An ontology-based data warehouse for diagnosis and communication in intensive care settings

Jeroen S. de Bruin¹, Mohamed Mouhieddine², Christian Schuh³, Michael Hiesmayr²
¹Institute for Artificial Intelligence and Decision Support, Medical University of Vienna, Vienna, Austria
²Division of Cardiac- Thoracic- Vascular Anaesthesia and Intensive Care, Vienna General Hospital, Vienna, Austria
³IT-Systems & Communications, Medical University of Vienna, Vienna, Austria

Abstract - In the intensive care unit (ICU), a timely supply of all needed information is of the utmost importance. To facilitate this demand, we plan for a data warehouse for the ICU that employs data from multiple clinical sources as well as clinical decision support systems for analysis. This clinically integrated system enables the automated generation of concise and accurate reports, the automated classification of patient symptoms and diagnoses, and evidence-based treatment planning. Three pilot projects are planned to implement and showcase the aforementioned capabilities of the data warehouse, all using knowledge-based methods and the International Classification of Diseases, 10th version as their foundation. The final solution is deemed feasible, expected to be interoperable with existing hospital information systems due to the extensive use of standards, and likely to support and impact existing clinical workflows in intensive care medicine.

Keywords: Knowledge Bases, Clinical Decision Support, Electronic Data Processing, Critical Care.

1 Introduction

In a stressful environment such as the intensive care unit (ICU), it is paramount that the necessary information is offered to the right persons in a timely manner. Information and reports need to be concise but complete. Too little relevant information will result in suboptimal care, while too much information will confound important facts and distract. Therefore, information about a patient has to be individualized, thereby providing data on relevant chronic and acute patient symptoms, diagnoses, and treatments. Furthermore, diagnoses need to be determined fast and accurately as a patient’s health is already severely compromised, and treatment or stabilization needs to proceed as fast as possible. Given these requirements, the medical team responsible for a patient’s treatment would benefit from a clinical decision support system (CDSS) that could rapidly determine (or confirm) a patient’s diagnosis, and streamline communication by providing information relevant to the patient’s diagnosis, characteristics, or treatment.

2 Proposed solution

Our goal is to design a data warehouse for the ICU that, using data available in the ICU’s patient data management systems as well as in the hospital information system, provides expert-systems for 1) the generation of accurate, role-specific reports with high-information density that contain all relevant information while leaving out unnecessary details, 2) classification of patients based on their symptoms, past diagnoses and treatments, for the determination of optimal treatments or prediction of disease progression, and 3) the presentation of data and information from the patient data management system directly in the hospital information system, as part of an integrated solution for patient care. For the generation of reports, a knowledge base was planned that defines for each medical role/profession involved in the treatment of a patient, which data should be included in the report, to what detail it should be included, and how it should be presented. For the classification of patient cases, the CDSS employs the patient data management system to assign values to higher-level, semantically rich and clinically relevant concept such as symptoms and diagnoses. To support the selection of treatment for these patients, a comparison with past cases can also improve healthcare quality, while speeding up the decision process; the effectiveness of different therapies in different cases may serve as a guideline or tiebreaker for the medical team in the choice of therapy.

To keep nomenclature uniform, we employ the International Classification of Diseases, 10th version (ICD-10) ontology for both classification and communication. Based on these classifications and knowledge on disease progressions, potential diagnoses might be predicted together with likelihood and options for intervention and treatment.

3 Pilot projects

To support a wide range of ICU protocols and workflows, three pilot projects are currently under development. The first project pertains a CDSS for the diagnosis of systemic inflammatory response syndrome (SIRS), which is the body’s response to an infectious or noninfectious affliction. It employs an ICD-10-based knowledge base for the accurate determination of SIRS symptoms. Symptoms are thereby determined in a complex, comprehensive fashion, rather than simplistic rules. Fever, for example, is not determined by the...
standard rule stating that a patient’s body temperature needs to be 38°C or greater, but is rather more individualized, as recorded normal body temperatures vary depending on many factors, including age, sex, time of day, ambient temperature, activity level, and method of measurement.

The second pilot application is meant for both the diagnosis and treatment of the acute respiratory distress syndrome (ARDS). ARDS is a severe, life-threatening medical condition characterized by widespread inflammation in the lungs. While ARDS may be triggered by a trauma or lung infection, it is usually the result of sepsis. For this pilot project, an ICD-10 knowledge base is planned that can detect ARDS, determine the symptoms, and based on those symptoms, propose interventions or treatments. Based on patient demographics, ontological annotation(s) of a patient case, as well as symptom and disease progression learnt through sequential analysis of data over time, a patient case can be classified with respect to past patient cases using a propensity score analysis. After a patient has been classified, the resulting group of similar patient cases can be presented, including their treatment details and outcome; this will provide the medical team with evidence-based background information that may help them in the determination of treatment, especially in complex cases.

The final pilot project pertains report generation for communication. In the ICU-environment, time is a luxury, and it is therefore important to have concise but complete reports on patient for quick communication. By communicating all the necessary information, and only the necessary information, quality of healthcare can improve, while time can be saved. To this end, a knowledge base is designed that, depending on the role of the user, generates all information on a patient or set of patients in a ward, so that their information can be quickly communicated between healthcare professionals, or used to provide optimal care and monitoring.

4 Discussion

We discussed a data warehouse currently under development with (semi-)automated patient classification and diagnosis capabilities, as well as the ability to generate high-quality communication reports. For the collection of data, we use patient data management systems commonly available in the ICU setting, as well as demographic and clinical data from the hospital information system. For data representation and communication, we use a widely accepted medical ontology called ICD-10 to keep nomenclature and communication uniform.

Currently, aforementioned systems are still under development, but early trials have already proven this system to be feasible. Furthermore, it’s integrated directly in clinical routine without the need for separate clients or processing, which enables the medical team to work in a familiar digital environment, and removes the need to familiarize themselves with another application.

However, there are also some limitations worthy of note. First, the choice of ontology determines the expressiveness of the system, as well as its ability to relate clinical linguistic concepts to raw data. While ICD-10 might be a widely accepted medical ontology, it is not the only one. The Systematized Nomenclature of Medicine–Clinical Terms (SNOMED-CT), for example, is also a medical ontology, and even more comprehensive than ICD-10. However, its use is not free. Furthermore, the system is currently only designed for functions involving retrospective data analysis. For the system to be more supportive to the ICU medical team and the ICU setting in general, real-time data analysis to support on-the-fly protocols and workflows should also be supported. This will be a future stage of the project.