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Architecture of a Decision Support System to Improve Clinicians' Interpretation of Abnormal Liver Function Tests

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Abstract. The objective of this work was to create a self-working computerized clinical decision support system (CDSS) able to analyze liver function tests (LFTs) in order to provide diagnostic suggestions and helpful care support to clinicians. We developed an expert system that processes exclusively para-clinical information to provide diagnostic propositions. Drugs are a major issue in dealing with abnormal LFTs, therefore we created a drug-disease causality assessment tool to include drugs in the differential diagnosis. Along with the results, the CDSS will guide clinicians in the care process offering them case-specific support in the form of guidelines, order sets and references to recent articles. The CDSS will be implemented in Geneva University Hospitals clinical information system (CIS) during year 2011. For the time being, preliminary tests have been conducted on case reports chosen randomly on Pubmed. Considered as medical challenges, case reports were nevertheless processed correctly by the program to the extent that 18 cases out of 20 were diagnosed accurately.

Keywords. Clinical decision support system (CDSS), Expert system, Liver diseases, Liver function tests abnormalities, Laboratory results interpretation.

1. Introduction

Clinical Decision Support Systems (CDSS) is an important challenge to address in the development of clinical information systems (CIS). CDSS were introduced more than 35 years ago, holding great promises for the future. Initial expectations have been mitigated by their real impact in clinical practice and their influence on outcomes [1,2]. Substantial work has been done to understand the reasons for that mixed success. According to publications, the main problems are: 1. a poor integration of DSS in the clinical practice workflow [3,4] 2. the excessive users' inputs requirements [5] 3. the lengthening of care processes [6] 4. the reliance of the CDSS on the existing CIS [7] 5. human factors such as users' reticence and frustration [8,9,10] 6. the need for users' continuous formation and feedback [11] 7. the considerable system maintenance requirements [12]. Most of the work concerning CDSS addresses computerized physician order entry (CPOE), guidelines implementation, and complex diagnosis or signal processing [13,14,15]. Little has been published specifically on laboratory results DSS. As an example, the following search on Medline : "liver function

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tests"[MeSH Terms] AND "decision support systems, clinical"[MeSH Terms] returns only five papers, none of them handling exclusively laboratory results.

The objective of this work was to create a computerized CDSS aiming to ease and improve doctors' diagnostic process in case of liver function tests (LFTs) abnormalities. Keeping in mind obstacles encountered by predecessors, we designed the system to optimize fieldwork integration. Most importantly, we wanted the DSS to perform independently in order to meet the requirements of a self-working system. To reach this goal, it became mandatory to use only structured information that was 100% available in the CIS. Clinical information, not systematically available under a structured computable form was therefore excluded.

Our DSS focuses on liver diseases. The prevalence of liver diseases is difficult to ascertain, since universal definitions are lacking and few population-based registers exist. However, from a laboratory focused perspective, researchers found substantial and consistent data. According to the ALFIE study [16], 21.7% of a normal asymptomatic population (Scotland) presented at least one abnormal liver function test (ALFT) during a median follow-up period of 3.7 years. In that group of patients with ALFT, 5.2% eventually developed a liver disease. LFTs are very popular tests within hospital practice as well as general practice. Their interpretation frequently addresses abnormal results that do not reflect underlying liver disease as a majority. Supporting interpretation is therefore required to aim best practice and cost-effective care. This conclusion is shared by ALFIE study's authors as well as Steinke et al., who wrote in 2002: "*electronic diagnostic algorithms are sensitive enough to identify liver disease using para-clinical data*" [17].

2. Background

The University Hospitals of Geneva (HUG) constitute the major public care providing consortium and teaching hospitals in Switzerland. It covers primary, secondary, tertiary and ambulatory care. HUG is using an in-house developed CIS that integrates commercial systems and covers all clinics and care. The system is Java service-oriented and has a component-based architecture with a message-oriented middleware. It has a full paperless CPOE coverage; it supports workflows, clinical pathways and complex decision-support. For the time being, DSS is however limited to drug interactions and dosage. Once fully tested, validated and implemented, our CDSS will therefore represent an important step towards intelligent and interactive tools introduction in the HUG information system.

3. Chosen Approach

Several computerized DSS techniques have been applied to liver diseases diagnosis [16,18-22]. Elaborate options, such as case-base reasoning (CBR), artificial neural networks (ANN) and hybrid approaches have had encouraging results but still faced some limitations. We previously listed obstacles but it is important to say that using their opposite actions has proved to have a favorable effect on CDSS introduction and efficiency [1,7,15]. Practitioners' confidence in CDSS, or their understanding of its functioning, is a key point which influence users' acceptance. For these reasons and after discussions with domain experts (gastroenterologists), we chose to use an expert

system as the artificial intelligence (AI) technique to process laboratory values. The reason behind it is that expert systems process data using rules that are intelligible to clinicians. We created these rules after a review of articles, textbooks, evidence-based guidelines and experts' opinions. The whole system has been designed to run automatically and iteratively on the same patient without user interaction. It uses only laboratory values and order entry information which are fully structured and 100% available in the CIS.

The DSS consist of three parts: 1) the expert system algorithm; 2) the drug induced liver injury (DILI) causality assessment tool; 3) the interactive interface to guide, facilitate and improve clinicians' work.

While running, the first step of the program will provide a set of possible diagnosis if a substantial ALFT is detected. If not, the program stops and requires no interaction. Step two initiates an automatic review of the patient's drugs from available CPOE information. Matching of substances with DILI and diseases is then performed to assess possible causality relationship between drugs and diseases suggestions. Step three consists of DSS reporting. Firstly, the user interactive interface will display the DSS results as a list of possible diseases. Secondly, "drug-to-disease" causality relationship will be (if existent) suggested to the doctor. Finally, the case specific care support such as guidelines, order sets, graphs and links to knowledge database will be provided.

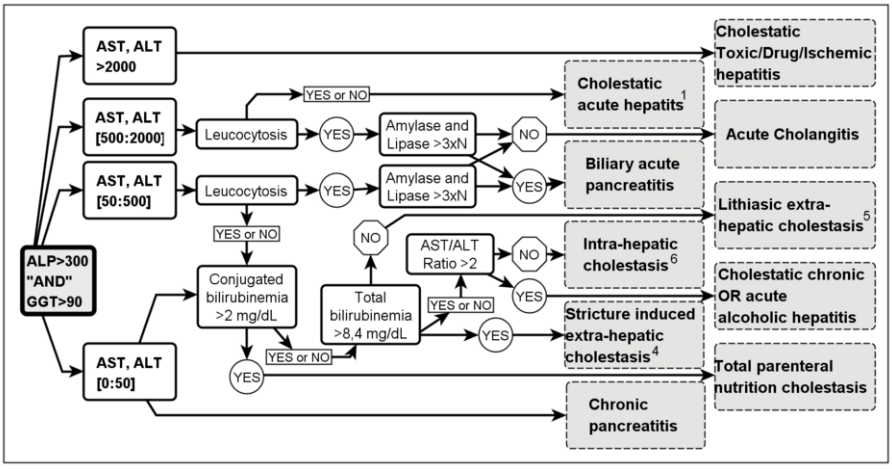

Figure 1.

The expert system decisional strategy is based on rules. It analyzes every patient LFTs in the hospital so as to detect any abnormality and uses eleven different enzymes or biologic parameters to do so. Progression through decisional algorithm is illustrated in figures 1 and 2. The first question that the system must answer is whether or not cholestatic enzymes are elevated in order to separate cholestatic (Figure 1) from non-cholestatic diseases (Figure 2). Then, depending on patient specific values, rules will lead to one or more diagnostics, which will be suggested to the user as possible causes of abnormalities. For the time being, we introduced 24 disease entities in the model most of which are liver diseases. The way values are handled at each junction is not by arbitrary cutoffs, as it could seem on the figures. Instead, transition functions will be used for better interpretation of borderline values.

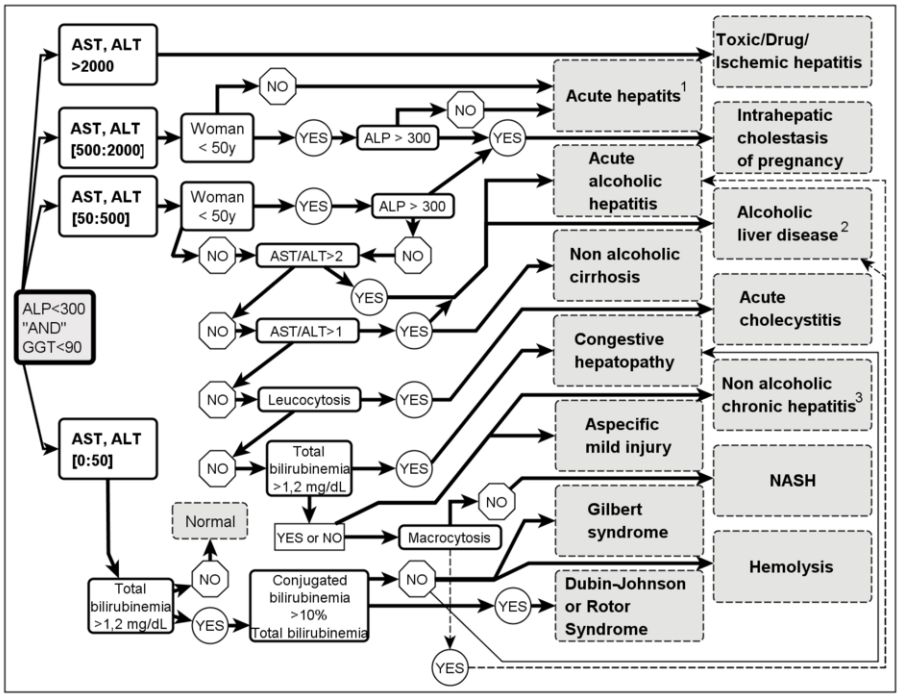

Figure 2.

Diagnostic(s) provided by the algorithm will be compared to patterns of DILI and ultimately to drugs that the patient is taking in order to reveal possible causality relationship between drugs and ALFT. This comparison process is depicted in Figure 3. Over a hundred hepatotoxic drugs were grouped by pattern of DILI they are known to cause (one drug can possibly be in several groups). Each pattern is linked to a group of disease entities that provoke the same enzymatic alteration. Any ALFT will thus correlate specific drugs, and relationship suggestions to clinicians will be more accurate.

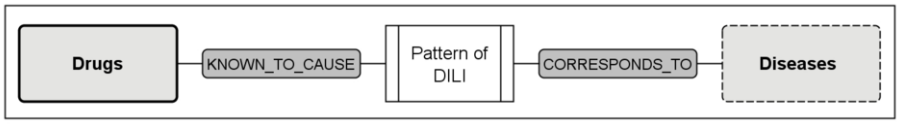

Figure 3.

4. Discussion

Full CDSS is to be implemented and evaluated in 2011. Firstly, decisional algorithm will be tested on a set of existing values from hospital database. As evaluated retrospectively, we will be able to confront the expert system sensitivity and specificity in term of diagnostic accuracy with definitive diagnosis established by doctors during patients' hospitalization. Secondly, field evaluation will take place and will include user satisfaction, system intrinsic performance and influence on outcome evaluation.

So far, preliminary results on the algorithm's precision are promising. We tested it with patients' values extracted from case reports randomly selected on Pubmed. In 18 cases out of 20, the system was able to find the precise cause of ALFT or to guide the clinician towards the right set of diagnosis.

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