Mapping care processes within a hospital: from theory to a web-based proposal merging enterprise modelling and ISO normative principles

Pascal Staccinia, Michel Joubertb, Jean-François Quarantac, Marius Fieschib

a Département d’Information et d’Informatique Médicale, Centre Hospitalier Universitaire de Nice, Hôpital Cimiez, 4 Avenue Reine Victoria, BP 1179, 06003 Nice Cedex 1, France
b LERTIM, Faculté de Médecine, Université de la Méditerranée, Marseille, France
c Coordination des Vigilances Sanitaires et de la Gestion des Risques, Centre Hospitalier Universitaire de Nice, France

Received 2 November 2003; received in revised form 12 July 2004; accepted 14 July 2004

KEYWORDS
System analysis, methods; Hospital information systems; Process assessment; Health care quality; Access; Evaluation

Summary Today, the economic and regulatory environment, involving activity-based and prospective payment systems, healthcare quality and risk analysis, traceability of the acts performed and evaluation of care practices, accounts for the current interest in clinical and hospital information systems. The structured gathering of information relative to users’ needs and system requirements is fundamental when installing such systems. This stage takes time and is generally misconstrued by caregivers and is of limited efficacy to analysts. We used a modelling technique designed for manufacturing processes (IDEFO/SADT). We enhanced the basic model of an activity with descriptors extracted from the Ishikawa cause-and-effect diagram (methods, men, materials, machines, and environment). We proposed an object data model of a process and its components, and programmed a web-based tool in an object-oriented environment. This tool makes it possible to extract the data dictionary of a given process from the description of its elements and to locate documents (procedures, recommendations, instructions) according to each activity or role. Aimed at structuring needs and storing information provided by directly involved teams regarding the workings of an institution (or at least part of it), the process-mapping approach has an important contribution to make in the analysis of clinical information systems.

© 2004 Elsevier Ireland Ltd. All rights reserved.

1. Introduction

Continuous quality management programmes and process-oriented reengineering of care activities
are currently held to be relevant and powerful approaches for managing and upgrading healthcare organisations. Growing attention is being given to the use of such a methodology for user requirements elicitation. In the analysis phase of hospital information systems, the usefulness of care-process models has been investigated to evaluate the conceptual applicability and practical understandability by clinical staff and members of user teams. They can be applied to the design of patient-centred information systems [1–4] to guide and emphasise requirements analysis. The following key points are aimed at clarifying this application.

First of all, the announcement of activity-based evaluation and prospective payment systems, coupled with the increase in social expectation as regards care safety, has led hospital managers and clinical staff to identify, define, implement, evaluate and refine current or new co-ordinated care pathways. Currently, in France, all care establishments, private as well as public, are involved in the mandatory procedure of accreditation conducted by the French agency for the evaluation and accreditation of healthcare (ANAES) [5]. To assist the implementation of this nation-wide program, a framework has been proposed that suggests care-process analysis as an effective means of federating both objectives and rules of practice and management. According to this programme (the second release will be available early 2004), the factors and the levels of quality and security of care, as well as the co-ordination of care activities and data exchanges between the various parties involved, are required to be traced, measured and analysed.

The second key point relates to the methods for designing and implementing hospital information systems. According to the results of previous experiments on designing and implementing process-oriented information systems, it seems that:

- Process-based modelling could provide a rational means of organising information: (1) that is processed to perform care activities; (2) that can be requested by a concerned party, conveyed to him/her according to the work context, or simply be available [6].
- The use of workflow technology is deemed to be valuable for the clinical personnel since the latter actively support the processes in a hospital and reduce administrative overheads: (1) by proposing tasks "just in time" when all the necessary information is available to perform them; (2) by respecting deadlines and other time constraints [7].
- Information systems must fit the dynamics of clinical pathways in terms of actions, roles and data exchange. This can be achieved through the medium of process models [8,9].

The third key point has been pointed out by several analyses focusing on the failure of information system projects in healthcare [10,11]. One of the reasons for this is the difficulty, or the impossibility, of linking system requirements and user needs, while taking into account the organisational context in which system and users will interact. Healthcare professionals experience difficulties combining individual and collective needs for meeting gathering strategies and useful content while designing and implementing a clinical information system [10]. It is obvious that the issue of information technology is designed to support professional activity as a whole. However, as regards the elicitation of users’ requirements, clinicians and nurses working at the point of care have to satisfy top-down organisational needs for data handling and activity monitoring, and would appreciate flexible, relevant, collaborative and multidisciplinary decision-support tools to help them improve outcomes [12]. The importance of design driven by a detailed understanding of patient care processes has been highlighted, as opposed to addressing individual or unrelated tasks [13]. Clinical information systems must satisfy two kinds of clients. They have to provide end-users with full event traceability, real-time data entry and retrieval features, context-based decision supply and measurement of activity performance. They must also reassure patients that everything is being done in compliance with practice and organisational rules. As the tendency of clinical practice is to move to a shared care environment, knowledge of clinical information systems should include definitions of all aspects of the clinical processes, as well as the functions and responsibilities of the people involved in them [11].

Care safety assessment, activity-based analysis, workflow technology and knowledge of care pathways are related to the methodological basics of continuous quality improvement. Changes in the ISO 9000 standards promote enterprise process analysis [14] and the use of business process redesigning to describe major processes and a cross-functional view of enterprises [15]. Generally speaking, process mapping may be used in a variety of performance improvement applications (some are listed in Table 1). This technique involves a set of maps that can show supplier–customer relationships, functions, steps and tasks. Process models can be used to drive the organisation’s processes through workflow applications used to manage the co-ordination and co-operation of agents.
Table 1 Usefulness of process mapping applied to clinical pathways management

<table>
<thead>
<tr>
<th>Applications of process mapping</th>
<th>Typical analysis questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waiting-time reduction</td>
<td>- Which steps are most time-consuming? Why?</td>
</tr>
<tr>
<td></td>
<td>- Which steps add value and which do not?</td>
</tr>
<tr>
<td></td>
<td>- Which steps are redundant, bottlenecks, or add complexity?</td>
</tr>
<tr>
<td></td>
<td>- Which steps result in delays, storage, or unnecessary movement?</td>
</tr>
<tr>
<td>Quality improvement</td>
<td>- Is variation due to common or special causes?</td>
</tr>
<tr>
<td>reduction, safety requirements)</td>
<td>- What are the causes of the defects?</td>
</tr>
<tr>
<td></td>
<td>- Which variables need to be managed to have the desired effect on the relevant quality or safety characteristics?</td>
</tr>
<tr>
<td></td>
<td>- How should the process be changed to reduce or eliminate variation?</td>
</tr>
<tr>
<td></td>
<td>- Which actions can be performed to prevent new adverse or unexpected events?</td>
</tr>
<tr>
<td>Patient satisfaction measurement</td>
<td>- How do process performance data compare to patient expectations and perceptions data?</td>
</tr>
<tr>
<td>Cost reduction</td>
<td>- What does it cost to operate the process?</td>
</tr>
<tr>
<td></td>
<td>- Which steps cost most? Why?</td>
</tr>
<tr>
<td></td>
<td>- Which steps add value and which do not?</td>
</tr>
<tr>
<td></td>
<td>- What are the causes of cost in the process?</td>
</tr>
</tbody>
</table>

performing tasks. They can also be used as a tool to capture existing or optimal work practices through multiple and interrelated activities to promote understanding of complex organisational behaviour.

2. Objectives

Process analysis techniques comprise [16]: (1) observation and interviewing; (2) modeling; (3) facilitated group decision-making; (4) performance analysis. Meaningful tools aimed at creating a link between clinicians and system analysts have to be developed to assist clinicians describe their practice and care processes, and to help analysts to extract models from clinical maps in order to identify data sets, formalise dataflows, define mandatory data and understand the context of user needs. The solution is to define a process model that can be easily understood by a clinician and used to outline a clinical process in terms of roles, activities, documentation, objectives and indicators. This same model must provide the analyst with technical views in terms of data items, forms, and document sources. Process analysis requires activity and data modelling through a top-down approach. Thus, it is necessary to define a process definition framework in order to describe the relationships between components at each level of the structure, and to be able to share documentation within a single process or a family of processes. The purpose of this paper is to present and discuss the choice and the enhancement of a basic process model, and to show how the process-mapping tool has been implemented.

3. Method

Davenport defines a process as “a specific ordering of work activities across time and place, with a beginning, an end, and clearly identified inputs and outputs: a structure of action” [17]. Process analysis techniques are aimed to facilitate communication via easy-to-understand language, to provide a means of defining boundaries, to encourage the analysts to think and document in terms of the problem as opposed to the solution and to make it easy for them to modify the knowledge structure. In order to adapt modelling to various contexts and various levels of granularity, an atomic component of a process has to be defined. This indivisible element is intended to express the notion of any form of activity or task. The basis of our process model is the element of the IDEF0 (Integrated DEfinition for Function modeling)/SADT (Structured Analysis and Design Technique) modelling technique. It is a structured methodology for functional process analysis [18,19]. The IDEF0/SADT activity modelling is based on a unit diagram, called the ICOM box that shows, for a task or set of tasks:

- The inputs (I): Information or material used to produce the output of an activity.
The controls (C): information or material that constrains an activity; controls regulate the transformation of inputs into outputs.

The outputs (O): information or material produced by or resulting from the activity.

The mechanisms (M): usually people, machines, or existing systems that perform or provide energy to the activity.

An example of the use of such a diagram applied to transfusion medicine is shown in Fig. 1. We refined the model of an activity. We changed "controls" and "mechanisms" and expressed them according to five categories (the "5M" checklist) inspired by Ishikawa diagrams [20]: men, machines, materials, methods, and environment.

We also added concepts from the ISO 9000:2000 specifications to describe the goal of an activity in terms of objectives and measurements. We detailed the activity with a more accurate grammar extracted from the conceptual domain of Enterprise Ontology [21]. After this refinement step, we designed the data model of a process and its components, using the results of a previous study [22]. We structured the architecture and the user interface of the process analysis tool. We implemented it as a web-based application running under an open-source content management system called Zope (ZObjects Publishing Environment) [23], in connection with the PostgreSQL relational database.

4. Results

We kept the top-down methodology of the IDEF0/SADT technique to break-down a process into sub-processes and tasks or activities, and the break-down of sub-processes into elementary tasks or activities. We applied the following rule: a process is composed of sub-processes and elementary tasks or activities. However, sub-processes are composed only of tasks or activities. A task or activity is defined as the smallest indivisible functional element of a process. Each category of the cause-and-effect diagram has been detailed (Fig. 2). For the category "method" we defined: (1) the type of content (rule, manual, guideline, procedure, instruction, record, planning); (2) the format of the support (folder, form, sheet, file); (3) and the source of content (legal, local, scientific society, agency). For the category "men", we adopted the semantics of Enterprise Ontology to define functions, skills needed and levels of responsibility. The representation of strategy in terms of demands, objectives, criteria, and threshold has been included. The notion of measurement has also been established (conformity, adverse event, delay). For each objective, the factors, whether critical or successful, can be defined. Factors may have their own objective and measurement. We also determined the type of activity (choose, decide, sign, check, fill, report, monitor, read, send, receive, acknowledge).

Fig. 1 Break-down of the prescription for a blood product, the first sub-process of the global transfusion process, showing for each task the inputs (I), the controls (C), the outputs (O), the mechanisms and roles (M, R).
transmit, call, operate, examine). Items and sets have been created to populate the interface of a task. Table 2 shows the list of terms used to enrich the description of components in our process model, as a result of merging the three approaches: the IDEF0/SADT activity modelling technique, the ISO 9000:2000 standard and the proposal of the Enterprise Ontology project.

We implemented the data model of the activity, the hierarchical composition of a process and the grammar to identify and describe process components in an open-source programming environment. Zope is a content management framework for building web applications. It comes with a built-in web server, a web-based interface, an object-oriented database, a relational integration and a scripting language support (DTML: Document Template Markup Language). The architecture of the process analysis application consists of three parts (Fig. 3): (1) the libraries of elementary components (item, set, role, task); (2) the library of the combinations of elementary elements into sets, tasks, sub-processes and processes; (3) a set of procedures that process information according to user interaction, and display information. A specific object class stores all the parameters to configure the user interface and the values in order to describe the type and content of components. For each library, a pack of management functions has been scripted in order to access each component, edit its properties, delete it under user control, add or remove sub-components, browse the entire library and list parents of each component (Fig. 4). Libraries of objects are controlled by the object-oriented database. Associations between objects are stored in a relational database. We did not use Zope built-in functions to manage sub-objects/sub-components. We wanted direct access to components of an activity/task. The smallest object type a user is able to create is the “item object”. This is a component that can be aggregated with others to constitute a set of items. Single items and/or sets of items can be associated with an activity. An item can be either a data element, a document, a file, or a criterion. Subtypes of an item are related to its type: Boolean, float, integer, long, string, text for a data element item; manual, guideline, procedure, instruction, record, planning for a document (Fig. 5). Items can be aggregated into sets of items: data elements can be aggregated into data sets, files into folders, and documents and criteria into indicators. As a basic example of a combination of items, when dealing with the task named “identification of a patient”, the identity label is a data set object composed of data elements such as “(name), (forename), (date of birth)”, and so on. This data set object can be linked to several

<table>
<thead>
<tr>
<th>Component</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identity</td>
<td>Item, set, task, role, sub-process, process</td>
</tr>
<tr>
<td>Item</td>
<td>Title, description, creation date, modification date, author</td>
</tr>
<tr>
<td></td>
<td>Type [data element; document, file, criterion], subtype [Boolean, float, integer, long, string, text, rule, manual, guideline, procedure, instruction, record, planning], default value, URL, source [legal, local, society, agency]</td>
</tr>
<tr>
<td>Set</td>
<td>Type [data set, folder, form, indicator], subtype [conformity, adversary event, delay]</td>
</tr>
<tr>
<td>Task</td>
<td>Purpose, hold purpose, intended purpose, strategic purpose, requirement, objective, help achieve, criterion, measure, threshold, influence factor, critical influence factor, non-critical influence factor, critical success factor, risk</td>
</tr>
<tr>
<td>Strategy</td>
<td>Item, set, task, role, sub-process, process</td>
</tr>
</tbody>
</table>
Fig. 3 Architecture of the web-based tool combining object-oriented database, user interface, and relational database.

Fig. 4 User interface to navigate through the objects libraries and the steps of processes and to describe a task: (1) tabs to access the libraries of components (items, sets, roles, tasks, sub-processes and processes); (2) hierarchical tree-view of the steps of a process; (3) set of object management functions (edit, delete, etc.); (4) area of the description of a task and its reviewed SADT attributes (input, output, methods, conditions, roles, etc.).
Mapping care processes within a hospital

Fig. 5 Browsing of the items library. In the column "Type" are listed the values such as "data" or "document" and, respectively, in the column "SubType", the types of data elements (string, date/time, etc.) or the types of document (legal text, guideline, procedure, etc.).

activities which deal with it. The way we built the process-building tool as a collection of independent libraries of objects, allows us to filter the retrieval of the objects in each library. Therefore, predefined queries have been written to generate: (1) the data dictionary of one or more selected processes, listing all the data elements and their origin as defined when describing the tasks (Fig. 6); (2) the list of all the documents that have been gathered to help all the people involved in performing their tasks, and that have been associated to one or more tasks in the process (Fig. 7). Because a data element is a type of item, the item library can be filtered to extract several data dictionaries. For each data element, the relational database can be parsed to retrieve its "parents" and so on. Hence, a user or an analyst can be provided with a data dictionary either for a specific process, or for a specific activity, or for each role in an activity, and so on. The same approach can be applied to the "document" type of item in order to create a dictionary of guidelines or procedures for the same kind of activities, or for specific roles.

5. Discussion

There has been some debate regarding the usefulness of process models in an analysis phase of the design of hospital information systems. The
important thing to remember is that maps are means not ends. Process models can help users to find their way through the process. They can be used to interview users, managers and other stakeholders. The model is used to reveal the process, the roots of problems, and possible trouble-shooting methods. Maps show how work currently gets done in an organisation. They represent a snapshot in time that shows the specific combination of functions, steps, inputs and outputs that the organisation uses to provide value to its customers. A better understanding of an organisation and the measurement of its performance depend on the understanding of all its activities. Applied to hospitals, analysis of the clinical processes which the maps represent can help care-givers and managers increase patient satisfaction and safety. This is achieved by identifying actions aimed at reducing waiting times, decreasing adverse events and cutting costs and non-value-added steps in order to improve resources allocation and establish customer-driven process performance measures (safety and efficacy of care). A web-based tool that merges several enterprise modelling techniques can usefully allow clinicians and analysts better understand each other. It empowers clinical staff to structure and share useful documentation, and system analysts to build technical maps and define relevant data dictionaries. We formalised cross-functional processes such as blood transfusion and organs transplantation processes (a public test platform is available at http://zope.unice.fr:8080/Process). Clinicians and analysts are now able to describe and understand care processes while maintaining technical and clinical relevance. This technique provides them with an overview of processes, subprocesses and tasks, and makes available a convenient method for arranging components and assigning roles. The different data dictionaries that can be generated from this process knowledge database can be of use in dealing with data quality [24]. This database can also provide a starting point for the construction of a documentary system based on all types of documents described and related to specific tasks and roles. User profiles for retrieving or pushing documents when needed can be deduced from activity and process analysis. Although the model and its implementation comprise a number of weaknesses, especially when one is trying to build parallel sequences of tasks, the resulting collection of processes and components (available under a web-based application) provides the first
documentary system to structure and diffuse, throughout the hospital, knowledge related to all care activities. We are seeking to extend the indexation of all objects with the basic Dublin Core set of attributes [25], while using other multiple classifications. Part of this work will be based on a Zope meta-product called Plone, which supplies workflow, indexing and refined content management functionalities [26]. In this way a care process could be indexed according to the ISO 9000 table of contents, and/or to the chapters and references of the accreditation manual, and/or to the MeSH terms classification (a specific scheme has been proposed to use controlled vocabularies to describe the subject or content of a resource according to the Dublin Core standard [27]). This approach would provide analysts with cross-reference retrieval capabilities in order to create several selections of processes, sub-processes and activities according to one or another normative, work- or knowledge-based context. These future indexing capabilities can be considered as the first step to handling the complexity of a multiple care processes environment of a kind found in hospitals. As a basic feature addressing these difficulties, the current tool already allows the sharing of objects the ones with the others: for example, the patient identification activity can form part of two different processes, or be repeated within the same one. Thanks to their extensive indexing features, all processes would have a descriptive sheet which could be inherited by all associated sub-components and could be used to build transversal queries merging, e.g. MeSH content markers, specific type of activity and specific role.

In conclusion, this work addresses some key-factors for developing a successful care process analysis approach [9,28]. Whatever the level of modeling ambition could be (aiming at solving a problem, organizing complex decision-making, improving a technique used up to now, or simply having an educational purpose), a formal description of a process model is necessary. The model has to be simple, transparent and understandable as possible. It has not to be considered too theoretical by health care professionals in order to enhance their collaborative participation in the development process. The way the web-based application has been built with independent libraries of objects, allows considering different levels of aggregation needs, while reusing already defined components. Using enterprise modeling and ISO normative principles when describing an activity, health care professionals can relate it to organization objectives and model the integration between context, people, applications, and systems.

References
