IT Support for Healthcare Processes

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Abstract. Patient treatment processes require the cooperation of different organizational units and medical disciplines. In such an environment an optimal process support becomes crucial. Though healthcare processes frequently change, and therefore the separation of the flow logic from the application code seems to be promising, workflow management technology has not yet been broadly used in healthcare environments. In this paper we discuss why it is difficult to adequately support patient treatment processes by IT systems and which challenges exist in this context. We identify different levels of process support and distinguish between generic process patterns and medical guidelines / pathways. While the former shall help to coordinate the healthcare process among different people and organizational units (e.g., the handling of a medical order), the latter are linked to medical treatment processes. Altogether there is a huge potential regarding the IT support of healthcare processes.

1 Introduction

Process-oriented information systems have been demanded for more than 20 years and terms like "continuity of care" have even been discussed for more than 50 years. Yet, healthcare (HC) organizations are still characterized by an increasing number of medical disciplines and specialized departments. The patient treatment process requires interdisciplinary cooperation and coordination. The recent trend towards HC networks and integrated care even increases the need to effectively support interdisciplinary cooperation along with the patient treatment process.

Healthcare heavily depends on both information and knowledge. Thus, information management plays an important role in the patient treatment process. Numerous studies have demonstrated positive effects when using IT systems in healthcare. In particular the preventability of adverse events in medicine has been in the focus of recent studies. Adverse events are defined as unintended injuries caused by medical management rather than the disease process [1]. It turned out that insufficient communication and missing information are among the major factors contributing to adverse events in medicine [2,3,4,5]. IT support for HC processes therefore has the potential to reduce the rate of adverse events by selectively providing accurate and timely information at the point of

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care [6]. Yet, there is a discrepancy between the potential and the actual usage of IT in healthcare. A recent IOM report even states that there is an "absence of real progress towards applying advances in information technology to improve administrative and clinical processes" [7].

Why is it so difficult to build IT systems that support a seamless flow of information along a patient's treatment process? In this paper we try to answer this question by identifying different levels of process support and by distinguishing between generic process patterns and the medical treatment process. Generic process patterns, such as medical order entry and result reporting, help to coordinate the HC process among different people and organizational units. Though clinical and administrative processes change over time, these generic patterns are a part of the fundamental processes of clinical practice, which basically remains the same for longer periods of time.

The specific patient treatment process, however, depends on medical knowledge and case specific decisions. Decisions are made by interpreting patient specific data according to medical knowledge. This decision process is very complex, as medical knowledge includes medical guidelines of various kinds and evidence levels, as well as individual experience of physicians. Moreover, medical knowledge continuously evolves over time. It is generally agreed that medical decision making cannot be automated. Yet, the patient treatment process can be improved by selectively providing medical knowledge in the context of the patient treatment process. The problem is to offer current knowledge, to only offer relevant knowledge according to the current context, to include the underlying evidence, and to support all of this in a way which seamlessly integrates with the physicians work practice.

In Section 2 we describe how traditional HC information systems support the fundamental processes in HC organizations and how standards contribute to integration. To find out how IT can support medical processes we will have a closer look on medical decision making and its implications for process-oriented IT architectures in HC environments in Sections 3– 5. Section 6 discusses demanding challenges with respect to the use of BPM technologies in the HC domain.

2 Generic Process Patterns in Healthcare

The architecture of typical hospital information systems is characterized by many different departmental systems, which are usually optimized for the support of different medical disciplines (e.g. radiology, cardiology, or pathology). The need to consolidate the data produced by these ancillary systems to a global patient-centered view and to support the cross-departmental processes has motivated the development of standards for data interchange in healthcare. These standards also play an important role when not only cross-departmental but also cross-organizational HC processes are to be supported. Today, HL7 is the leading standard for systems integration in healthcare. The name "Health Level 7" refers to the application layer in the OSI reference model [8].

HL7 is a message-based standard for the exchange of data among hospital computer applications. The standard defines which data items are to be interchanged when certain clinical trigger events occur (admission, discharge, or transfer of a patient are examples for such events). Since version 2.3 (1997) the standard has covered trigger events for patient administration, patient accounting, order entry, medical information management, clinical observation data, patient and resource scheduling, and others. The standard is continuously extended and newly arising topics, such as the integration of genomic data in Electronic Health Records, are handled in special interest groups (SIGs). Yet, the HL7 trigger events are intended to support standard communication patterns that will occur in any HC organization in basically the same way. Today's commercially available HC software usually only covers a relatively small portion of HL7, covering those communication patterns that are typically requested as essential basis for interconnecting disparate applications.

Despite well accepted standards for data integration (e.g., HL7, DICOM), HC applications are still far from plug and play compatibility (which is essential for realizing process-oriented clinical information systems). One reason is that existing standards do not address functional integration issues sufficiently. In order to avoid these difficulties common application frameworks are required which serve as a reference for programmers to create functionally compatible software components. Requirements for an application framework directed towards open systems in the HC domain are described in [9]. In general such a framework must provide specifications of interfaces and interaction protocols which are needed for embedding a software component into a system of cooperating components.

The best example for such a standard in the HC domain is the IHE initiative ("Integrating the Healthcare Enterprise") [10]. IHE does not develop new standards for data interchange but specifies integration profiles on the basis of HL7 and DICOM. Thereby actors and transactions are defined independently from any specific software product. An integration profile specifies how different actors interact via IHE transactions in order to perform a special task. These integration profiles serve as a semantic reference for application programmers, so that they can build software products that can be functionally integrated into an IHE conformant application framework. The core integration profile of IHE is called "Scheduled Workflow". The Scheduled Workflow Integration Profile establishes a seamless flow of information in a typical imaging encounter, by precisely specifying the actors and transactions that are involved in the process of image acquisition. By fixing the required workflow steps and the corresponding transactions, IHE ensures the consistency of patient information from registration through ordering, scheduling, imaging acquisition, storage, and viewing. This consistency is also important for subsequent workflow steps, such as reporting. However, this kind of workflow support has nothing to do with the traditional idea of workflow management systems: to separate the flow of control from application logic in order to keep the workflow maintainable [11]. The idea of these standards is to establish stable generic communication patterns that help to integrate autonomously developed IT components.

3 Medical Decision Making

The HC process is often called a diagnostic-therapeutic cycle comprising observation, reasoning, and action. Each pass of this cycle is aimed at decreasing the uncertainty about the patient's disease or the actual state of the disease process [12]. Thus, the observation stage always starts with the patient history (if it is available) and proceeds with diagnostic procedures which are selected based on available information. It is the job of an (Electronic) Patient Record to assist HC personnel in making informed decisions. Consequently, the system should present relevant information at the time of data acquisition and at the time of order entry. Thereby, an important question to be answered is how to determine what is relevant. Availability of relevant information is a precondition for decisions - medical knowledge guides these decisions. Medical knowledge, however, is not limited to what is found in medical textbooks. A large part of medical knowledge is not explicit but tacit, and tacit knowledge heavily influences information needs by care providers as well as the course of the care process [13,14]. Moreover, medical knowledge evolves over time. According to [15] knowledge is created and expanded through social interaction between tacit and explicit knowledge (cf. Fig. 1). This process, called "knowledge conversion", is a social process between individuals, rather than a process within an individual. Stefanelli describes this process of knowledge creation in [14]. In order to make medical knowledge broadly available, medical experts need to externalize their tacit knowledge. Thus, improving HC processes has a lot to do with stimulating and managing the knowledge conversion processes.

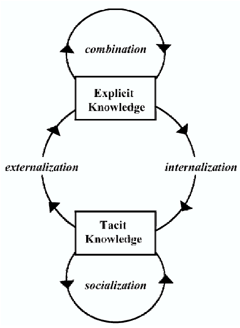

Fig. 1. The knowledge conversion process in a knowledge creating organization [15]

Supporting the HC process by bringing explicit medical knowledge to the point of care is closely related to developing and implementing medical practice guidelines. The MeSH (Medical Subject Headings) dictionary defines medical practice guidelines as "work consisting of a set of directions or principles to assist the health care practitioner with patient care decisions about appropriate diagnostic, therapeutic, or other clinical procedures for specific clinical circumstances". Guidelines are aimed at an evidence-based and economically reasonable medical treatment process, and at improving outcomes and decreasing the undesired variation of HC quality [16]. Developing guidelines is essentially a consensus process among medical experts. Yet, there is a gap between the information contained in published clinical practice guidelines and the knowledge and information that are necessary to implement them [16,17]. Methods for closing this gap by using information technology have been in the focus of medical informatics research for decades (e.g. [17,18,19]).

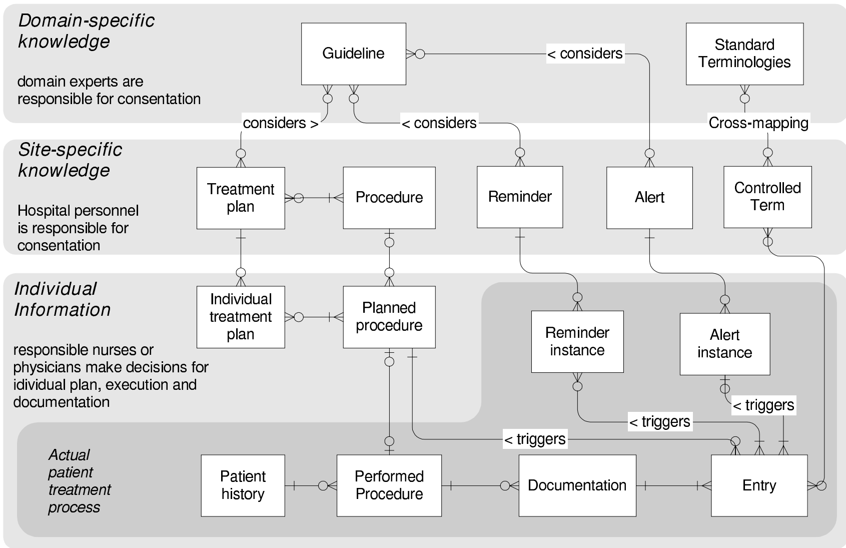

Fig. 2. Influence of explicit medical knowledge on the HC process

Medical pathways can be used as a basis for implementing guidelines [20] and sometimes they are confused with guidelines. In contrast to guidelines, though, pathways are related to a concrete setting and include a time component: Pathways are planned process patterns that are aimed at improving process quality and resource usage. Pathways are not standardized generic processes like those described within the IHE integration profiles (cf. Section 2). Pathways need a consensus process; they must be tailored to local and individual circumstances, which requires a cooperative initiative of clinical experts, process participants, and managers. Pathways can be used as a platform to implement guidelines (e.g., by routinely collecting the information required by a guideline). Selecting a guideline for implementation also requires an agreement of HC professionals and patients, because there are different kinds of guidelines with different origins and goals, and sometimes even conflicting recommendations. Likewise, to improve a patient treatment process across organizational borders, consensus on common practices is required in the first place. Once this consensus is achieved, the next question is how to implement it in practice. To be effective, a guideline must be easily accessible. Ideally, it should be embedded into the clinical work practice, and the physician should not need to explicitly look it up. Otherwise, there is always a risk of overlooking important information while the patient is in the office. Previous work has primarily demonstrated a positive influence of computer-generated alerts and reminders [21], which can be integrated into clinical work practice. Recent research indicates that this is exactly the major difficulty with implementing more complex multi-step guidelines: How to integrate them into the clinical workflow [19]?

The influence of different levels of explicit medical knowledge on the patient care process is illustrated in Fig. 2: Medical guidelines are distinguished from site specific treatment plans (e.g. clinical pathways). A treatment plan comprises multiple diagnostic or therapeutic steps (procedures). Instances of a treatment plan need to be adapted to the specific needs of an individual patient. The actual treatment process may still deviate from the individual treatment plan, because it is also led by tacit knowledge and not only by explicit knowledge. Yet, explicit medical knowledge can still be brought to the point of care: Documentation of performed or ordered procedures may trigger alerts or reminders. An alert (e.g., "Lab alert" for values out of bounds or about to evolve into dangerous areas) requires some kind of notification system to inform the physician. Reminders can be used to inform the person who enters data instantaneously if data are entered which are not plausible or if expected data entries have not been made.

4 Integrating Knowledge and Information Management

Medical pathways are one attempt to establish a platform for implementing complex guidelines. Thereby, predefined checklists that ask the right questions in the right context, predefined order sets, and well placed reminders are some of the techniques that can be used to improve process quality and reduce the required documentation overhead. All these techniques require the computer to be able to make use of the patient's clinical data. The first obstacle to achieving this is to represent guidelines in a computer-interpretable form, i.e., translating narrative guidelines into equivalent ones that use coded data. This task is cumbersome and also bares the risk of distorting the intent of the original guideline.

To overcome such problems numerous models have been developed to formally represent medical guidelines and medical knowledge (e.g., Arden Syntax [22], GLIF [23] PROforma [24], EON [25], Asbru [26]). Recent surveys have compared these approaches [27,28] One of the central goals is to define standard representation formats for medical knowledge in order to be able to share guidelines among different information systems in different organizations. In practice, however, it turned out that the main obstacle to be solved here is - once again - an integration problem: The data definitions in pre-defined formal guidelines may not map to the data available in an existing electronic health record system [29]. Typically, operational systems have to be modified and extended in order to acquire the necessary information needed for guideline implementation. Few guidelines have been successfully implemented into real clinical settings by using these systems and predefined, formally specified guidelines. Recent research has recognized these difficulties and focuses on process models for transforming text-based guidelines into clinical practice [17]. Standard formats for guideline representation do have their place in guideline implementation, but the integration problems to be solved are a matter of semantics rather than format. Guideline implementation requires a high level of data integration, because computerized reminders typically refer to both type and instance level semantics. More complex guidelines also need to refer to a formally established context comprising status information. The challenge to be solved for distributed HC networks is to establish a sufficient degree of integration as basis for guideline implementation, and to find practical solutions to cope with the evolving HC domain.

5 Implications for Process-Oriented IT Architectures

The adequate support of HC processes raises a number of requirements for process-oriented IT architectures. In particular, an integrated process support, information management, and knowledge management on different levels is needed.

In order to adequately support generic process patterns (cf. Section 2) and to provide the needed information at the point of care, responsive IT architectures must consider the cross-departmental nature of clinical processes. To avoid media breaks we either need highly integrated systems or semantically compatible application components. Semantic compatibility, in turn, subsumes functional integration. Besides application integration comprehensive process support is needed for coping with clinical and administrative processes. Process support functions should comprise both standard services (e.g., process enactment and monitoring, worklist management) and advanced features (e.g., ad-hoc changes of single process instances during runtime).

The handling of medical guidelines and pathways requires an approach which allows reaching an organization-specific consensus on them. Due to the evolving nature of guidelines and pathways, in addition, responsive IT infrastructures must enable their continuous extension and adaptation (cf. [11]). This should be accomplished under the control of the respective HC organization and its medical staff. In order to achieve this, we need sophisticated tools for (graphically) specifying the flow logic of guidelines and pathways at a high semantic level. Furthermore, patient treatment processes (and their monitoring) as well as patient information must be linked to the defined guidelines and pathways.

IT infrastructures, which support medical guidelines, should allow the explicit definition of medical knowledge and enable its combined use with patient-related information. This requires a minimum of semantic control. In order to avoid problems at the operational level (when linking guidelines with patient information), we need tools for defining guidelines based on the medical concepts and medical terminology already used within the operational systems. Doing so, again we must consider the evolving nature of the HC domain. In particular, we must support the evolution (and versioning) of ontologies and controlled vocabularies, to which the different guidelines refer, as well.

Current hospital information systems are far from having realized such process-oriented architectures. This has led to pragmatic solutions and workarounds in order to reduce the overall effort for integrating heterogeneous application components and to enable a requirements-driven system evolution.

6 Challenges for Process Management Technologies

Recently, we have seen an increasing adoption of BPM technologies and workflow management systems (WfMS) by enterprises. Respective technologies enable the definition, execution, and monitoring of operational processes. In connection with Web service technology, in addition, the benefits of process automation and optimization from within a single enterprise can be transferred to cross-organizational processes as well. In principle, WfMS offer promising perspectives for the support of HC processes as well. By separating the process flow logic from the application code, processes can be quicker implemented and adapted when compared to conventional approaches. Current WfMS, however, are far from being applicable to a broader range of HC processes. Existing WfMS are either too rigid or they do not meet the various requirements discussed above. In particular they are not able to cope with the dynamics and the evolving nature of HC processes. In any case, we need a more advanced process management technology, which enables the integrated support of medical processes, medical knowledge and patient-related information on different levels.

Though the scope of generic process patterns and medical pathways is different there are several commonalities. Graphical descriptions of the respective flow logic are useful and in both cases these descriptions must be linked with other components of the system architecture (e.g., application systems or patient-related information). At the process instance level, in addition, in both cases deviations from the pre-defined flow logic may become necessary and should therefore be supported. As mentioned, variations in the course of a disease or a treatment process are deeply inherent to medicine; the unforeseen event is to some degree a "normal" phenomenon. Medical personnel must be free to react and is trained to do so. However, respective deviations from the pre-planned process must not lead to errors or inconsistencies. Tools enabling them must be easy to handle, self-explaining and - most important - their use in exceptional situations should be not more cumbersome and time-consuming than simply handling the exception by a telephone call to the right person. Altogether we need adaptive process management technology which allows to rapidly set up new HC processes and to quickly adapt existing ones.

When deviations from predefined process patterns or medical pathways occur they should be documented and logged. A logical next step then is to continuously monitor, analyze, and mine this change log and to "learn" from it. Best case, based on this data necessary decisions can be made quickly and accurately to modify HC processes, to dynamically allocate resources, or to prioritize work.

Healthcare more and more changes from isolated patient treatment episodes towards continuous treatment involving multiple HC professionals and HC institutions. Therefore hospitals need to be linked with other HC organizations and general practioners, but also with insurance companies and governmental organizations, over wide area networks transporting sensitive patient data. The adequate support of distributed HC networks will result in novel workflow scenarios raising a number of challenging issues. A sufficient degree of process and information integration and the semantic interoperability of the different HC systems are crucial in this context. The same applies to privacy and security issues in connection with the exchange of patient data.

With advances in technology we can further observe that HC processes, which were previously confined to the hospital, will more and more be provided outside it. In this context technologies like mobile devices and wearable computing will be important drivers of change. Examples of upcoming application scenarios include the contactless monitoring of patients, the provision of smart agents collecting patient data during homecare, and the automatic detection of emergency situations. All these scenarios will demand further challenges with respect to the management of HC processes, ranging from the support of mobile and distributed processes to the seamless integration of different devices.

7 Summary

Based on many years of first-hand knowledge of the HC domain and our personal working experience in hospitals, based on the experiences made in numerous clinical projects, and having also deep insights into existing BPM technologies, we believe that the IT support of HC processes offers a huge potential. However, a number of challenges exist and new ones will arise in connection with novel technologies, which must be carefully understood and which require basic research before we can come to a complete solution approach. We believe that the realization of process-oriented IT architectures in HC is a great challenge for the BPM community - if not even the "killer application" for this type of technology.

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