PROBLEMS AND SUGGESTIONS FOR AN EXPERT SYSTEM IN SURGERY

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ABSTRACT. In Italy a strategic project of the National Research Council, called "Expert System in Medicine" is in progress; such a project supports the research described in this paper. It regards the design and the development of a Surgical Pancreatic Expert System (SPES) to assist oncologists and surgeons both in the pre-operative diagnostic procedure phase and in the intra-operative diagnostic procedure and surgical management phase, with regard to the pancreatic cancer problem. In this paper we discuss about problems existing in this particular area and why an expert system in the surgery is suggested.

1. INTRODUCTION

The current widespread interest in Expert Systems, and in particular their importance in industrial, medical, scientific, and other fields, jointed with the growing success encountered to develop such systems has induced some researchers to underline the difficulties to realize expert systems in the medical domain. Their use is not yet sufficiently developed to a great extent, according to the expectations of their potential users [FA85], [FI86], [FO85], [KU85], [RA86], [SH83]. This fact is due to the large quantity of requisite knowledge and to the limitations of the available methods, for which one is often led to investigate problems of diagnosis and treatment of a particular disease rather than the management of the patient as a whole [FI86]. An expert system in surgery has some common characterizations with other systems whose application domains are in different areas of the medicine, for instance to be useful both for tutorial and for assistential purposes. In particular, for the latter its utility is evident in areas where is lack of human experts, both for pathologies with quick increase of occurrence and/or knowledge, and for concentration of experts in defined geographical areas or in determined health care centers.

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This is particularly evident in the case of surgery, in which concentration of experts in definited centers (relatively to determined specializations) is a frequent phenomenon. The training of an expert surgeon usually requires an amount of time larger than the training in other medical fields. Moreover, the time to take a decision is often more stringent than the other areas.

The above listed reasons are some of the main reasons suggesting to develop such systems in surgery. In this particular medical area, "knowledge" and "expertise", that is "surgical planning", can be often more important than surgical skill; whenever human experts are in great demand and short supply, an Expert System can help to amplify and disseminate the needed expertise.

Surgery is "a complex therapeutical system" that is integrated with other therapies much more frequently than other therapeutical systems. The assistance of a consultant acquires a stronger relevance in the operating room, where the decisional time is generally "urgent" (it is not possible to suspend a surgical act to wait the coming of an external expert consultant, admitted that such an expert is available) but not "very urgent" (it is possible to wait some minutes to obtain an opinion in order to use one or more defined procedures). Also in this case the medical-surgical decision making is founded on two cornerstones of medicine: "scientific" knowledge (insight in problems and processes) that is primarily gained during medical research, and "empirical" knowledge (experience acquired during patient care) that has a phenomenological character [VA85]. Medical experience is less formally described than medical knowledge, but it appears to be the leading factor in treating patients. An expert system oriented towards the real need of the surgeon, appears, then, much more complex than systems developed in other medical areas. This higher complessity depends on the need to integrate "in real time" diagnostic and therapeutical decisional supports, sometimes multy-disciplinary.

2. CHARACTERISTICS OF EXCELLENT APPLICATIONS IN SURGICAL DOMAIN

According to Shortliffe [SH83] the most important design features in consultation systems are:

1) the ability to explain their diagnostic strategy and treatment decisions to physician users;
2) their portability and flexiblity, so that the medical doctor can access them at any time and any place;
3) possibility of displaying an understanding of their own medical knowledge;
4) possibility of improving the cost efficiency of tests and therapies;
5) possibility of learning automatically new information when interacting with medical experts;
6) possibility of displaying common sense.

No current consultation system meets all these criteria, but in surgery the first, the second and the fourth point should be emphasized. True expertise involves several different perspectives and approaches. A physician will use these different knowledge sources and their concomitant reasoning techniques as required by the particular circumstances with which he is faced. The molteplicity of views is not easily implemented in existing systems, principally due to the lack of scope and the limited representation of meta-knowledge [FI86]. The difficulties of evaluating expert systems are underlined in [FI86], in order to demonstrate that particularly in the medical domain their routine applications have not yet been developed to a great extent. Moreover the pedagogical importance of these systems is, at present, their principal value, even if it is not their primary purpose.

What are the expectations from an expert system in surgery ? Two different sceneries must be foreseen:

1) Its employment in a surgical department having one or more experts not always available.

   In this case the expert system will be useful for didactical purposes, eventually for integrating the informative system, and to be consulted when the human experts are absent.

2) Its employment in a surgical department with skilled surgeons which have no particular knowledge of the expert system domain. In this case a routine utilization could be predicted.

An expert system in surgery could be divided into three subsystems relating to these three phases:

1) Pre-operative phase;
2) intra-operative phase;
3) post-operative phase.

This subdivision is made necessary because the surgery is part of an integrated system of diagnosis and continous therapy.

In the <u>first phase</u> the decisional support for the surgeon must be performed for accomplishing more tasks :

1) <u>Necessity of surgical therapy.</u>

   This must be considered a minimal and essential goal, such to justify the system's use by surgeons, but also by other specialists (oncologists for example), to come to an advice on the opportunity of performing the surgery. An opinion should be given, even if not definitive and with a certain diagnosis. It is essentially the same as in a diagnostic expert system with the typical aims of performing a differential diagnosis, reducing diagnostic time and improving diagnosis reliability. It is limited to the surgical domain with data useful and to be verified during the intra-operative phase.

2) <u>Operative risks</u>

   Evaluation of one-month mortality and morbility probability relating to anaesthetic risk factors, range of possible surgical procedures, performance status, concurrent and occurrent diseases.

3) Temporal evaluation

Advice for emergency, urgency (surgery can be deferred for some hours) or elective surgery. This can modify the operative risk.

4) Social evaluation

Evaluation of the life expectancy and standard of post-operative living.

5) Medical-Legal evaluations

6) Pre-operative management

Before the second phase, the availability of the necessary resources (tools, drugs, medical staff) must be verified.

In the intra-operative phase two different aspect are evidenced.

In the first one (staging phase) the system modifies, if it is necessary, the first phase's informations in relation to the further intra-operative diagnostic informations. In the second one the system interacts with the surgeon as a decisional support for the surgical planning and eventually for other intra-operative therapy. Therefore, the intra-operative system continously follows the surgical procedures, considering, if it is necessary, the steps to take for an optimal performance by an interactive process.

Three sceneries can be foreseen:

1) All the pre-operative hypotheses formulated at the highest level of probability are intra-operatively confirmed.The surgical planning does not present particular difficulties for the surgeon, further investigations or intra-operative therapies are not needed. The intra-operative data, given by the system, will be used as input for the third phase.
2) There is a sufficiently big agreement with the pre-operative hypotheses, with or without of further intra-operative investigations as confirmation or modification of the diagnostic and therapeutic formulated hypotheses, with or without of therapies integrated to the surgery. The system continously interacts with the surgeon. That is the usual scenery.
3) There is a minimal confirmation of the pre-operative hypotheses. This can happen because of:
   a) unreliability of imaging and/or laboratory findings or wrong evaluation of clinical findings; one comes out of the expert system domain;
   b) insufficiency or unreliability of data in the same domain.

In the third phase or in the post-operative phase (from the exit out of the operating room to the hospital discharge) the expert system, after elaborating the informations needed for this phase, gives suggestions for the post-operative management and the follow-up.

In Italy a strategical project of the National Research Council called "Expert Systems in Medicine" is in progress. Our research is supported by this project and regards the project and the developing of an Surgical Pancreatic Expert System integrated system, called SPES (Surgical Pancreatic Expert System) to assist oncologists and surgeons in the pre-operative diagnostic procedure phase, in the intra-operative diagnostic procedure and surgical management phase, with regard to the pancreatic cancer problem, and in the post-operative phase (adjuvant therapies).

It consists of three integrated subsystems, regarding the different phases of the pancreatic cancer treatment:

SPES-1, for the *pre-operative* phase;

SPES-2 for the *intra-operative* phase;

SPES-3 for the *adjuvant therapies*.

The structure of the project is shown in Fig.1.

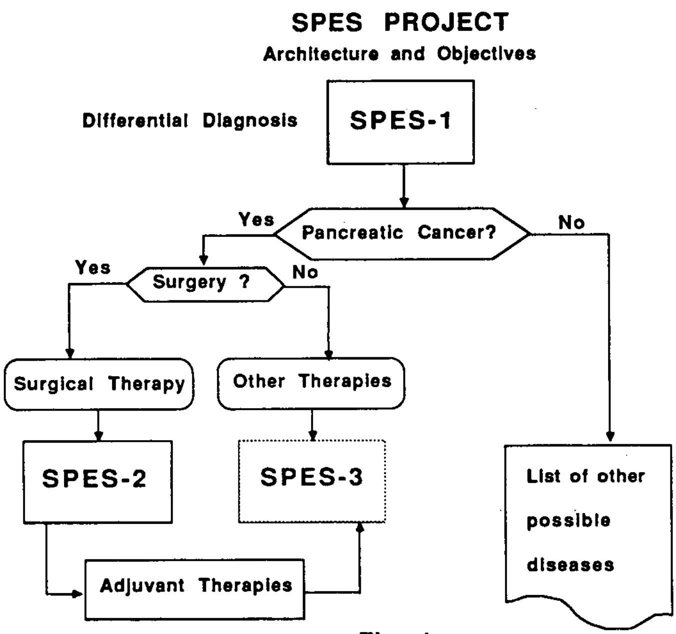

Fig. 1

In particular, the architecture of SPES-2 is shown in Fig.2.

3. DISCUSSION

Many expert systems could be fruitfully implemented for surgical applications, but at present

S P E S - 2

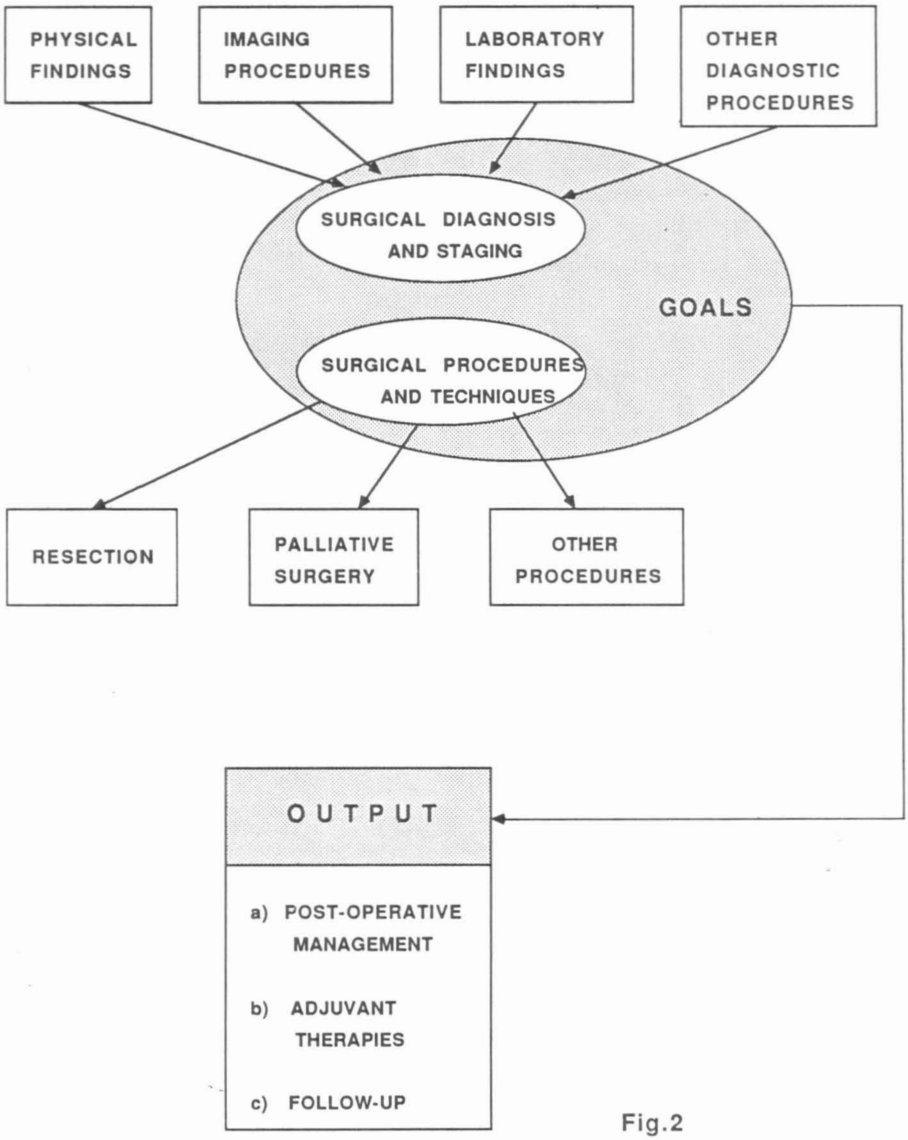
PHYSICAL FINDINGS
IMAGING PROCEDURES
LABORATORY FINDINGS
OTHER DIAGNOSTIC PROCEDURES
SURGICAL DIAGNOSIS AND STAGING
GOALS
SURGICAL PROCEDURES AND TECHNIQUES
RESECTION
PALLIATIVE SURGERY
OTHER PROCEDURES
OUTPUT
a) POST-OPERATIVE MANAGEMENT
b) ADJUVANT THERAPIES
c) FOLLOW-UP

Fig.2

there are no system known designed to be used in the operating room.

In the USSR Molokowa et al. [MO84] have implemented the first version of ***Consultant***, an expert system for diagnosis of acute abdominal surgical diseases. In this version 7 diseases and 32 observations are described. It realizes the following possibilities: the correct knowledge-base creation; input, acceptability, testing and interpretation of the patient data; decision-making in the most probable diagnostic hypotheses and generation of explanations with required level of detail.

An interesting expert system for a domain contigous to surgery is *Attending* [MI84], designed to criticize a physician's pre-operative anaesthetic plan management. It is currently used in a tutorial mode which allows the anaesthesiologists self-assesment, with potential social and medical-legal advantage. The system would be interesting if developed even for the intra-operative phase. It receives as input informations common for surgical needs:

1) a list of patient medical problems;
2) a planned surgical procedure;
3) an anaesthetic plan for pre-operative and intra-operative phase.

Cadiag-2 [AD86] is also very interesting, a data-drive fuzzy medical expert system connected to the medical information system of the teaching hospital of the Vienna University Medical School (WAMIS). Through this interaction Cadiag-2 is able to access patient data and laboratory test results stored in the data-base of WAMIS. Cadiag-2 operates in two subsequent phases:

1) as automatic screening procedure for detecting pathological states in the patient, for generating diagnostic hypotheses and for proposing further useful examinations;
2) as on-line consultation system for the clinician, to assist him in clarifying the patient's disorders completely and in great detail.

Its application areas are four: rheumatic, pancreatic, biliary and colonic diseases. The system optimizes and clarifies the cost-benefit ratio. Its great advantage is the integration in an hospital information system based upon "problem-oriented medical record" (POMR) approach, as suggested by Szolowits [SZ85] and the possibility of integration in a data base for other applications (clinical trials etc.).

Breatscan [GA86] and *Oncocin* [FA85] are two examples of expert systems with possible surgical integration.

Difficulties and expectations of medical expert systems were well detailed by Kulikowski [KU85]. The improvement of the editing features will allow to tailor and to update the medical knowledge-base to the users needs. The vocal interface and biomedical instrumentations or imaging data bank integration will ease the utilization in the operating room by the surgeon.

Kohane [KO86], Tsuji and Shortliffe [TS86], Lane et al. [LA86] put down the emphasis on the use of professional workstations with high density graphic interfaces

4. CONCLUSION

In this paper, after a brief rewiew on the main difficulties to realize expert systems in the medical domain, have been pointed out the further difficulties in the case of surgery.

Then we have foreseen two possible scenaries regarding the employment of a expert system in a surgical department, giving also three temporal moments regarding the operative phases; for the first phase six tasks have been evaluated, for the second phase two different aspect have been evidenced. Moreover, always in this second phase, other three possible scenaries have been hypothesized.

At last, a brief sign about a project in progress regarding a system formed by three expert systems for the differential diagnosis and the pre and intra-operative therapy of the pancreatic cancer, as soon as the post-operative phase has been made and a brief discussion regarding the more recent papers in this area are made too.

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