Multifunctional Health Information System for the Comprehensive Management of a Sleep Clinics Franchise Chain

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Abstract: In this paper it is presented the prototype of a multifunctional Health Information System for the Comprehensive Management of a Sleep Clinics Franchise Chain. This prototype should facilitate the process by which it obtains, uses or displays a variety of basic resources to support the objectives of a Sleep Clinic, should facilitate the decision-making process, the control of the administrative and other day-to day workflow activities and the clinical management for the diagnosis and treatment of sleep disorders and related diseases. The rationale of the project is the creation of a system to ensure the availability of highly skilled and well trained staff that takes care of patients attending a specialised centre of this kind. The system has three main sub-systems, these are: a system to manage all the administrative and (or) day-to-day workflow activities aspects of the clinic. The second, is a diagnostic and treatment (decision) support system and an electronic health record, it suggests the physician a diagnostic–therapeutic plan (following standard and updated guidelines) for each patient; this rule-based subsystem has been developed following the method for building Expert Systems (ES). The third subsystem supports an educational program and training tool for the staff to ensure that they will manage appropriately all the activities of a specialized centre for diagnosing and treating sleep disorders. The paper describes the ideas supporting the design, some comments about the system architecture, the methods that we follow to build it, some conclusions, and further research.
Key Words: Information Systems, Expert Systems, Sleep Disorders, Medical Diagnosis, Artificial Intelligence.

1 Introduction

Artificial Intelligence (AI) and Information Systems [1,3,6,10,11] have many applications in the medical field, such as Expert Systems (ES), which have been used to support both specialists and general practitioners to facilitate the diagnosis of diseases that usually are only performed by an expert in the field [2,5,7,8,13].

This multifunctional health information system (HIS) was developed: 1) to guide the user how to comprehensive and accurately perform the management and all tasks of a specialised centre for sleep disorders, 2) to support the diagnosis and treatment of the patients, and 3) can be used to train the staff and transfer them highly-specialised skills.

All general practitioners, or specialists in other areas of medicine, should master the knowledge and skills in the field of sleep disorders. Sleep disorders are a major global public health problem (high prevalence, morbidity, mortality, high costs, treatable), which require that every physicians should appropriately follow the guidelines in order to ensure a good assessment and a qualified and efficient medical care. Evidence-based guidelines on sleep disorders hold considerable promise for continued improvement of health-care delivery. However, the availability of clinical practice guidelines does not automatically lead to changes in practice patterns. Unfortunately most physicians do not know much about sleep disorders or do not follow the guidelines available, that is why a franchise system was developed in Venezuela (Clínicas del Sueño y Terapia Respiratoria SLEEPCARE) in order to guarantee the same level of expertise, quality and service in all major cities of the country.

A franchise system always requires accurate execution of all the operation manuals and guidelines and that is the cornerstone of this kind of business. Most contract clauses are based on this, and if a franchisee does not follow appropriately (by mistake, misunderstanding or deliberately violation) the guidelines contained on the operation manuals severe sanctions could be adopted; including rescission of the contract and pecuniary sanctions.

So, accurate, reliable and effective execution of all the guidelines is always sought by both franchisee and franchisor. On the other hand, confidentiality of the operation manuals is extremely important for the franchisor and the system as a whole. Violation of a confidentiality agreement is easy and could be done to develop an independent business different to the original (copied) franchise. Privacy and appropriate security of the business secrets is mandatory for a franchise system.

This Health Information System for the Comprehensive Management of a Sleep Clinic franchise chain (ISSC) provides the following functions: easily transfers the know-how that a franchise system requires; guides the management of all the activities to be conducted in the centre, which includes the control of administrative activities; supports the medical decisions-making process and manage the electronic health records, the differential diagnosis, a retrievable knowledge base, descriptions of the system, explanation about its decisions, among others.

Achieving the diagnosis of sleep disorders is difficult in most cases, even for experts in the field and, as far as we know, nowadays there are no applications based on AI to facilitate the diagnosis of these diseases. Therefore, based on the techniques of Knowledge Engineering, ISSC was developed to achieve these goals.

This article is organized as follows: section 2, a brief review of the concepts of AI and ES, and its applications in medicine is presented, section 3, methodology followed for developing this ES is explained; in section 4 we explain the justification for developing the system, Section 5 describes the ISSC and in Section 6 we present some conclusions.

2 Artificial Intelligence and Expert Systems

AI is the part of computer science that deals with the design of intelligent computer systems, i.e.: systems that exhibit features that are associated with intelligence in human behaviour, understanding of language, reasoning, problem solving, among others [1,6]. AI systems have generated interest and enthusiasm in the industry and are being widely commercially developed. These systems include programs capable of solving complex problems in similar way that human experts do. It includes fields as chemistry, biology, geology, engineering, medicine, among others. Due to technological advances AI has taken two basic directions: the physiological and psychological research on the nature of human thoughts and the development of increasingly complex softwares. In this context, the most important research areas are information processing, patterns recognition and applied areas such as medical diagnosis [2,5,9,12,14].

Medical knowledge-based systems have a long-standing history and their applications are many; such is the case of ES. ES are computer programs that capture experts' knowledge and try to imitate the reasoning process when solving problems in a certain domain. A formal definition is that an ES "is an intelligent computer program that uses knowledge and inferential problems solving procedures that require the competence of a human expert for its resolution" [3,6,15,16,17,18]. Clinical decision support is the provision of "clinical knowledge and patient-related information, intelligently filtered or presented at appropriate times, to enhance patient care." [27]. Medical institutions are increasingly adopting tools that offer decision support to improve patient outcomes and reduce errors.

Clinical decision support ES have the advantage of being able to synthesise patient specific information, to perform complex evaluations, and to present the results to health professionals quickly. For instances, these programs can suggest diagnoses, make recommendations about subsequent tests, and calculate the probabilities of success and total costs of various therapies, helping the physician to choose the most appropriate treatment. They have been shown to enhance clinical performance in terms of drug dosing, and preventive care [14, 28], to improve the quality of general medical care [29], reduce serious medication errors [30, 31], to improve compliance with prescribing guidelines, reducing the occasions when doctors ignored a cheaper, equally effective drug [32]; and have shown to be are easy to operate, safe and effective and improved the quality of treatment by trainee doctors [28]. The benefits of computers are clearer when they are used as administrative aids for detection, registration, and recall [33, 34, 35].

ES also provide additional tools in the form of user interfaces and mechanisms for explanation. User

interfaces, like any other application, allow users to make queries, provide information and interact with the system in other manners. The explanation mechanisms, the most fascinating part of the ES, allow the systems to explain or justify their conclusions and also enable developers to verify the systems operation by themselves.

3 Methodology for Designing Expert Systems

This methodology [23] arises from the integration of some other well-known methodologies of areas as Software Engineering and Knowledge-based Systems. It considers the computational nature of ES and is comprehensive but easy to follow. Its structure is based on stages, steps and phases. The methodology description is presented next:

Stage 1: Analysis and description of the problem:

Step 1.1.- General description of the problem:
- 1.1.1.- Familiarisation with the process selected for using an ES.
- 1.1.2.- Familiarization with the computational environment where are located the data that will be used by the ES.
- 1.1.3.- Detailed definition of the problem to be solved using ES.

Step 1.2.- Feasibility analysis for developing the ES: In this step the conditions for developing the ES are verified considering:
- 1.2.1.- The problem to be solved requires of knowledge handled by an expert?
- 1.2.2.- Expert or team of experts availability
- 1.2.3.- The expertise is required in many places at the same time?
- 1.2.4.- The system requires uncertainty manipulation and personal criteria?
- 1.2.5.- Does exist a potential group of users?
- 1.2.6.- Is there time for developing the ES? (The problem is important but not urgent).

Step 1.3.- Data Analysis: Search for data location and representation format, considering database type (industrial, relational, object-oriented, etc.), computational platform (Windows, DOS, UNIX, VMS, etc.).

Step 1.4.- Knowledge source election: It is necessary that an expert or a team of expert want to help with the project. The users should consider as an expert the person to be used in the knowledge engineering process.

Stage 2: Requirements specification:

Step 2.1.- Information requirements: It is specified the kind of information that must give the ES as presentation format, direct users and interconnection with other programs.

Step 2.2.- Functional requirements: Have been specified the general functions that the ES must satisfy.

Step 2.3.- Input data requirements:
- 2.3.1.- Selection of the possible inputs to be given to the ES.
- 2.3.2.- Data source identification.
- 2.3.3.- Specifications for Data acquisition process.
- 2.3.4.- Specification for Parameters generation processes.
- 2.3.5.- Databases interconnection required for implantation Stage.

Step 2.4.- Hardware and Software requirements for implanting the ES:
- 2.4.1.- Specification of the Hardware platform to be used for building and operating the ES.
- 2.4.2.- Software Analysis and selection: Verification of available computational tools for building ES.

Step 2.5.- Definitions of the final users for the ES

Step 2.6.- Requirements verification with the users

Stage 3: Cost, time and resources analysis.

Step 3.1.- Construction, development and implantation activities plan

Step 3.2.- Required time estimation for building the ES

Step 3.3.- Hardware-software requirements estimation of for building the ES

Step 3.4.- Cost estimation for building the ES.

Stage 4: Knowledge Engineering

Step 4.1.- Knowledge Acquisition: Is the most important part of an ES. It is when the Knowledge Engineer interacts with the expert in order to obtain the information about the appropriate way for solving the problems. Also evaluates the strategies used for obtaining that solution.

Step 4.2.- Knowledge structuring: In this step, the knowledge engineer must organize, in a Knowledge base, the information given by the expert. The knowledge can be of superficial or deep nature depending of the intern structure and the interaction between its components.

Stage 5: Preliminary design of the ES

Step 5.1.- Preliminary design of the architecture for the ES.

Step 5.2.- Computational tool selection according to requirements that have appear in the Knowledge Engineering Stage.

Step 5.3.- Preliminary design for data acquisition and storage processes.

Step 5.4.- Preliminary design for interconnection processes

5.4.1.- Internal Integration

5.4.2.- External Integration

5.4.3.- Auxiliary software selection

Step 5.5.- Verification of the ES preliminary design.

Stage 6: ES building and implantation

Step 6.1.- Prototype construction (This paper presents up to this point)

Step 6.2.- Prototype validation

Step 6.3.- Operational model construction

Step 6.4.- Test and refinement: In this step some situations are given to the human expert and to the ES and it is verified if both give the same solution using the same strategies. If any discordance exists between the human and the ES, the knowledge base is reviewed or modified.

Step 6.5.- Maintenance and actualization

4 Justification for developing the system

Sleep disorders are a global major cause of mortality, morbidity (independent primary risk factor for cardiovascular and metabolic diseases), traffic and occupational accidents and low business productivity [4]. Achieving the diagnosis of sleep disorders may be difficult in most cases, even for experts in the field; and, as far as we know, nowadays there are no applications based on AI to facilitate the diagnosis of these diseases. The use of IS applied in various daily living activities increase productivity and facilitate tasks that often require a lot of time and resources to be done. HIS have the potential to enable a dramatic transformation in the delivery of health care, making it safer, more effective, and more efficient. Some organizations have already realized major gains through the implementation of multifunctional, interoperable IS built around an electronic health record. HIS, have improved many of the quality of health care indicators; such as, increasing the number of diagnoses that have been performed or the number of assisted patients, accurately following guidelines, decreasing the utilization of care, medication errors, improving efficiency in making decisions or simply solving problems when experts are not present.

Sleep disorders are relatively ignored by most people, even by most doctors, in addition, there are not many experts or trained personnel, nor many institutes to train them; therefore we have developed a prototype of a HIS for the comprehensive management of a sleep clinics franchise chain. Clínicas de Sueño y Terapia Respiratoria SLEEPCARE was created in Venezuela in order to assure that high standards of quality, service and clinical care could be available to most citizens in major cities of the country.

Developing a franchise system means to spend good time and money developing operations manual, complete with systems, knowledge base, procedures, compliance and every facet of interaction that defines

the business. Also efficiency on administrative and financial transactions is indispensable to reduce costs and improve the quality and quantity of care provided. Since computational tools have proven that are very good at gathering information and performing repetitive calculations and several computer systems have been designed to help doctors to improve their practice in terms of efficiency, safety and reliability, we assessed the benefits of these systems to establish whether they should be systematically used in this franchise system.

5 Multifunctional Health Information System for the Comprehensive Management of a Sleep Clinics franchise chain

Our aim was to develop a comprehensive health information system (HIS) that could assist the user to effectively and efficiently follow the guidelines that contain all the know-how of a sleep clinics franchise system (from how to clean and tidy up the facilities, or answering a phone call, up to a CEO position administrative or management rolls) and the clinical guidelines for diagnosing and treating every patient.
We have proposed that all the support that the software confers would be automatically applied as part of the normal clinical, administrative or regular day-to-day workflow and at the time and place of decision making. Every single action or procedure done by any member of the staff should be executed using the assistance of the software. This all-in-one system should handle most of the franchise activities without the need of multiple softwares and complexity levels.

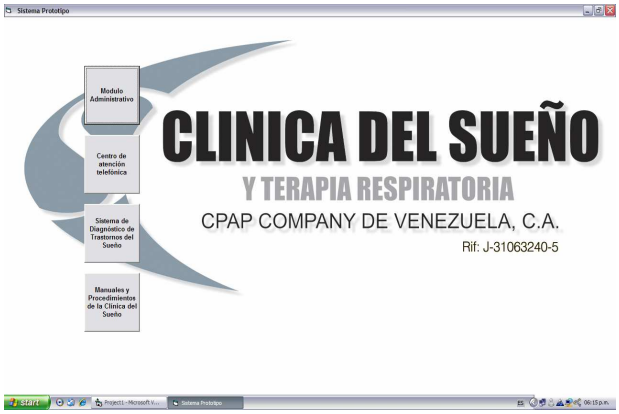

Figure 1. Main menu

Intended functional capabilities and uses of this HIS are:
1) for the franchisee: electronic guidelines and operation manuals (easy to follow instructions for executing tasks while working), computer-assisted staff recruitment process (web-deployed employment offers with detailed information about working conditions, responsibilities and activities, attitude and skills requested; web-based application submission, on-line psycometric tests and assessment, interviewing, automatic exclusion of non-compliant aspirants and replying them with a denial letter, preliminary selection and scheduling for personal interviewing or further assessment), a staff training module (offers support for teaching and learning, for tests and evaluations, for managing and monitoring the entire educational process by means of multimedia presentations, descriptive text, images and graphical displays, video sequences and sounds, tests, surveys, etc.), a computarised guided call centre (for assessing, informing, scheduling and teleconsulting patients or any other information seeker; feeding a clients and suppliers database), computer-assisted administrative management processes,

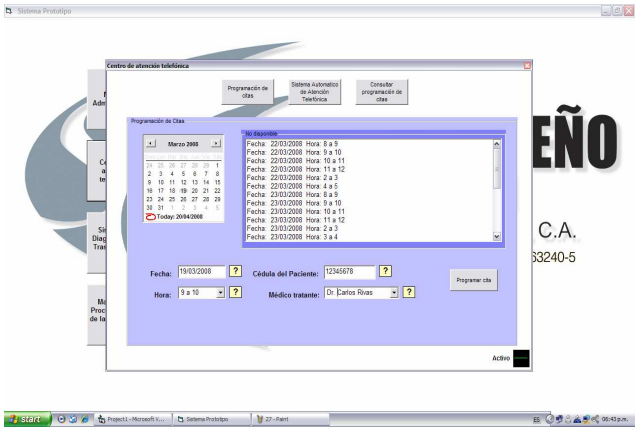

Figure 2. Administrative module. Appointments scheduling

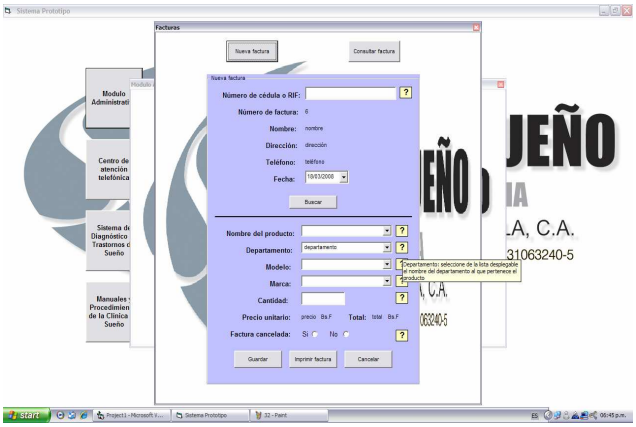

Figure 3. Administrative module. Billing.

2) for the clinicians: an electronic health record, knowledge base and clinical documentation (health information/data), results management, a computarised prescriber order entry system, a decision support system (The system anticipated clinicians' requirements by using information contained within a patient's computerised record to trigger the guideline and present patient scenarios and a specific individualised diagnostic-therapeutic plan), electronic communication and connectivity, reporting and health statistics, database management for clinical trial or other scientific purposes,

3) for patients: patient support and information access or retrieval system, teleconsultation (via call centre), complete privacy of all personal data, immediate access to result, bills, quotations; on-line appointments fixing, rescheduling and payments; reminding messages, notification of special offers, promotions,

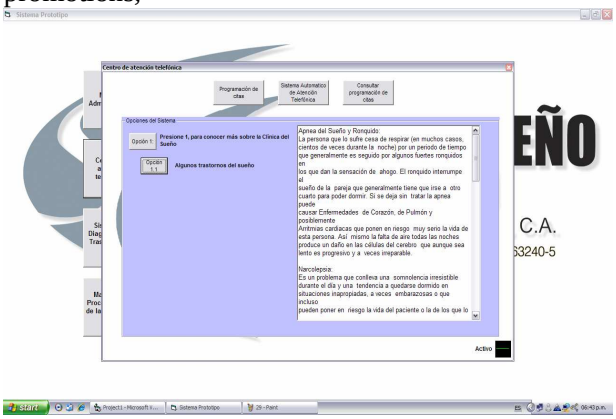

Figure 4. Information retrieval from the call centre module.

4) for the franchisor: confidential electronic guidelines and operation manuals (protected, non-printable documents for assuring the compliance of the confidentiality agreement, restricted accessibility provides multiple levels of access, so most key procedures will need multiple workers to be done and they will master just the know-how for their particular roll and not for the others; some procedures are automatically processed hiding explanations and formulas without revealing business secrets), franchisor is the administrator of the software and has the right to restrict, revoke, or blockade the access to a particular user according to contract clauses (if violations, sanctions, lack of payments, etc.), computer-assisted franchisee recruitment process (similar to that for staff recruitment but investor oriented), a franchisee and staff training module, computer-assisted administrative management processes (budgeting, client or supplier contact, resource management, establishment of deadlines and generation of quotes, inventory and particularly audit, surveillance, evaluation, feedback, surveys); easily modifiable guidelines and operation manuals by non-computer programmers, based on surveys that are automatically performed during the software usage it can suggest key operational changes that would improved the guidelines and their productivity, efficiency or profitability.

Every member of the staff or patient has a specific level of access and privilege. Each user has a unique code and a confidential password, both of which are needed to log into the system. The privileges assigned to a user determine which actions are available for him/her. The user's code is associated with any actions performed while they are logged in and/or securely guarantee privacy of personal data for patients and financial or any other confidential information for the staff.

The computational tool used for developing the system was Visual Basic® 6.0 [21] programming language, but particularly for the development of the clinical decision support system, which was designed following the ES development methodology presented in section 3 [23]. A production rules programming component consistent with the language, called Visual Rule Studio ® [22] was also used. This tool is based on the Production Rules Language (PRL) and inference engines. Visual Rule Studio® allows developers to pack the set of rules that lead to specific problems solution in reusable components called Rulesets (Figure 5).

```
Class Hipertension
With PA1 Numeric
With PA2 Numeric
With DxHTA Compound Normal, Prehipertenso, Hipertenso grado I, Hipertenso grado II

Rule 1
If Hipertension.Prom1 <= 120 And Hipertension.Prom2 < 80
Then Hipertension.DxHTA Is Normal

Rule 2
If Hipertension.Prom1 > 120 And Hipertension.Prom1 < 140 Or Hipertension.Prom2 >= 80 And
Hipertension.Prom2 <= 89
Then Hipertension.DxHTA Is Prehipertenso

Rule 3
If Hipertension.Prom1 >= 140 And Hipertension.Prom1 <= 159 Or Hipertension.Prom2 >= 90 And
Hipertension.Prom2 <= 99
Then Hipertension.DxHTA Is Hipertenso grado I

Rule 4
If Hipertension.Prom1 >= 160 Or Hipertension.Prom2 >= 100
Then Hipertension.DxHTA Is Hipertenso grado II

End
```

Figure 5. Rulesets

Visual Rule Studio® is used in the programming language as an ActiveX designer, which is similar to a Visual Basic form that allows creating classes, which are in line with the application like the common forms of Visual Basic®. The knowledge base with all rules have been created using the Rulesets; this is responsible for assessing existing conditions based on data received over the system interface and finds the conclusions; then these findings are shown to the user through a specific interface, so the designer is responsible only for scheduling functions related to the logic of the application and then the logic for resolving the problems will be programmed using the language of Visual Rule Studio® and Rulesets.

A set of forms has been designed for the data acquisition that feed each subsystem, which have clearly identified fields for entering information, and is general for all subsystems. There are also certain features of income data that require the selection of options either list or checkboxes. In the developed prototype it was used to ensure data storage and the persistence of relevant information to the system operation, a Microsoft Access® database, that due to the ease of handling this type of database from Visual Basic®.

Upon entering the system diagnostic screen shows a new option labeled "Medical Record". Pressing this button appears the first form that lets the user enter personal information or consulting the record of previous visits of any patient (Figure 2).

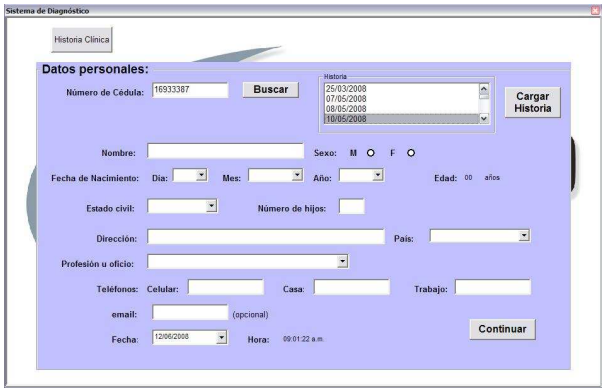

Figure 6. Medical Record. Patient's Information Form

At that point, the forms that appear consecutively in the diagnostic system show a list of all signs and symptoms that will be selected by the user according to the patient's interview and clinical examination data in order to reach a set of possible diagnoses (Figure 7, 8 and 9).

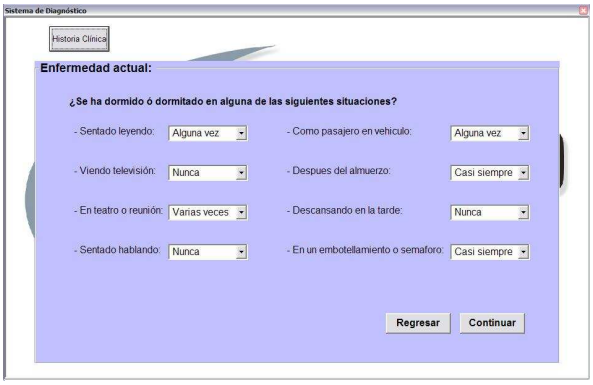

Figure 7. Signs and symptoms form 1

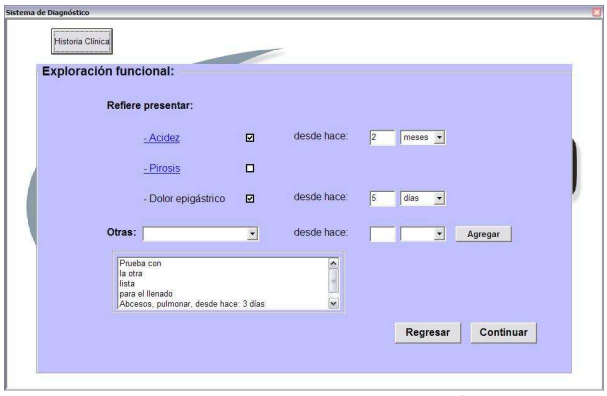

Figure 8. Signs and symptoms form 2

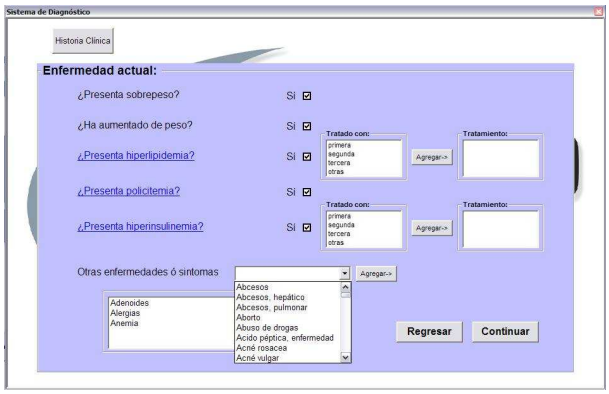

Figure 9. Signs and symptoms form 3

Once the interview, physical examination, laboratory tests, images and special exams data have been registered and having selected all the signs and symptoms that the patient reports. Selecting the appropriate option, it will print the fulfilled medical record. Patient's medical record is presented in the format shown in Figure 10 and the option "possible diagnosis" shows a new window (Figure 11) where the diagnoses proposed by the system appears, as well as a set of risk factors, evidence of damage to target organs and possible causes of the diagnosed disease.

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Historia de consulta sucesiva

Motivo de la consulta: ronquidos, insomnio, hipertensión resistente al tratamiento, síndrome metabolico, síncope, insuficiencia cardiaca

Enfermedad actual: masculino de 24 años de edad, natural de Mérida y procedente de esta localidad, Soltero(a), sin hijos, de profesión Estudiante, quien inicia su enfermedad actual hace muchos años (no precisa), desde cuando presenta, ha oido su propio ronquido, somniloquia, diaforesis nocturna, movilización de miembros al dormir, insomnio, sueña que se ahoga, reflujo esofágico, dolores musculares, excesiva somnolencia diurna, se ha dormido o dormitado. Alguna vez sentado leyendo, Alguna vez como pasajero en vehículos, Casi siempre despues del almuerzo, Casi siempre en un embotellamiento o semáforo, refiere cansancio tras despertar, desconcentración, amnesia o pobre memoria anterógrada, depresión, disminución del libido, palpitaciones, sobrepeso, ha aumentado de peso, hiperlipidemia, policitemia, hiperinsulinemia, Adenoides, Alergias, Anemia. Tiene actualmente 3 categorias del cuestionario de Berlín acompañado de clanosis y síncope. Fue referido por Dr. Carlos Rivas.

Antecedentes familiares: Madre, Hermano, roncadores Hermano, Padre, hipertensos Padre, sufrió infarto al miocardio.

Antecedentes personales: Intervenido quirúrgicamente de Apendicitis hace: 2 días, Amigdalitis hace: 2 meses, obesidad, rinitis, hipotiroidismo, macroglasia, retrognatia, síndrome de Down, alcoholismo. Niega pólipos nasales, tábique nasal desviado, micrognatia, acromegalia, parálisis cerebral,

Hábitos psicosociales: Consumo de alcohol los fines de semana en alta dosis, fuma desde hace 2 meses, drogas depresoras del sistema nervioso central, entre ellas: , primera, otras. Niega otros de importancia

Figure 10. Patient's Medical Record

The developed system guides the user to easily collect information from the patient, based on these data that can lead to a set possible of diagnoses. It also guides the user about how to perform the clinical examination that have to be done to the patient showing definitions and images of each sign and verify that the doctor did not forget to consider any of the diagnostic criteria, even if it's the first time he/she sees or knows about this sign or symptom. Once the data is obtained from the patient, diagnostic decisions are based on medical knowledge stored.

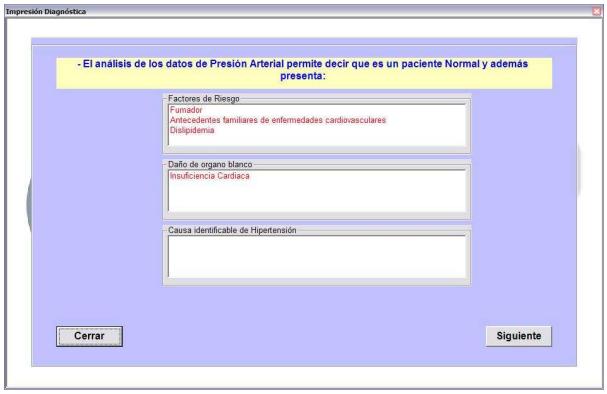

Figure 11. Possible Diagnosis

The qualities of this subsystem include:

1. Diagnosis of one or more diseases associated with sleep disorders and suggests appropriate plan following the guidelines.
2. Diagnose the absolute absence of any of these diseases.
3. Find some signs or symptoms attributable to any exogenous causes (differential diagnosis).
4. Physician is warned that the patient meets some criteria but not the minimum established diagnostic criteria for certain disease and in this case:
   - Suggests a subsequent reassessment or
   - Suggests referring the patient to a specialist.

The rules of the current version (prototype) of this IS include the more standardised worldwide diagnostic criteria for different sleep disorders, as well as algorithms designed by the authors and experts in this field.

6 Conclusions

Thanks to scientific and technological progress, there are tools such as information systems and ES, which applied to the realm of medicine, allow the detection of many diseases, facilitating their early diagnosis and treatment to avoid future complications that jeopardize the quality of life of the patient and avoiding many cases a premature death. A user-friendly HIS has been developed which is a tool for the comprehensive management of a sleep clinic and the computer-aided diagnosis of certain diseases associated with sleep disorders. This system helps the users to accurately perform all tasks related to the management of a sleep clinic. Scheduling,

administrative management, diagnosing, proposing treatment, and training of the staff are some of the capabilities that the system have. Evaluation of this support system will be presented in a future paper and is not the scope of this presentation. We have widely explained the diagnostic module and will explore the other modules and capabilities in another article. Systems like the developed require careful assessment and, if they prove to be effective and accurate, they should be presented as a new tool for providing high quality standard medical care. This HIS is currently being evaluated on its effectiveness and its use for medical training in a Sleep Clinic.

Acknowledgements: The research was supported by the CDCHT-ULA, through grant FA-320-04-07-B.

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