decision support systems focusing bacteremia, SIRS and sepsis are rare. Searching the PubMed database using the MeSH terms "Decision Support Systems, Clinical", "Diagnosis, Computer-Assisted", or "Drug Therapy, Computer-Assisted" and "Sepsis/diagnosis", "Systemic Inflammatory Response Syndrome/diagnosis", or "Bacteremia/diagnosis" yields only 21 results (February 08, 2012). Research in the field of analyzing vital signs in intensive care units (ICU) for early warning of patient deterioration or sepsis has been done by Cao, Moorman et al. [5,6], Tarassenke et al. [7] and Pilz et al. [8].

Cao and Moorman developed a predictive heart rate characteristics monitoring algorithm to support early diagnosis of sepsis in neonatal intensive care units. Tarassenke et al. describe a probabilistic model that generates alerts when a single vital sign deviates by close to ± 3 standard deviations from its normal value or when two or more parameters depart from normality. Wang et al. [9] present a statistical approach based on a support vector machine algorithm including further parameters such as laboratory values to predict whether a septic patient progresses into severe sepsis. Both are limited in their practicability since comprehensive and causal explanations are incompatible with their approach. Pilz et al. [8] describe the ability of scoring systems to promptly detect septic patients. Scoring systems are designed to predict the outcome of patient populations but do not allow the prediction of individual risks. An approach to classify ICU patients' states based on artificial neuronal networks is proposed by van Gils et al. [10], where methods are described to identify novel sets of parameters a diagnosis could be established on, a clinical validation is pending. Herasevich et al. [11] present an automatic screening system for sepsis, scanning patients' data in the electronic medical records and notifying the research coordinator.

However, taking multiple diagnoses into account, including microbiological findings, accurate handling of the specifics of hemato-oncological patients, and providing comprehensible result explanations remains unconsidered.

3. Design considerations

Our work on the CDSS part of the joint project pursued two key objectives. The first goal was to implement a system which allows creating new concrete knowledge models, modifying models, and executing models. Thus the system has to embody execution engines based on certain inference methods and knowledge maintenance modules based on a generic data model.

The second objective was to demonstrate the capability of the implemented inference methods and knowledge model