Knowledge-based approach to the management of serious arrhythmia in the CCU

P. Windygà1, D. Almeida2, G. Passariello1, F. A. Mora-Ciangherotti1, J. L. Coatrieux2

1 Grupo de Bioingeniería y Biofísica Aplicada, Universidad Simón Bolívar, Apartado 89000, Caracas, Venezuela 1080A.
2 Coronary Care Unit Hospital, Universitario de Caracas.

Abstract—An expert system (SETA) for the management of patients in the CCU environment has been developed. SETA suggests therapeutic actions for the treatment of serious arrhythmias that complicate the pathophysiological state of patients recovering from acute and suspected myocardial infarction. The prototype begins by reasoning from the arrhythmia, diagnosed from the ECG signal, and progresses through its inference process by considering ECG changes (i.e. heart rate, ORS width), patient clinical data, patient history and therapeutic drug data, to reach the most appropriate actions for each particular patient. The system was implemented on production rules using M1 as a development tool. SETA uses a multiknowledge base (KB) architecture, one for each particular arrhythmia and relevant complication, and a decision board that controls the firing of the KBs and keeps track of patient status through time. The system takes into consideration aspects that are very important for the human expert, e.g. sequence of arrhythmia appearance, drug contraindications and priority in the case of simultaneous arrhythmia. The development of this system has given insight into the management of critical CCU patients, that should influence the specification and design of intelligent instruments for this clinical environment.

Keywords—Arrhythmia, Artificial intelligence, Coronary care unit, Expert systems, Intelligent instrumentation

Correspondence should be addressed to G. Passariello at the Universidad Simón Bolívar, Dept. Electronica-GGBA, Depto. 89000, Caracas, Venezuela 1080A.

First received 26th February and in final form 19th June 1990

© IFMBE: 1991

1 Introduction

Expert systems have been used in medicine for the interpretation of signals and data, diagnostic and monitoring use, patient status prediction and therapy planning. Until now the most successful systems have been designed as diagnostic consultants or advisers, such as Mycin (Shortliffe et al., 1973) for antimicrobial therapy, Casnet (Weiss et al., 1985) for ophthalmology, Puff (Aikins et al., 1985) for pulmonary function testing and Internist (Miller et al., 1985) for general internal medicine. Blum (1985) pointed out that prototype expert systems of the 1980s can be grouped into two categories: large systems, which are a continuation of the experimentation of the 1970s, and smaller, more targeted, systems designed for clinical use. Among these, there are systems that deal with dynamic clinical processes such as patient monitoring and management. Later examples of these are a ventilator manager for an intensive care unit (VM) (Fagan et al., 1985), the fluid and electrolyte disorder manager (Shansolmaali et al., 1988), a manager for respiratory weaning therapy (Ester) (Hernández et al., 1989) and an intensive care alarming system (Sukuvaa et al., 1989). In these examples, the dynamics of the process and the urgency of the required output impose restrictions on the size of the knowledge base, the architecture of the system, the man-machine interface and the hardware used. These are challenges for the 1990s.

Patient monitoring and management in critical care has been recognised as a task that requires expertise (Steffik et al., 1982). Monitoring means the continuous interpretation of incoming patient data to recognise alarm conditions. Management implies making decisions about the required interventions on the patient being monitored. In monitoring, the alarm conditions can be masked by the large amount of data that have to be handled at any time. These data are obtained from monitoring devices, laboratory analysis, manual measurements and visual observations. Real-time reaction is another major constraint. For management purposes, the significance of the different data sources depends on the state of the patient, which means that an individualised and dynamic assessment of the information is required. Monitoring and management presupposes an existing model of the pathophysiological state of the patient (Breuker and Wielinga, 1986), which can be either a model based on medical experience or a patient-tailored physical or conceptual model (Kalli and...
Sztipanovits, 1988). In complex monitoring applications, both approaches are necessary.

Owing to the characteristics of the task outlined above, experts in cardiac patient monitoring and management are scarce, making the development of expert systems for this area very attractive. The need for real-time operation and the interface with bedside instrumentation makes the task a difficult one. In previous work, the problems involved in the management of post-infarcted patients in the coronary care setting (Long et al., 1983; Guarino et al., 1985) have been reported. The characteristics of the problem prompted our group to propose a system that would be able to deal with the overall problem: ECG signal interpretation, therapy selection and follow-up over time (Mora et al., 1989). In the present work, the development of a prototype expert system, which suggests therapeutic actions over time, is presented for the management of patients with serious arrhythmias, as a result of acute myocardial infarction (AMI), in the CCU. The system is intended to help in the training of CCU physicians and nurses, and will constitute a CCU environment and decisionmaking simulator to specify and design future developments in intelligent instrumentation.

2 The CCU environment

Coronary or cardiac care units (CCU) have been in use all over the world for around 30 years. In their early days, only patients with acute myocardial infarctions were admitted to the units. Now all patients with suspected as well as proven myocardial infarction (MI), and those showing many other manifestations of cardiovascular disease, are admitted (Thibault, 1985). Patients arrive at CCU in a variety of pathophysiological states, from critical and unstable conditions to suspected MI. Their treatment and monitoring depends on the staff time response (in most cases immediate attention) and on the reliability of the alarming system (low false-positive and false-negative rate).

Fig. 1 shows the treatment dynamics of a patient in a typical coronary care unit. Patient data are obtained from bedside instrumentation (ECG, BP, oral temperature), laboratory tests (drug toxicity, enzyme analysis), clinical observations (chest auscultation, reflexes), patient information (chest pain, dizziness) and patient history (previous chronic diseases, age). All data sources are integrated by the CCU expert to interpret and take the most appropriate actions. These therapeutic actions constitute a finite repertoire composed mainly of drug administration, electric shocks, pacemaker stimulation and mechanical interventions. The decision about the specific action to be taken is an adaptive function that depends on the previous actions taken, changes of the pathophysiological state of the patient over time, and patient history.

As a matter of principle, arrhythmias arising from CCU AMI patients should be treated. However, a patient can be affected by single arrhythmias, combinations of them (in sequence or simultaneously) and arrhythmias triggered by a previous one. Also, the time evolution of each arrhythmic episode is random, going from seconds to days in some cases. For these reasons, arrhythmia treatment is not unique; it depends on the context of the arrhythmia being treated and on the response of the patient to the actions taken. In general, the treatment consists of selecting a candidate action, applying it to the patient, monitoring the result and selecting alternative actions, in the case that the previous one failed. The process must continue until clinical death is diagnosed or until the patient recovers enough to leave the CCU. Consequently, it is not possible to predict, for any patient, the procedure to be followed and the moment when the arrhythmic episode will disappear.

3 Management of CCU patients

There are different aspects of CCU patient management that have to be considered to design an expert system. The most relevant are summarised as follows.

3.1 Therapy selection

For any given arrhythmia, there are a number of choices to make in terms of the required therapy. It is possible to apply pharmacological as well as physical procedures. Owing to the availability of four large classes of antiarrhythmic drugs, and several subclasses, all of which comprise a large number of compounds, drug selection becomes very difficult. Contraindications, possibility of intoxication, combination of compounds, site or form of administration (IV or PO) and maintenance dosage are among the main variables to be handled in the decisionmaking procedure. Another treatment is the use of electric shocks; in this case, the energy to be delivered and the need for synchronisation should be quickly determined. Pacemaker placement is also necessary in some arrhythmias; the correct instant for placement and the rate have to be chosen. Event recurrence implies reassessment of the approach and, sometimes, the initial diagnosis. In many cases, the selected treatment cannot be considered separately; for instance, some drugs are administered to establish the required conditions for the application of electric shocks. Also, combinations of therapeutic methods must be used under different circumstances.

3.2 Complications

During patient management there are other pathophysiological conditions that can appear spontaneously or as a result of the therapy, often leading to an immediate change of treatment. Of particular interest are the management of angina pectoris, low cardiac output and heart failure, which are frequently associated with AMI. The first condition has to be treated in parallel with the arrhythmia, while the other two affect the haemodynamic state of the patient and therefore complicate treatment and monitoring.