

On-Line Integration of Cardiological Data to Support Medical Decision Making in Patients with Ischemic Heart Disease

GA L'Abbate, C Carpeggiani, C Marchesi, A L'Abbate*

CNR Institute of Clinical Physiology and *Scuola Superiore S. Anna, Pisa, Italy

Abstract

In the last years we developed a system that integrates through a virtual 3D-dynamic heart model all the pertinent clinical and instrumental information obtained in patients hospitalized for suspected or documented ischemic heart disease (IHD). In the present study we retrospectively compared the diagnosis formulated by the cardiologist in the discharge record with the one automatically provided by the system. Divergences were found in 27% of the 110 patients studied and classified into four types: I) inability of the system to provide the correct diagnosis because of the lack of the pertinent diagnostic parameters in the model (3%), cardiologist's diagnosis which was either II) not supported by objective data (3%), or III) in conflict with the available information (10%), or IV) incomplete (11%). An experimental trial has been started in which the cardiologist in charge of the patient uses the automatic system during the diagnostic process and the compilation of the discharge report.

1. Introduction /Aims

The management of patients with suspected or asserted IHD is frequently complicated by the redundancy and heterogeneity of information, which is often gathered by different techniques, at different times and by different specialists who might have a fragmented knowledge of the patient [1-3].

Aim of this project was to support the cardiologist's integration process. To this purpose all the available information belonging to a single patient was integrated and graphically rendered in a synthetic 3D dynamic heart model, able to retrieve the origin and nature of each information. One of the core ideas was that the strength of the integration could overcome the limits posed by forcing the results of different methodologies into the graphic model constraints and by neglecting some of the peculiarities of each technique. Furthermore, presenting the integrated information in a graphic form points out at

a glance possible incompleteness of the picture, the presence of conflicting data and, at a higher level, clinical or physiopathological inconsistencies.

2. The 3D model

The main target of the model was to represent the patient's heart conditions graphically in a unique 3D picture. We designed the picture to be as clear and immediate as possible. The parameters of main clinical interest in IHD had to be rendered so that the picture can disclose at a glance what is known about the patient underlining at the same time missing information and conflicting data.

The 3D model [4] was built to represent simultaneously left ventricular dimensions, global and regional mechanical function, presence, site and extension of ischemia and necrosis and their correlation with coronary lesions and electrocardiographic (ECG) alterations, site and type of revascularization procedures, valve abnormalities and presence of permanent cardiac pacing. Starting from the patient's history the system added, step by step, the information derived from the various tests. The system automatically provided weighted solutions for conflicts and lack of information, which however had to be validated by cardiological supervision. The conclusive picture included also risk factors, medical therapy, and dates of events.

In brief, the left ventricle was subdivided into 16 segments, according to the widely used echo standard segmentation [5] (conversion to the new 17 segment standard, recently adopted for nuclear and echocardiographic tests is in progress). Each segment was free to move according to a wall motion parameter scored from normal to dyskinesia. In addition each segment was differently and gradually coloured depending on the estimated presence of 6 different conditions: normality, necrosis, ischemia, partial necrosis, combination of necrosis and ischemia and finally hypoperfusion without necrosis or ischemia. The colour grey was used to indicate the inability of the system to reach a conclusion because of lack of information or presence of conflicting

information. The coronary tree was constructed according to the anatomical distribution in each patient, subdivided into 18 segments and positioned around the heart. For each coronary segment, the presence and severity of stenosis, the presence, degree and origin of feeding collaterals, and type of revascularization procedures (CABG, PTCA, and stent) were graphically represented. Venous grafts were distinguished from arterial conduits. Stenoses and revascularization procedures on these conduits were also reported. Icons containing the electrocardiographic markers of ischemia (ST-T) and necrosis (Q wave) were associated with the 12 ECG leads and positioned around the heart. Alterations of cardiac valves (stenosis and insufficiency) and permanent cardiac pacing were also represented. Registry data, cardiovascular risk factors and medical therapy were illustrated beside the 3D virtual heart. Each final shot referred to a precise time of the patient's life and to a short period observed (typically hospitalisation). Events such as necrosis, bypass and stent were considered permanent; accordingly they were included, if present as historical data, in the first picture and automatically reported in the succeeding frames during the follow-up.

2.1. Integration system

The target of the automatic integration process was to provide a regional diagnosis for each sector of the left ventricle in order to describe regional wall motion and presence or absence of necrosis and ischemia. The system suggested weighted solutions in order to evaluate the convergence of the available data toward a certain diagnosis and to consider lack of information.

The kernel of the automatic reasoning process simply reflects into a fuzzy set environment the rules derived from the established cardiological practice. Each diagnosis was represented as a fuzzy set [6]. The membership function of each fuzzy set measures how much data supports the considered diagnosis. Single data may differently contribute to different diagnosis in order to reflect the specificity of the information for the considered regional diagnosis.

The automatic process is based on three steps: evaluation of the contribution of each set of data to all the possible diagnoses, evaluation of conflicting and missing information, selection of the most probable diagnosis.

The first step collects all the information supporting a certain diagnosis (-signs of, votes for-) as the measure of the cardinality of the diagnosis fuzzy set.

The second step considers and measures the conflicting and missing data. Data in favor and against a certain diagnosis are compared. The rate of the in favor and in spite data measures the confidence of the considered diagnosis, that may also be expressed as the conjunction of the diagnosis set and the complementary

sets associated to the conflicting diagnosis (i.e. complete necrosis and no vitality and no ischemia and no regional motion). Unfortunately, this rate is not able to express into the process the amount and the quality of the information involved. To evaluate the conflicting or converging data into the available information contest (lack or redundancy) we introduced an "information degree factor" proportional to the amount of data. The amount of information was measured as the sum of the cardinality of all the diagnostic sets. The product of converging/conflicting rate and of the information factor gave us the measure of certainty of a given conclusion. Thus low value, indicative of uncertainty, may be the result of conflict and/or lack of information.

The third step, in a competition between the different diagnoses, selects the maximum score. Thus the system overall suggests the "probable" diagnosis: a full color indicates a high confidence, while a color gradually blurring into gray warns the user of the presence of conflicting data or the lack of information relative to that particular ventricular region.

3. Cardiologist vs Model

At the moment of discharge patient data are summarized in the "discharge report". This is an important document reporting final diagnosis, results of tests performed, conclusions about patient's condition and therapy prescription. The diagnosis has to be correct, complete and supported by objective data.

We retrospectively compared the diagnosis provided by the cardiologist in charge of the patient, as it appeared in the discharge report, with the one automatically provided by the system following the integration of all the stored clinical and instrumental data.

Divergent conclusions were found in 27% of cases. They were classified into four types: inability of the model to formulate the correct diagnosis because of the absence of the pertinent diagnostic parameter in the algorithm (3%), cardiologist's incomplete diagnosis (11%), cardiologist's diagnosis not supported by objective data (3%), or in conflict with the available information (10%).

The inability of the model to provide a correct diagnosis was confined to the cases of non-Q myocardial infarction as the diagnostic algorithm did not include the humoral markers of necrosis.

3.1. Diagnosis in conflict with data

Conflicts between diagnosis and available information fell in two categories : formal and substantial. Formal conflicts were generally ascribed to a lack of attention in typing and preparing the final report. Major formal errors were encountered in the reported location of myocardial

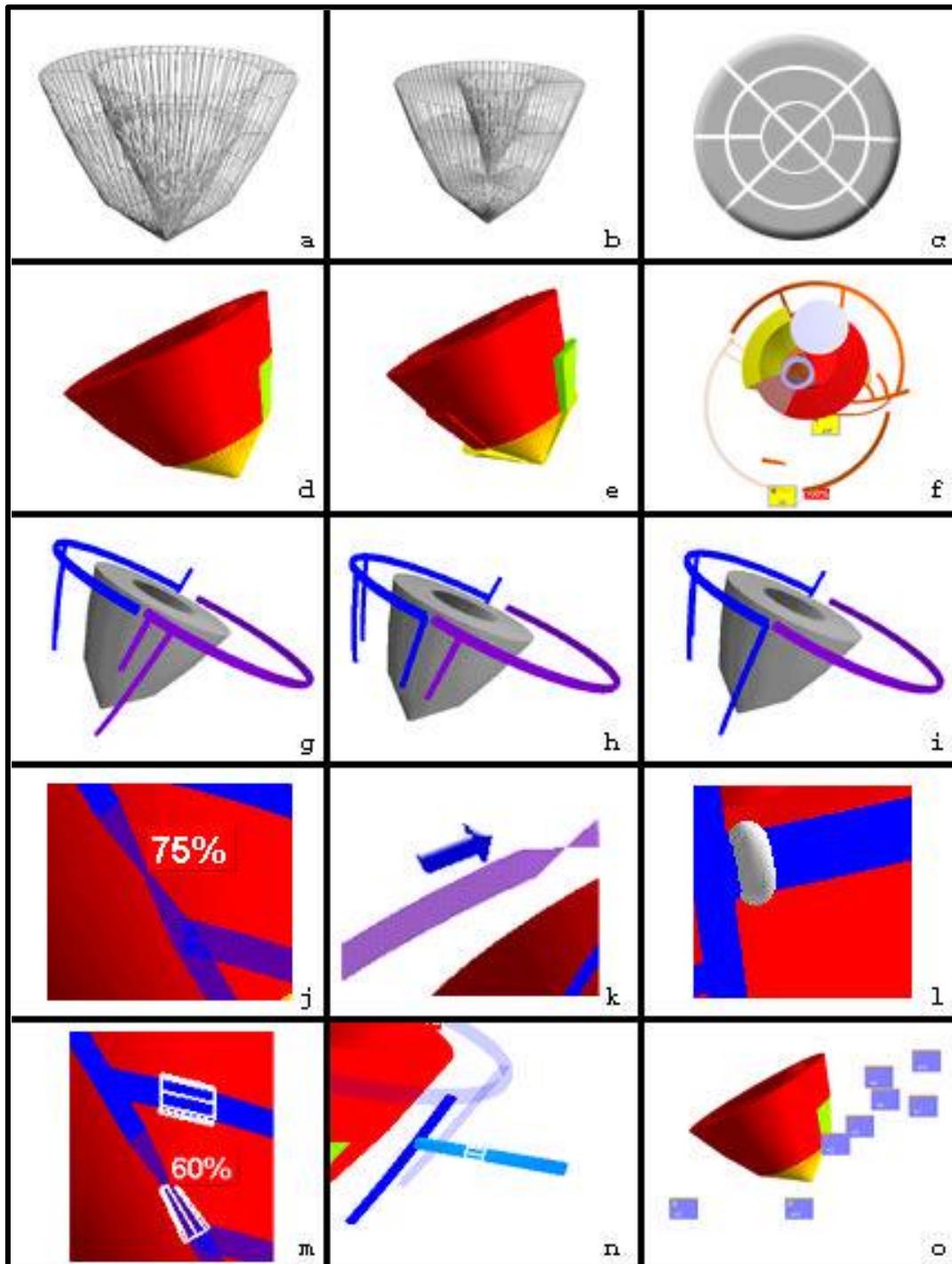


Figure 1. The left ventricle is built according to the echocardiographic diameters in systole and diastole and to the wall thickness (a, b). The ventricle is subdivided in 16 sectors according to the echo standards (c). Each sector is free of moving according to its function (scored from normal to dyskinesia) and its surface is color coded for the presence of necrosis, ischemia, partial necrosis, combination of necrosis and ischemia, hypoperfusion or absence of information (d, e). The coronary tree is represented around the heart (f) according to 3 anatomical variants: right dominance (g), balanced (h) and left dominance (i). Each of the 18 coronary segments can show the presence and severity of stenosis (j), magnitude and origin of collateral circulation (k), type of revascularization procedure i.e. PTCA (l), PTCA with stent (m), or CABG (n). ECG signal alterations (o), permanent pace-maker and valve abnormalities (f) are also displayed.

necrosis or in the number of diseased coronary arteries; minor errors were misused terms such as restenosis in the place of stenosis and others. Substantial conflicts were relevant for patient therapy. Examples are coronary revascularization not supported by the documentation of ischemia or viability, in some cases complicated by adverse events.

3.2. Diagnosis not supported by data

In 3% of the population studied, the diagnosis was not supported by objective data. This was the case of the diagnosis of previous myocardial infarction or ischemia accepted on anamnestic basis without searching for instrumental confirmation.

3.3. Incomplete diagnosis

The analysis of discharge reports showed partial or incomplete diagnosis in 11% of cases. The majority was related to the lack of description of previous myocardial necrosis or other documented and significant cardiac alterations such as ventricular dilatation or hypertrophy.

4. Online Cardiologist + Model

Starting march 2002, a resident cardiologist was asked to adopt and test the system in his routine work-up of IHD. The system was applied to 50 consecutive hospitalized patients.

The integration of the 3D system in the Institute cardiological database, its friendly user interface, and the possibility of retrieving instrumental data, speeded up (instead of than prolonging) the consultation time. In addition, according to the test-cardiologist, the use of the intelligent graphical support turned out to be crucial in exploiting undetected incomplete information and/or conflicting results in 6 cases. The cardiologist found the system particularly useful in complex situations such as those of patients with multiple cardiac events (i.e. multiple and successive revascularizations) or with multiple and different imaging tests.

The model offered a simple tool for matching function to perfusion and viability in the same ventricular segment, for testing the correspondence of pathophysiological assumptions with the clinical findings, and more importantly for reaching a global view of the patient's cardiac conditions.

5. Conclusion

Results from the present study suggest the potential of the online utilisation of the 3D dynamic model by the cardiologist in charge of the patient.

Its implementation may assist step-by-step the work-up of IHD on a routine basis and make the cardiologist aware of missing or conflicting data.

The model's ongoing systematic application to all benefit patients admitted to our Institute for suspected or documented IHD will allow evaluating the ability of the system in describing the evolution of the disease and the succession of events in the single patient through a dynamic sequence of frames.

References

- [1] Schiller NB. Echocardiographic assessment of left ventricle. Chapter 10. In: "Comparative cardiac imaging: function, flow, anatomy, and quantitation". Ed: BH Brundage, Aspen Publisher, Maryland, USA, 1993.
- [2] L'Abbate A. Pathophysiological basis for noninvasive functional evaluation of coronary stenosis. *Circulation*, 1991, 83 (5)III: 2-7.
- [3] Understanding Cardiac Imaging Techniques: from basic pathology to image fusion. Edited by Paolo Marzullo. IOS Press Ohmsha, NATO Science Series.
- [4] GA L'Abbate, C Marchesi, A L'Abbate. Validation of a dynamic 3-D model for integrating clinical and instrumental data of patients with ischemic heart disease. *Computers in Cardiology* 2000; 27: 781 - 785.
- [5] American Society of Echocardiography Committee on standards, subcommittee on quantitation of two-dimensional echocardiograms. Recommendations for quantitation of left ventricle by of two-dimensional echocardiograms. *J Am Soc Echo*, 1989, 2: 358-67.
- [6] Fuzzy System in Medicine. PS Szczepaniak, PJG Lisboa, J Kacprzyk editors. Physica- Verlag.

Address for correspondence.

Giuseppe Andrea L'Abbate
CNR Institute of Clinical Physiology
Via Giuseppe Moruzzi 1, 56124 Pisa, Italy
email: pallino@ifc.cnr.it