Hypertextual Navigation Operationalizing Generic Clinical Practice Guidelines for Patient-Specific Therapeutic Decisions

J. Bouaud†, Ph.D., B. Séroussi†, M.D., Ph.D., E.-C. Antoine‡, M.D., M. Gozy‡, M.D., D. Khayat‡, M.D., J.-F. Boisvieux‡, M.D., Ph.D.

† Service d’Informatique Médicale, AP–HP & Département de Biomathématiques, Université Paris 6, Paris, France
‡ Service d’Oncologie Médicale, Groupe Hospitalier Pitié-Salpêtrière, Paris, France

Despite the proliferation of implemented clinical practice guidelines, there is still little evidence of physicians compliance to formal standards. The ONCODOC project proposes a framework for elaborating generic decision support guidelines in a document-based paradigm with a knowledge-based approach. It has been first applied to assist clinicians in the treatment of breast cancer patients. Therapeutic expertise has been encoded as a decision tree. The decision process is driven by the clinician who interactively browses a hypertext version of the decision tree. During the navigation, he incrementally assigns values to decision parameters on the basis of his free interpretation of his patient’s condition and thus builds a clinical context leading to patient-specific therapeutic recommendations. These guidelines are distributed on a hospital intranet and are evaluated at the point of care in an oncology department.

INTRODUCTION

The rapid growth of internet-based technologies have triggered an information revolution. Despite its obvious benefits, the increase in the availability of medical information may result in a cognitive overflow syndrome. There is too much information that may be high quality medical knowledge, but also contradictory, incomplete, misleading, or inaccurate resources. Beyond considerations of cost-effectiveness, clinical practice guidelines (CPGs) can thus improve quality of care by providing medical practitioners with valuable decision support, serving as template for correct, up-to-date, best practice. In the special case of medical oncology, the rapidly evolving domain knowledge and the highly complex treatments used result in significant practice variation partly due to the lack of a strong consensus on best therapies. Clinicians themselves admit that not all patients benefit from modern best treatments.

Developed in collaboration with the “Service d’Oncologie Médicale Pitié-Salpêtrière” (SOMPS), ONCODOC is a computer-based system designed to disseminate on the hospital intranet the SOMPS therapeutic recommendations for breast cancer, and thus enhance the accrual of patients in the best care plan. Taking advantage of hypertext technologies, we have developed, implemented and evaluated the corresponding CPGs to assist care providers in making more informed treatment decisions. Elaborated in a document-based paradigm with a knowledge-based approach, ONCODOC relies on generic CPGs. However, the decision process formalization provides patient-specific therapeutic recommendations on the basis of a physician-controlled clinical context which is interactively built.

ISSUES IN DEVELOPING AND IMPLEMENTING CPGS

Most CPGs are developed by governmental or professional organizations. Then, to enhance their utilization, numerous attempts have been made to design knowledge representation systems able to implement CPGs in clinical practice. These are strictly encoded guidelines using specific programming languages, relational database models, elementary state-transition tables, situation-action rules, reflex logic modules, decision-tables, or narrative guidelines edited as textual documents with hypertextual browsing facilities allowing to navigate across the sections.

However, despite the proliferation of implemented CPGs, there is still little evidence of physicians compliance to guideline recommendations. Additional developments such as computer-generated reminders or individualized feedback to clinicians have been shown to enhance guidelines utilization but still, median compliance remains very low. Among the barriers to the use of CPGs, psychologic resistance comes from physicians’ concerns about clinical freedom, doctor autonomy and importance of ownership in guideline implementation. Another reason, more practical, is that CPGs frequently lack specificity. A deeper reason comes from the difficulty to assign individual situations into formal categorizations of models that often rely on incomplete and imprecise medical knowledge (the “decidability” mentioned by Liu).
ONCODOC DESIGN CONCEPTS FOR CPGS

In our application, as advised by Tierney et al.\textsuperscript{10} and Berger and Rosner\textsuperscript{9}, CPGs have been developed by two domain experts from the SOMPS after extensive study and review of medical and scientific literature. The methodology used for the implementation addresses problems usually strongly critized by clinicians. ONCODOC provides a context-based patient-centered operationalization of generic guidelines at the point of care. There is no automatic exploitation of patient data from the electronic medical record, but a free physician-controlled interpretation of patient clinical parameters.

Design principles
The goal of ONCODOC’s CPGs is to provide clinicians with the alternative treatment plans suited to a patient’s condition. The expertise that CPGs account for relies on a vast amount of knowledge. But, the semantics of the notions on which medical knowledge relies is not always strictly formally defined, \textit{e.g.} patient’s state, bad cardiac function. Natural language is often the only access to such notions. As a consequence, their interpretation may be context-dependant. Capturing medical knowledge from its linguistic traces into a formal model is the aim of knowledge acquisition. The challenge of knowledge representation is that the formal semantics of computer transformations conforms with human interpretation. In some situations, the formal categorizations do not always cater for their intended meaning. The known result is the difficulty of encoding reality and the possible mismatches between a clinician’s and a system’s inferences.

The methodology we adopted in ONCODOC’s design presents both formal and informal aspects, and is halfway between knowledge representation and literary writing. The clinician is proposed a structured encoded knowledge base (KB), but has the freedom of interpreting this knowledge for a given patient according to his decision task. Therapeutic knowledge is encoded in a flowchart to form a decision tree (in a broad sense) which constitutes the formal skeleton of the KB. Decision tree’s properties ensure that the CPGs are complete, and that its use is unique and non ambiguous (see Shiffman and Greenes’ work\textsuperscript{6}). However, this KB is not supposed to be run by a program (expert system shell, classifier, etc.), but it is aimed at being browsed under the form of a hypertext. While traversing the hypertext, the user operationalizes step by step the guideline knowledge by controlling every inferences through his own interpretation.

The “Decision Tree”
The decision tree is the formal skeleton of the guidelines. Each node refers to a decision parameter and each of its leaving arcs corresponds to one of the parameter’s value.

Using the decision tree is done by traversing the tree from the root to a leaf trough an ordered set of elementary decisions consisting in the assignment of one value to each decision parameter. At each leaf, a list of treatment plans is proposed which are accurate in the clinical context summarized by the parameter assignments. Figure 1 shows an excerpt of a decision tree.

![Decision Tree Diagram](image-url)

Figure 1: A part of a decision tree.

Additional constraints are added to control the use of such a tree. These constraints are similar to those used for decision-tables.\textsuperscript{5} When used at decision node, parameter’s values must constitute a partition of the parameter’s domain. Such values are therefore mutually exclusive and exhaustive. Mutual exclusivity guarantees that, given a particular parameter set assignment, a unique path to a leaf is valid; exhaustivity, that the decision tree is complete. The first property ensures there is no possible ambiguity using the decision tree; the second that whatever the parameter, there will be always an appropriate value to be assigned.

Decision Parameters
The first task of knowledge acquisition is to identify the parameters that drive the decision process. But as pointed out previously, the underlying notions are not necessarily formal. All parameters are not strictly unambiguous coded data. Many call for the physician’s interpretation in the context of the patient’s state. The only expression of such notions is in natural language using medical jargon. To eliminate the pitfall of wrong inter-
pretations in the decision tree, their intended meaning must conform to the formal framework of the decision tree. To control this, terminological work is necessary to clarify (normalize) such notions, and first ensure they have a unique meaning. Clinical parameters have been chosen among standard, well quantified classifications, e.g. TNM-UICC for cancer staging. When a parameter’s label is ambiguous, an explicit definition is provided to control the correct interpretation, with possible references to medical literature. As for the values, they also must be exclusive and cover the whole parameter domain. To make sure that they do not overlap, we impose to use one point of view, to consider a parameter in the perspective of a single semantic axis. For instance, the point of view of existence yields present and absent; the severity one, high and low. Such points of view, e.g. for metastatic extension, should not be mixed because of the inherent ambiguities that are generated.

As a result, the set of decision parameters constitutes a reference thesaurus for the decision task in the considered medical domain. Each parameter is identified by its label and recorded along with its definition and optional comments, its values and their definition. For instance, cardiac function is evaluated by either fractional shortening (echocardiography) or ejection fraction (myocardial scintigram) and has two modalities: good cardiac function when fractional shortening > 35% or ejection fraction > 50%, bad cardiac function when fractional shortening ≤ 35% or ejection fraction ≤ 50%.

On the informal side previously described, a clinician could provide a slightly different interpretation and consider apparently contradictory assignment for borderline values. e.g. a bad cardiac function for a fractional shortening of 36% in an old patient with prior uncontrolled AHT and a cumulative dose of anthracyclines close to the maximal one.

Treatment Plans
In this kind of application, a treatment plan is reduced to a sequence of therapeutic units (chemotherapy, surgery, hormonotherapy, radiotherapy, follow-up). Therapeutic units are semi-structured documents which basically describe the administration scheme and management plan. Therapeutic units for clinical trials are more sophisticated. They replicate the usual synopsis accompanying the trial specification.

SGML Encoding
The CPG base is encoded as a document using SGML whose interest lies in its ability to mix structured data and free text, and to handle hypertext links. A Document Type Definition (DTD) has been designed to account for the various components of our decision model: decision tree, parameters, and therapeutic units. CPGs are then a document instance that conforms to this DTD.

HYPERTEXTUAL CONSULTATION OF CPGS

Implementation
CPGs are implemented in a web server architecture and can be consulted through any connected web browser, e.g. in the physician office. A software suite has been developed to handle SGML transformations on the input guidelines. Each component is extracted from the SGML resource and presented as uniform HTML pages using style sheets. The decision tree is transformed in a straightforward manner into a hypertext which structure replicates the decision tree. To each node in the tree corresponds a HTML page, with links to its subnodes.

Navigating the CPGs in a patient specific context
To benefit from the CPG recommendations, a clinician has to browse the “CPG web site”. When a particular CPG is selected, the user is positioned at the root node of the decision tree. Whatever the node, the corresponding parameter label is displayed with its definition and the list of its values with their definition. Each value is a hyperlink that can be selected to access to the corresponding subtree. To avoid being lost during navigation, a recapitulation of previous parameter assignments is also displayed. Figure 2 shows a screenshot at a decision node level.

[Figure 2: Instanciating the patient-specific context.]

When consulting a CPG for a given patient, the clinician dynamically answers the question asked by clicking on the appropriate parameter value. This interactively built hypertextual navigation isolates a specific path in the decision tree that best matches the patient’s case. When reaching a leaf, the corresponding page presents the recapitulative clinical context and the list of appropriate therapeutic recommendations (Fig. 3).

At the leaf level, each of these recommendations is a link to a “prescription page” (Fig. 4) which gives more details about the treatment plan by including the administration scheme for each therapeutic unit of the plan.
Such a page corresponds to the final decision and could be included in the patient record. Complete documentation for each therapeutic unit can be accessed either from a prescription page or, independently of any patient context, from a table of contents.

**Figure 3:** A list of appropriate therapeutic recommendations for a given clinical context.

Because the decision tree is explicit and available as a hypertext–as an electronic resource–arbitrary navigations are allowed. As a result, a clinician may explore alternative paths to recommendations when he cannot decide on a parameter’s value, for instance if data is missing or because of borderline values. He can therefore anticipate the therapeutic implications of his local choice, understand the “logic” of the CPGs and make an informed decision. The CPGs may also be browsed for educational purpose. While traversing the hypertext flowchart, physician entry of data is implicitly done through the link selection corresponding to appropriate parameter assignments. However, there is no classical structured data entry: even if the tree traversals are logged, no patient data is explicitly captured.

**RESULTS**

**ONCODOC CPGs for Breast Cancer**

In the current version, ONCODOC uses 38 clinical parameters organized in a decision tree made of 1107 nodes which cover the CPGs implementation of therapeutic decisions for non metastatic breast cancer (early and locally advanced tumors), first-line, and second-line or more metastatic breast cancer. The 563 different clinical contexts (leaves) corresponding to the set of all the paths obtained by the exhaustive expansion of the decision tree lead to treatment recommendations among either routine oncology protocols (321) or clinical trials (242). Recommendations are reached at depth levels ranging from 1 to 13, with a mean value of 7.

**Off-line validation**

We proceeded to a multi-steps qualitative evaluation, each one led to a substantial refinement of the decision tree. A first evaluation has been carried out on a randomized sample of 22 real patient records, based on the comparison of the system recommendations when a clinician (different from the guidelines developers and different from the actual patient physician) simulated the case, the guidelines developers conclusion, and the treatment actually received by the patient. The system demonstrated a significant performance with 95% of good answers compared to the expert.

**Pilot-Site Experiment**

The last step, currently being carried out, consists of a real-size experiment in a clinical setting at the SOMPS. It involves an intranet web server, 6 client workstations located in medical consultation offices, and concerns the 8 department residents and attendings. Table 1 summarizes the results obtained 2.5 months after the starting of the experiment expected to last 4 months.

<table>
<thead>
<tr>
<th>Reason</th>
<th>#</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breast cancer therapeutic decision</td>
<td>77</td>
<td>8.2</td>
</tr>
<tr>
<td>Breast cancer monitoring</td>
<td>381</td>
<td>40.7</td>
</tr>
<tr>
<td>Other</td>
<td>478</td>
<td>51.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>936</td>
<td>100.0</td>
</tr>
</tbody>
</table>

In the experiment protocol, the system is consulted for
every breast cancer therapeutic decisions (i.e. currently 77). For each patient for which a prescription is issued, an “experimentation form” was filled by the physician where he evaluates the CPG recommendations and indicates his own therapeutic decision. Reviewed recommendatios included 195 therapeutic plans. Evaluation of the different cognitive tasks distinguished physician adherence, defined as the agreement of the physician with the recommendations, from physician compliance, which means the physician actually followed the recommendations. Clinicians agreed with 187 of the recommendations so that adherence has been measured at 96%. As for compliance, clinicians followed one of the CPG recommendations in 65% of cases.

CONCLUSION

Asking clinicians to provide information to drive CPGs is generally avoided. We adopted a radically different point of view in order to involve the physician in an active medical reasoning process although following CPGs and preserve thus his autonomy. As opposed to “black box” systems usual approaches, when using ONCODOC, the clinician has the opportunity to control the knowledge operationalization by his free interpretation of the information provided, and can participate to the therapeutic decision by building the patient-specific clinical context and by choosing among the proposed recommendations. The use of a disjunctive decision tree to represent domain knowledge as well as explicit and quantified definitions allows to eliminate the denounced ambiguities responsible of physicians low compliance to CPGs. However, any activity generated by guidelines should not take time to the physician. That is why we formalized the decision tree to allow data input as simple mouse clicks and avoid any type-writing. From the first results of the current experiment, the average consultation session duration is 90 seconds (std. dev. 88) which is quite acceptable. Another real-size experimentation is planned to test the decision tree robustness and the therapeutic breast cancer recommendations validity outside the SOMPS.

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References


