

**AN EXPERT SYSTEM SUPPORTING
RISK STRATIFICATION
IN ACUTE CORONARY SYNDROMES**
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Abstract: The aim of the project was to create a computer program, an expert system (ES), which would support physicians when a management for patients with acute coronary syndrome needs to be chosen. A knowledge database was created with the support of clinical experts, based on the current management standards. Data from new patients are added to the case database. The inference engine integrates two types of reasoning rule-based and case-based. The ES gives unambiguous and objective answers, its recommendation are reliable. At present, the ES is tested in clinical practice. Strategies recommended by the ES are compared with the management applied in a clinic.

Keywords: expert system, decision making, acute coronary syndrome, risk stratification

1. Introduction

Acute coronary syndromes (ACS) include acute coronary syndromes with ST-segment elevation and without persistent ST-segment elevation [1]. Both of them may lead to unstable angina, non-Q myocardial infarction or Q-wave myocardial infarction as a discharge diagnosis. Patients with acute coronary syndromes are subjected to a range of therapeutic alternatives. There are two main directions: an early invasive strategy versus a conservative therapy. The decision which therapy should be used for individual patients depends on clinical presentation, risk stratification and the estimated treatment benefits. Computer-based technologies such as expert systems (ES) can be helpful in diagnosis and therapeutic decision making concerning patients

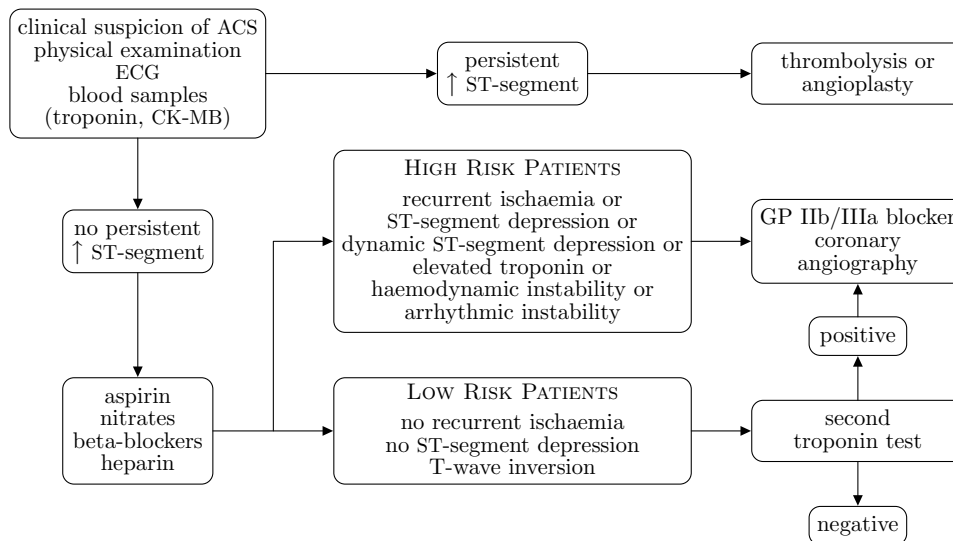


Figure 1. Recommended strategy in Acute Coronary Syndrome
(adapted from Braunwald E *et al.*)

with a presumed acute coronary syndrome [2]. A strategy recommended in ACS is shown in Figure 1.

ES's are intelligent computer programs that use knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution. ES's emulate the decision-making ability of a human expert. ES's together with neural networks belong to the domain of artificial intelligence.

A typical ES consists of three main components: (i) a knowledge base, which contains knowledge on the subject, (ii) an inference engine, which draws conclusions from this knowledge and (iii) an explanation module [3]. A schema of components of a typical ES is shown in Figure 2.

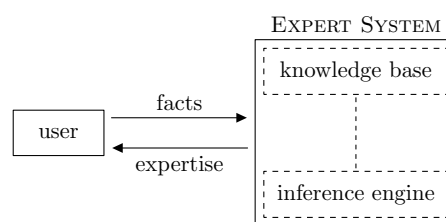


Figure 2. Components of an expert system

2. Objective

The presented ES is a part of the *Cardio.net Project*, which is a distributed teleinformation system for cardiology integrating teleinformation and network solutions and simultaneously introducing new standards of cardiological care with particular reference to intervention cardiology. The purpose of the project has been to increase the efficacy of cardiological care by creating a network of cooperating cardi-

ological centers and the use of teleconsultations to access specialist knowledge on the basis of data acquired from electronic patient records.

The aim of this paper is to present our very first experience with the ES, a computer program, which will support a physician when a therapy needs to be chosen for an ACS patient.

3. Methods

At first we analysed the need for and advantages of such a computer program. Then we specified functions of the system and its users' expectations.

A knowledge database was created with the support of clinical experts, based on the current management standards, guidelines and results of clinical trials according to evidence-based medicine rules. For risk stratification in ACS without persistent ST-elevation we adopted the TIMI Risk Score for Unstable Angina/Non-ST Elevation Myocardial Infarction, which uses seven predictor variables: aged 65 or older, at least three risk factors for a coronary artery disease, prior coronary stenosis of 50% or more, ST-segment deviation on an electrocardiogram at presentation, at least two anginal events in prior 24 hours, use of aspirin in prior seven days, and elevated cardiac markers [4]. For risk stratification in ACS with persistent ST-elevation we adopted the TIMI Risk Score for ST-Elevation Myocardial Infarction, which uses eight predictor variables: age, history of hypertension or diabetes or angina, blood pressure, heart rate, the Killip class, weight, anterior ST elevation or a Right Bundle Branch Block in an ECG, time to treatment [5].

Data from new patients are added to the case database due to key data elements and definitions for measuring the clinical management and outcomes of patients with acute coronary syndromes [6]. A schema of a dialog between a physician and the expert system is shown in Figure 3.

An inference engine integrates two types of reasoning rule-based and case-based reasoning [7]. Rule-based programming is one of the most commonly used

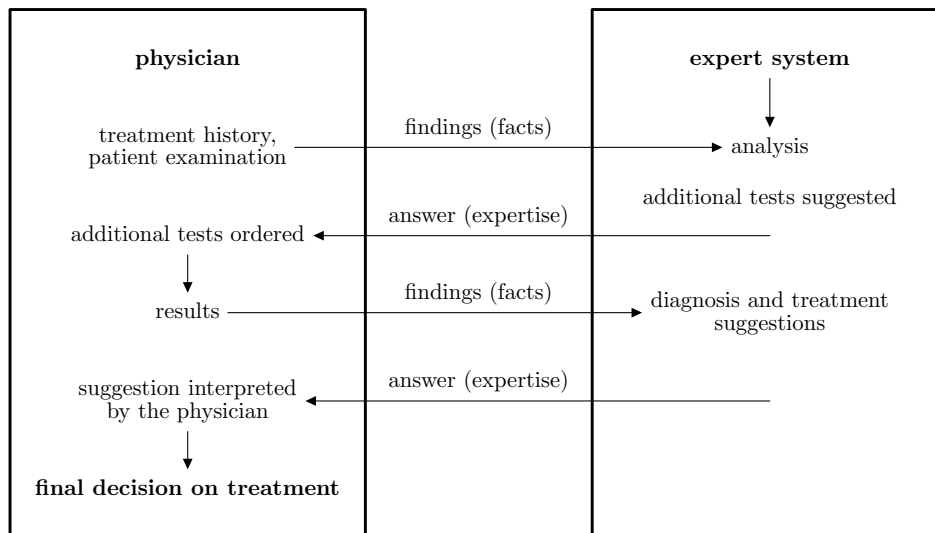


Figure 3. Schema of a dialog between a physician and the expert system

techniques for developing expert systems. In this programming paradigm, rules are used to represent heuristics, or “rules of thumb”, which specify a set of actions to be performed for a given situation. A rule is composed of an *if* portion and a *then* portion. The *if* portion of a rule is a series of patterns which specify the facts (or data) which make the rule applicable. The process of matching facts to patterns is called pattern matching. The expert system tool provides a mechanism, called the inference engine, which automatically matches facts with patterns and determines which rules are applicable. The *if* portion of a rule can actually be thought of as a condition. The *then* portion of a rule is a set of actions to be executed when the rule is applicable. The actions of applicable rules are executed when the inference engine is instructed to begin their execution. The inference engine selects a rule and then the actions of the selected rule are executed (which may affect the list of applicable rules by adding or removing facts). The inference engine then selects another rule and executes its actions. This process continues until no applicable rules remain. An example of an *if rule* is presented below:

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IF conditions1 (e.g. high risk patient) are TRUE  
THEN action1 (e.g. invasive strategy recommended)  
ELSE action2 (e.g. further stratification)
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We used CLIPS as the programming environment, which is a productive development and delivery expert system tool providing a complete environment for the construction of rule and object based expert systems. CLIPS is used by numerous users throughout the public and private community including all NASA sites and branches of the military, numerous federal bureaus, government contractors, universities and many companies [7].

4. Results

A decision-making procedure begins when the expert system receives information of a new patient who has appeared at the Admission Department. The following clinical factors are analysed: chest pain character, presence of risk factors, findings in a physical examination, changes in the electrocardiogram and the results of a quick test for specific markers for cardiac damage, such as troponin, myoglobin and creatine kinase isoenzyme MB (CK-MB). Then the system suggests one from the following managements: early reperfusion, transport to a cardiac intensive care unit or observation at a chest pain unit.

For patients taken to a cardiac intensive care unit, risk stratification is performed. For patients with intermediate or high risk the system recommends an early invasive strategy: coronary angiography followed by angioplasty or coronary artery bypass grafting. For patients with low risk conservative treatment is proposed.

For patients observed at a chest pain unit, a check-up of the electrocardiogram and markers is ordered in the next three hours.

At each stage the system analyses indications and contraindications for thrombolysis and drug treatment and, if it is advisable, recommends usage of antiplatelet drugs (aspirin, thienopyridins, glycoprotein IIb/IIIa antagonists), heparin, morphine, beta-adrenolitics and nitrates. An example of a screenshot from a consultation performed by our ES is shown in Figure 4.

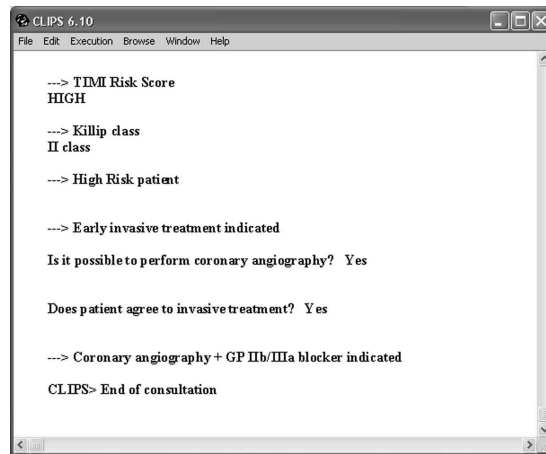


Figure 4. Example of a screenshot from a consultation performed by the expert system in an acute coronary syndrome. Data analyzed by the system based on a real patient's case

As an initial assessment of the reliability of suggestions given by the ES, we used data from 147 patients with ACS. For 127 (86%) patients the ES suggested the same strategy as the physician (see Figure 5a). An invasive strategy was more often advised by physicians ($n = 123$) than by the system ($n = 115$, see Figure 5b). No significant difference in outcomes of both groups of patients in 1-month follow-up was observed.

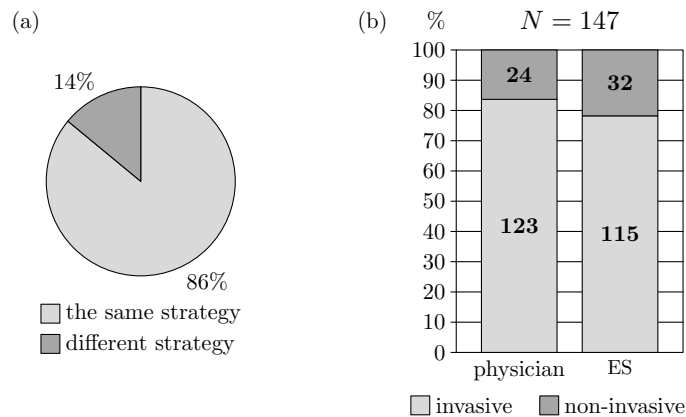


Figure 5. Results from reliability assessment of suggestions given by the expert system (ES)

5. Discussion

Our program has been developed for physicians from peripheral hospitals who have to decide between an invasive and a conservative treatment. Experience with use of the ES in medical decision support has shown that recommendations given by an ES can be reliable. A computer ES gives unambiguous and objective answers, does not get into a rut and, once created, can be used as many times as needed. Its knowledge database includes knowledge obtained from many experts. Contraindications for drugs are quite clear and can be included in the knowledge database of an ES.

The use of ES's in cardiology, a rapidly changing domain of knowledge, can provide expertise to novice clinicians and support their training. An ES works faster than a human expert, does not get tired, avoids delays when expertise is needed, is available at all time and records decision-making processes, actions and outcomes.

However, while our program offers advice and suggestions to its user, it is the physician who makes final decisions on therapy.

6. Conclusion

The verification based on archival data has confirmed the reliability of the proposed expert system. The differences between physicians' decisions and ES advice may be attributed to changes of guidelines. The expert system has to be continuously updated according to new guidelines and recommendations. Different classes of recommendations must be considered.

Our future plans include augmenting the knowledge database to enable the ES to propose management of ACS complications, assess the clinical reliability of answers given by the system, connect to a telecardiology system database, use case-based reasoning, and make it accessible via the Internet.

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