Workflow Analysis and Evidence-Based Medicine: Towards Integration of Knowledge-Based Functions in Hospital Information Systems

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The large extent and complexity of scientific evidence described in the concept of evidence-based medicine often overwhelms clinicians who want to apply best external evidence. Hospital Information Systems usually do not provide knowledge-based functions to support context-sensitive linking to external information sources. Knowledge-based components need specific data, which must be entered manually and should be well adapted to clinical environment to be accepted by clinicians. This paper describes a workflow-based approach to understand and visualize clinical reality as a preliminary to designing software applications, and possible starting points for further software development.

INTRODUCTION

Successful clinical decisions are very complex. In making them we draw on information from many sources: primary patient data, clinical and personal knowledge and experience, external rules and scientific evidence. The ever-growing tide of medical knowledge clearly overwhelms the individual clinician, who must stay abreast of the current state of scientific evidence and apply it in his clinical decision-making. Availability, correctness and facilities to process this information are crucial for effective patient service.

Archie Cochrane, a British epidemiologist, recognized in 1972 that people who want to make well-informed decisions about health care must have easy access to reliable medical knowledge.¹,² Evidence-Based Medicine (EBM), the conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients³ is a milestone in retrieving medical information and currently a hot topic. One of the problems facing the clinician who wishes to practice EBM and to apply clinical guidelines is the disparate way research findings are disseminated. Although the Cochrane Database⁴ is the premier source for identifying results of systematic reviews, other sources such as clinical practice guidelines, scores, algorithms and briefing papers may also be of interest.

Hospital Information Systems (HIS) can act as a bridge between medical data and medical knowledge through context-sensitive merging and filtering of patient data, individual clinical knowledge and external evidence. These Knowledge-Based Functions (KBF), such as presentation of scores, guidelines, algorithms and references to other information sources, depend vitally on the detailed clinical data which has to be entered manually by the clinician, such as chief complaint, physical examination and vital signs.

Although computerization of the medical record has been shown to improve compliance with guideline recommendations and to improve outcomes⁵, it is very complex and often rejected by clinicians.⁶,⁷ Knowledge-based functionality joining existing data in the database with manually entered data must offer additional non-knowledge-based benefit. Data which is entered in time-consuming dialogs should be recyclable for other tasks such as printing forms, statistics, reminders⁸, alerts, etc. External scoring systems will only be successful if they meet clinical needs and if they are adapted to clinical circumstances.

However, to be effectively implemented in clinical routine, these functions must face organizational characteristics such as structures, roles, policies and preferences. Hospital information systems often do not relate to organizational issues, unlike business applications, where the concept of Workflow Management has become crucial.

To integrate and expand an existing external scoring system for decision support in acute abdominal pain¹⁰,¹¹,¹² as an invoked application in different hospital information systems, with the experience of knowledge-based drug prescription¹³, we analyzed the clinical process of a surgical outpatient ward using workflow analysis technology to get a better picture of clinical reality.

WORKFLOW TERMINOLOGY

Workflow is defined by the Workflow Management Coalition¹⁴, a non-profit, international organization, as the automation of a business process, in whole or
part, during which documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules\textsuperscript{15}. The automation of a business process is defined within a Process Definition, which identifies the various process activities, procedural rules and associated control data used to manage the workflow during process enactment. Process Definition is the representation of a business process in a form which supports automated manipulation, such as modeling, or enactment by a workflow management system. The process definition consists of a network of activities and their relationships, criteria to indicate the start and termination of the process, and information about the individual activities, such as participants, associated IT applications and data, etc. \textsuperscript{[...]} The process definition may contain references to sub-processes, separately defined, which make up part of the overall process definition\textsuperscript{16}. The process definition meta-model describes the core objects within the process definition, their relationships and attributes and their usage semantics. It identifies five basic entities and attributes used in the exchange of process definitions: The workflow process definition describes the process itself; the workflow process activities are logical units of work within the process definition and may be decomposed workflows (i.e. subworkflows) themselves, linked by transition information. Activities are performed by participants and applications on the basis of workflow relevant data. These blocks allow the specification of a complex net of activities which are connected in a specific order to achieve a common goal.

Although Workflow Management terminology was initially designed for business processes it is widely applicable and can easily be transferred into a clinical context. Currently, Hospital Information Systems rely increasingly on workflow management technology\textsuperscript{17, 18, 19}.  

METHODS

As a first step, a survey in three university surgery clinics was conducted to assess experiences and attitudes towards decision-aids such as scores, guidelines and algorithms among physicians (n=102). Paper-based decision-aids are already used by 71 percent of the survey participants; most of them were interested in computer-based systems\textsuperscript{20}. The second step was the process analysis of the workflow "surgical outpatient ward" and its decomposition into subprocesses with detailed information on infrastructure, locations, actors, and flow of information in written, oral and electronic form, putting emphasis on gathering information about interdependencies and how to facilitate them. Participating in the clinical routine ourselves, we used our own clinical experience, participating observation and interviews with the medical and nursing staff, completed by an additional review of representative traditional paper-based medical records. As a practical approach we transformed the Workflow Management meta-model into a clinical setting:

- Process definitions of subworkflows (admission of outpatients, putting them in the waiting-loop, physical examination, further diagnostics, operation if necessary, discharge)
- Participating actors or roles (patients, medical staff, nursing staff and laboratory staff)
- Activities assigned to one or more actors (admitting patients, clinical examination, processing laboratory analysis, filling out paper-based forms, etc.) and their locations and circumstances
- Transition information (exchange of information and data in the clinical pathway such as forms, oral communication, existing electronic data processing, patient and staff movements) and transition conditions (emergency admission, normal admission, availability of medical staff, results of clinical examination, etc.)
- Workflow relevant data.

These observational data were put into a complex net of activities and visualized by a set of hypertext markup language files.

RESULTS

Figure 1 shows a model of the analyzed workflow. We described three major units: admission, diagnostics and therapy/discharge. Each unit consists of different interdependent subworkflows, which are marked by a unique identification number, main activity, participating roles, location and possible flow of information, and are linked by specific transition conditions. Subprocesses can be internal activities such as admission, examination, etc., or external "black boxes" interacting with the process as a whole.

In the HTML-presentation, the workflow model is embedded in a set of numerous additional information and explanations (see Figure 2). The two-frame browser window shows the workflow model in the upper part and textual information in the lower part. Hotspot tags allow interactive retrieval of additional information in the textframe according to the clinical reality. If applicable, scanned forms currently used can be shown in the graphics frame to illustrate the current handwritten data entry program.
The interpretation of the workflow network outlines some major starting points for further software development:

- Existing HIS often do not support specific and problem-oriented documentation.
- Additional manual data entry is necessary to gain a basic set of information being processed in the KBF.
- This data entry must promise additional benefit to justify the effort of entering.
- The GUI must be quickly available on a mouse click from the HIS without invasion of the clinician's personal autonomy and authority, providing a homogenous, intuitive and flexible data entry environment.

Figure 1: Workflow (extract)
• Internal communication with other knowledge-based applications such as scoring systems must be invisible to the user in order to avoid redundancies.
• Existing clinical data shall be reused and merged with these data for printing request forms (radiology, laboratory, external diagnostics, discharge documents, etc.).
• Warning activity such as alerts triggered by noticeable events could possibly induce specific reactions.
• Entered data can be processed for scientific purposes or quality assessment.
• Problem-specific linking to internal and external information resources may reduce time and improve outcomes.

![Process Analysis Surgical Outpatient Ward](image)

Figure 2: HTML-presentation

- Knowledge-based functionality shall allow interactive bedside teaching.
- Patients in the waiting-loop should eventually give preliminary information about their symptoms and history by filling out machine-readable forms or using palmtop-technology. These data could be processed directly by the knowledge-based system.

**DISCUSSION**

Workflow analysis in health care must always take into account that clinical processes are highly complex and interdependent. Sometimes unpredictable circumstances (such as emergencies) require rapid adaptations to the current situation, which cannot generally be covered by workflow management.

Being applicable to other clinical settings, our workflow-based process analysis has been proven to be an effective and promising method of visualizing and understanding complex clinical processes and infrastructure in clinical health care. It can be used to identify areas of weakness in these processes and develop computer-based methods of improving them in order to improve outcomes, effectiveness and cost-effectiveness. An initial investment of time for process analysis will be paid off later by increasing usability and users' compliance and acceptance.

Future software development must always rely on the performed analysis as an internal guideline in order to achieve high usability of the product. This will be supported by the internet-based presentation, which is a useful tool for tracking clinical pathways.

Providing context-related additional information and external evidence concerning a specific clinical problem just in time and on a single mouse click is the key to managing and filtering large amounts of information and meets the increasing role of evidence-based clinical practice.
FUTURE WORK

Currently we are designing a JAVA/CORBA/XML-based external graphic user interface being invoked by the HIS in accordance with the process analysis. The use of a dynamic and flexible data model and a specific medical data dictionary, linking to the external AAP scoring system and embedding internal and external scientific evidence such as guidelines or systematic reviews from the Cochrane Collaboration provide a maximum of information with a minimum of effort to clinicians. Possible integration of multimedia applications could extend this functionality to a knowledge-based, interactive clinical teaching system.

Acknowledgements

This project is supported by a grant from the German Federal Ministry of Research and Technology (MEDWIS2).

References

4. URL: http://www.cochrane.co.uk.