Knowledge management-enabled health care management systems: capabilities, infrastructure, and decision-support

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Knowledge management-enabled health care management systems: capabilities, infrastructure, and decision-support

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Abstract

The health care industry is increasingly becoming a knowledge-based community that is connected to hospitals, clinics, pharmacies, and customers for sharing knowledge, reducing administrative costs and improving the quality of care. Thus, the success of health care depends critically on the collection, analysis and seamless exchange of clinical, billing, and utilization information or knowledge within and across the above organizational boundaries. This research envisions a knowledge management-enabled health care management system that would help integrate clinical, administrative, and financial processes in health care through a common technical architecture; and provides a decision support infrastructure for clinical and administrative decision-making. Hence, the objective of this research is to present and describe the knowledge management capabilities, the technical infrastructure, and the decision support architecture for such a health care management system. The research findings would immensely help the health care information technology (IT) managers and knowledge based system developers to identify their IT needs and to plan for and develop the technical infrastructure of the health care management system for their organizations.

Keywords: Knowledge management; Technical infrastructure; Management system

1. Introduction

In the 1990s, the health care industry has increasingly tried to embrace new information technologies as well as software applications, as it searched for opportunities for efficiency and higher-quality care (Raghupathi & Tan, 1999). Most notable among them are the Internet technologies and decision support technologies (Ba, Lang, & Whinston, 1997; Brooks, 1999; Detmer & Shortliffe, 1997; Hersch, Brown, Donohow, Cambell, & Horacek, 1996; Inmon & Hackathorn, 1994; Raghupathi, 1997; Silver, 1991). Health care organizations are recently experimenting with the e-commerce business models to take advantage of the global reach as well as the potential to react to changes in the market place quickly by gathering and analyzing critical-to-success information (Forgionne, Gangopadhyay, Klein, & Eckhardt, 1999a,b). As a result, the concept of *e-health* is currently evolving, which refers to the use of Web-enabled systems and processes to accomplish some combination of the following objectives: cut costs or increase revenues, streamline operations, improve patient or member satisfaction, and contribute to the enhancement of medical care.

Also during the last decade, health care organizations started to use information systems for clinical purposes to improve patient care (Anderson, 1997; McDonald et al., 1998). Computerized decision support or expert system, which is targeted at assisting health care providers and administrators with such decision tasks as information retrieval, data analysis, diagnosis and test, procedure and case management recommendation has been one of the critical information technologies heavily deplored to transform health care (Achour, Dojat, Rieux, Bierling, & Lepage, 2001; Forgionne & Kohli, 1996; Hunt, Haynes, Hanna, & Smith, 1998; Sim et al., 2001; Zitner, Paterson, & Fay, 1998).

In spite of these advances made, there are several specific challenges that are being faced relating to the use of information technology (IT) in health care, such as the complexity of medical data, the absence of industry-wide recognized electronic health care record (EHCR) for patients in which medical data about the patient is recorded, data entry problems, security and confidentiality concerns, systems integration concerns in clinical practice, and a general lack of awareness of the benefits and risks of IT (Blumenthal, 1999). A significant IT challenge in the clinical practice is how to integrate several disparate, stand-alone, information repositories into a single logical

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repository—for software applications—to create a single version of truth for all users. In addition, the infusion of IT in health care has progressed slowly compared with other industries. Industry segments such as finance and retail typically spend 7–9% of their operating budgets on IT, yet the typical expenditure of a health care organization is 2–3% (Blumenthal, 1999).

Health care in the United States is currently undergoing unparalleled change. Employers and the federal government have sent a clear and repeated signal that they wish to maintain or increase the quality of health care while shrinking the health care budget. This, in turn, leads to pressure on insurers to decrease premium costs and encourages providers to do more with less. Another key driver is the pressure to ensure that the care delivered to the patient is based on best practice, which is referred to as *evidence-based medicine* (Thorsen & Makela, 1999; Van Bemmel & Musen, 1997). Best practice is increasingly being encoded in the form of clinical guidelines and protocols that drive the delivery of health care.

It seems reasonable to speculate that a core component of the solution to the future health care delivery system could be addressed by the proper infusion of IT, although the blueprint for execution is unclear. However, there is a growing realization that: (1) the widespread restructuring in the health care sector caused by government cutbacks is driving growth in IT and knowledge-based solutions, and (2) technology and knowledge management can both pare additional costs from strained budgets and increase the quality of health care (Heathfield & Louw, 1999; Matheson, 1995).

Knowledge management involves the strategies and processes for identifying, capturing, structuring, sharing and applying an individual's or an organization's knowledge to extract competitive advantage and create sources of sustainable growth (Alavi & Leidner, 2001; Davenport & Prusak, 1998; Holsapple & Joshi, 2002; Liebowitz, 2000; Nonaka & Takeuchi, 1995). The health care industry is increasingly becoming a knowledge-based community that is connected to hospitals, clinics, pharmacies, and customers for sharing knowledge, reducing administrative costs and improving the quality of care. Thus the success of health care depends critically on the collection, analysis and seamless exchange of clinical, billing, and utilization information or knowledge within and across the above organizational boundaries (Jadad, Haynes, Hunt, & Browman, 2000; Kohli, Tan, Piontek, Ziege, & Groot, 1999).

This research envisions a knowledge management-enabled health care management system that would help integrate clinical, administrative, and financial processes in health care through a common technical architecture; and provides a decision support infrastructure for clinical and administrative decision-making. Hence, the objective of this research is to present and describe the knowledge management capabilities, the technical infrastructure, and the decision support architecture for such a health care management system. The research findings would immensely help the health care IT managers and knowledge based system developers to identify their IT needs and to plan for and develop the technical infrastructure of the health care management system for their organizations.

The system purposes are as follows. First, to improve access to information and knowledge at all levels (physicians, hospital administrators and staff, the insurer, the consumer of health services, pharmacies, and health insurance companies) so that efficiencies and cost reductions are realized. Second, to transform the diverse members (care recipients; providers—physicians, nurses, therapists, diagnosticians; pharmacists; regulators; retail-suppliers) of the health care sector into a knowledge network/community of practice. Third, to promote self-care by providing easy and friendly access to relevant information, and; enable evidence-based decision-making to improve quality of health care.

The remainder of this paper is organized as follows. Following the introduction, background material on knowledge management, health care management, benefits of their integration, and the research contribution is provided. Section 3 discusses the knowledge management environment with its processes and capabilities. The technical capabilities and infrastructure needed for e-health are discussed next. Then, the knowledge based decision support architecture, the system interface, and the future research needs are discussed. Finally, concluding remarks are provided.

2. Background

2.1. Knowledge management

In a broad sense, knowledge management is a business concept, which includes concerted, coordinated, and deliberate efforts to manage the organization's knowledge through the processes of creating, structuring, disseminating and applying it to enhance organizational performance and create value. The knowledge management strategy of an organization is predicated on shared learning, collaboration, and the sharing of knowledge (Hibbard, 1997; Holsapple & Singh, 2001; Liebowitz, 2000; Nonaka & Takeuchi, 1995; Quinn, Anderson, & Finkelstein, 1998). Furthermore, it is based on the belief that significant organizational productivity improvements can be achieved through retaining and reusing knowledge across the organization.

The primary difference between the commonly used terms *information* and *knowledge* is in the level of understanding of their underlying organizational data. The accumulation of transactional data into a meaningful context provides information. The next level of higher understanding is characterized as knowledge. Well-managed information that is properly cataloged and structured,

available and accessible by the right people and processes at the right time becomes knowledge.

Information management can be characterized as organizational document or content management. Information management tools enables users to aggregate, manage, and deliver content over the company's intranet. Knowledge management treats knowledge as a resource by exercising selectivity, imposing order on information resources, adding structure to ill-structure information—such as the insights, understanding, and intuition of experts for solving specific problems—to increase its value, and proactively capturing information that might be useful in the future.

Thus, knowledge management incorporates careful identification of the target user community and its needs, meta-information that defines the types of information to be included and how they will be categorized and summarized, and administrative tools providing quality control and high availability. The primary distinction between knowledge management and information management is that the content itself is different. The former is inevitably less structured and ideally incorporates informal problem-solving experience and expertise rather than being limited to automated data manipulation and reporting.

A well-designed knowledge management infrastructure is needed by an organization to facilitate the creation and management of e-business knowledge that would help improve back-office efficiency, greater customer intimacy, and flexible adaptation to market changes (Beveridge, 1997; Borghoff & Pareschi, 1998; Bose, 2002; Junnarkar & Brown, 1997; Jutla et al., 1999; Liebowitz, 1999). Thus, it is imperative that health care organizations invest in knowledge management and establish processes and infrastructure necessary to create and manage e-health knowledge (Anderson & Aydin, 1997; Forgionne et al., 1999b).

2.2. Health care management

Delivering health care to patients is a complex endeavor that is highly dependent on information. Health care organizations rely on information about the science of care, individual patients, care provided, results of care, as well as its performance to provide, coordinate, and integrate services. Like human, material, and financial resources, information is a resource that must be managed effectively by the health care managers (Heathfield & Louw, 1999).

The traditional single physician–patient relationship is increasingly being replaced by one in which the patient is managed by a team of health care professionals each specializing in one aspect of care. Such seamless and shared care depends critically on the ability to share information easily between care providers. Hence, the ability to access and use EHCR of the patient is fundamental (Beveridge, 1997). This research does not address the design and implementation of EHCR; however, several researchers have been and are currently being involved with the issue. The goal of such research project is to design and develop comprehensive patient health records that span inpatient, outpatient, and long-term care over all clinical encounters—the lifelong, longitudinal EHCR (Blumenthal, 1999).

Clinical data, to be incorporated into the health care record, are acquired from and input by patients, physicians, and other health care providers. The data fall into three general categories. First, the historical information that the patient provides; second, the information obtained from physical examination; and third, the results of the tests or procedures performed on the patient or the patient's tissues or body fluids. Data gathered by the physician or other health care provider, are the results of observation or examination. These data may be directly entered by any of the three sources (patient, physician, or other health care provider) by a series of different techniques.

At present, one of the major impediments in the health care business's progress toward efficiency and cost-effectiveness is the difficulty or inability to share information across systems and between care organizations (Grimson, Grimson, & Hasselbring, 2000). Historically, the use of IT has been independent and autonomous in each organization or unit and very little clinical benefit was perceived for sharing of information between organizations.

Health care management systems must effectively address the needs of its three major players: the clinicians, administrators, and patients. From the clinicians' perspective, performance is measured by speed, reliability, and best clinical practices (Bria & Rydell, 1996; Pulde, 1999). At the health care enterprise level, performance is tied to best business practices, patient satisfaction and retention, and the ability to generate revenue. Therefore, from the administrators' perspective, performance is measured by comprehensive picture of the cost, quality, and outcomes of health care services (Ahwah & Karpiel, 1997; Kohli et al., 1999). The design of health care management system, consequently, must not only provide the technical infrastructure that can support myriad applications, but must also integrate the systems applications in order to collect data that are accurate, complete, and stored in compatible formats (Grimson et al., 2000).

From the patients' perspective, what once was a physician–patient relationship is now becoming a customer–company relationship. The customers (patients) expect the company (enterprise) to know everything about their contracts, schedules, and medical histories from the first contact point (telephone) through the completion of an encounter, and over a continuum of time. It is universally understood that EHCR brings risks of potential abuses and liabilities; medical information in clinical systems applications must be confidential and secure, and a client's privacy must be respected.

Health care management systems must support both clinical and administrative decision-making processes (Sim et al., 2001). While clinical decision-making leads to diagnostic, prescriptive and treatment processes,

administrative decision-making leads to a list of work and environmental requirements. Clinical decision support systems (CDSS) are clinical consultation systems that use population statistics and expert knowledge to offer real-time information for clinicians (Teich & Wrinn, 2000). These systems aid patient management and consultation through analysis of patient-specific information in comparison with an expert knowledge base (Thorsen & Makela, 1999). The administrative or operational decision support systems make use of corporate repositories (i.e. data warehouses) of clinical and financial information that are scrutinized for utilization review, component cost evaluation, and clinician performance evaluation (Niederman, 1997).

2.3. Benefits of the integration

The knowledge management infrastructure and capabilities would facilitate integration and interoperability between previously disparate knowledge repositories belonging to different organizational units (Broadbent & Weill, 1997; Liebowitz, 1999; Maurer, 1998). It would help eliminate the traditional separations between, for example, hospital, physician office, rehabilitation, patient home, and chronic care facilities. Thus, not only the services could be coordinated across previously separate environments but also the integration of financial systems, quality assurance and utilization management programs are possible to support an efficient and unified approach to health care practice.

The use of CDSS to facilitate the practice of evidence-based medicine promises to substantially improve health care quality (Jadad et al., 2000). Several studies have reported that CDSS assist the physicians in early detection of diseases, such as cancer, that lead to fewer office visits, to better outcomes, and to decreased overall costs to the health care system (Forgionne & Kohli, 1996). CDSS have also been hailed to help improve many aspects of the medication use process, that is, preventing medication errors and adverse drug events (Schiff & Rucker, 1998).

The knowledge management based health care management system would also provide the ability to do sophisticated analysis on different types of knowledge, such as clinical knowledge, stored in the repositories. Thus, clinical best practices can be easily kept up-to-date on a continuous basis, which is a fundamental requirement for evidence-based medical practice.

2.4. Contribution of the research

Several knowledge management frameworks have been reported in the literature that characterize the strategic view of knowledge management, these models provide a high level view of the activities that should be part of knowledge management (Holsapple & Joshi, 2002; Quinn et al., 1998; Rubenstein-Montano et al., 2001). However, they fall short of incorporating necessary processes, tools and techniques. This research attempts to integrate relevant enabling technologies into an environment that would support organizational knowledge creation, use, and management. Moreover, the knowledge management-enabled health care management system design would help integrate clinical, administrative, and financial processes in health care through a common technical architecture.

The research provides a design of proactive knowledge based DSS that utilizes the knowledge management processes to facilitate quick access to different types of knowledge. There is a great interest in designing active knowledge based DSS, which incorporate past experiences (Holsapple, 1995; Rubenstein-Montano et al., 2001; Scott, 1998). Individuals and organizations learn over a period of time, and it is useful to incorporate this new knowledge into the problem solving and managerial decision-making. Traditionally, DSS have been closed systems and are limited to the data and models contained within the system. In this new breed of DSS, there is greater emphasis on providing feedback loops between individuals and the systems that are normally used in problem solving and decision-making. The overall idea is to pool together this collective knowledge and experience, and infuse it into the DSS on an ongoing basis.

The design of the knowledge management-enabled health care management system directly supports evidence-based medical practice because the care recommendations made by the system are based on best practice knowledge. The clinical knowledge base uses both the medical literature-based evidence as well as practice-based evidence provided by physicians from their site-specific clinical decision-making. To support the clinical decision making process, the system is designed to match the characteristics of an individual patient to the above clinical knowledge base and patient-specific assessments or recommendations are then presented to the clinician or the patient for a decision.

3. Knowledge management environment

Knowledge management environment is put forth for efficiently gathering, evaluating, structuring, and distributing intellectual capital.

3.1. Knowledge management processes

An organization's knowledge is its professional intellect such as know-what, know-how, know-why, self-motivated creativity, best practices, concepts, values, beliefs and method of working that can be shared and communicated. The knowledge may be explicit, which means the knowledge is in a structured form that is suitable for easy storage and processing such as knowledge stored in databases and knowledge bases; or it may be tacit, which means the knowledge is in a subjective (non-structured) form that

needs to be structured before it is used for storage and processing such as ideas, insights, values, and judgments of individuals.

The knowledge management cycle, see Fig. 1, consists of four processes namely, knowledge creation, knowledge structuring, knowledge dissemination and knowledge application. A brief description of each is provided below.

The *knowledge creation* process includes knowledge acquisition and knowledge representation. Knowledge can be created from several sources and methods such as R and D center, organizational learning outcomes, lessons-learned analysis and innovation. The procedure for and the method of acquiring knowledge from both internal and external sources need to be developed. The knowledge is represented using the formal representation methods developed by the organization for processing (Wielinga, Sandberg, & Schreiber, 1997).

The *knowledge structuring* process includes defining, storing, categorizing, indexing, and linking digital objects such as documents and images to knowledge units. Mapping the existing and available knowledge (including expertise and skills) in terms of its context, relevance, and locations helps in the classification of the knowledge into taxonomies. Storing the knowledge in properly indexed and inter-linked

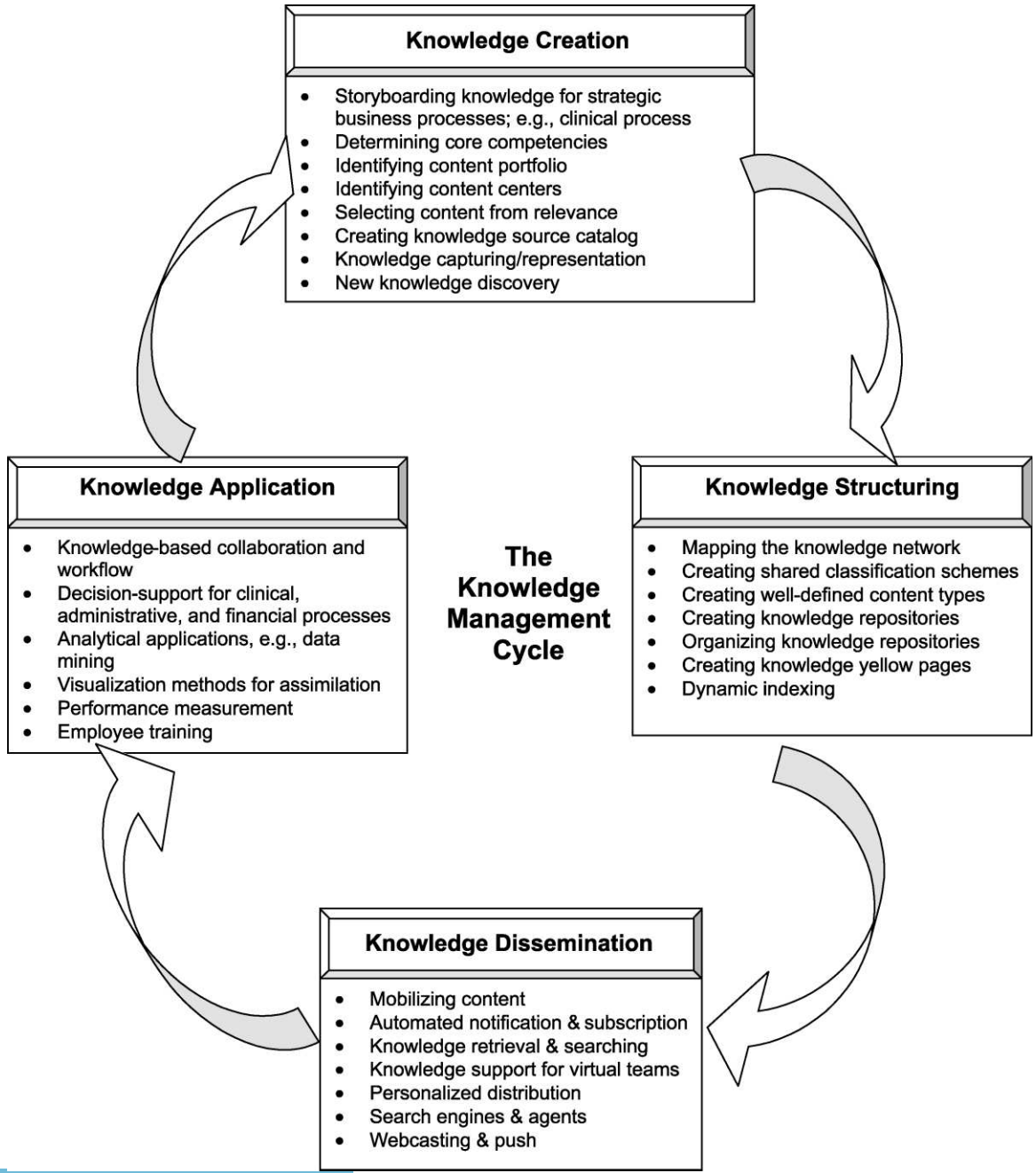


Fig. 1. The knowledge environment.

knowledge repositories such as company yellow pages of expertise and knowledge, skills inventory, best practices inventory and lessons learned inventory are then performed.

Devising a classification system is the key to building knowledge taxonomies. For example, each topic heading in yellow pages directories of business is an example of a category in taxonomy. The classification system groups similar documents together and fits them into topical categories; which can be generated by manual or automated means, or a combination of the two. To truly add value to knowledge spread across the enterprise, organizations must provide multiple ways to categorize it. This allows knowledge management system users to slice through the knowledge using the method best suited for their specific problem.

The *knowledge dissemination* process primarily involves knowledge sharing and collaboration. Presenting, which includes searching for (pulling) and subscribing to (pushing), automatically relevant content to users on the basis of their needs and interests, with sufficient flexibility to render it meaningful and applicable across multiple contexts of use. It includes, among other categories of knowledge, the transfer and diffusion of best practices. Knowledge sharing is done using different means, some of which are automatic and some manual, such as training and education, company intranet, communities of practice, external or internal benchmarking, documentation and newsletter, and cross-functional teams.

The *knowledge application* process involves applying, which includes retrieving and using, knowledge in support of decisions, actions, problem-solving, developing competency maps to place people in best jobs and teams for improving productivity, establishing communities of interest, automating routine work (for example, workflow), providing job aids (for example, customer support) and training to bring people up to speed quickly.

3.2. Knowledge management capabilities

In order to implement the aforementioned four processes to create the knowledge environment, organizations need to provide and support several categories of knowledge management capabilities through the deployment of currently available technologies (Ruggles, 1997). This section identifies many different kinds of knowledge management capabilities, organizes them into several logical categories, and describes each category. Fig. 2 shows them as a capabilities framework for health care management systems.

The capabilities framework, at a high level, can be explained in two parts. First, it is designed to leverage existing knowledge and to enable creation of new knowledge through a continuous learning process denoted by the knowledge learning loops. Secondly, the capabilities component is denoted by the rectangular, labeled boxes. Brief description of each of the capabilities is provided below.

Presentation involves personalizing both the access to and displaying the results of user interactions with the system. It is designed to let every organizational user know where to go to find the organization's knowledge through a single browser-based point of entry to all information that the user needs. Personalization provides the ability to customize what type of information are relevant to a user and how that information is presented.

The *personalization* function helps personalize content and services to deliver tailored content or information to users based on several user criteria or preferences. The primary capabilities of this function include creation of personalization profile of individual users or groups or departments or divisions, providing personalized navigation, providing personalized notification, and the ability to personalize the content categorization. Personalization is often accomplished by using software agents, commonly called spiders, to get the information and handle user profiling.

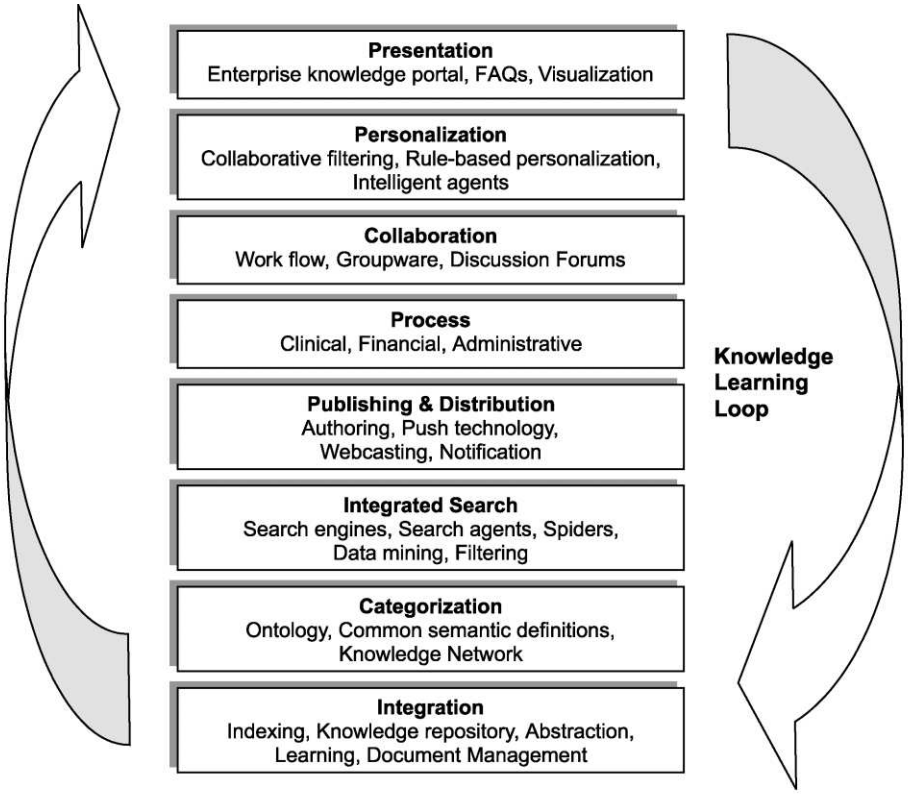
The *collaboration* function is designed to connect people with people through communities of practices; to preserve the discussions; and to stimulate collaboration by integrating the knowledge repositories and collaboration applications such as workflow.

The *process* function allows users to participate in relevant business processes in the context of their own roles. Through this function, users have access to knowledge management applications such as knowledge or evidence based decision support system applications that enable increased responsiveness to customers and partners.

The *publishing and distribution* function provides the means and a platform for users to easily capture and distribute the particular kinds of knowledge assets they need to monitor without requiring them to learn complex programming syntax. Software agents are used extensively for this function. These agents are designed in such a way that users can set up and control them. The users can specify in them the type of knowledge he or she wants to publish, distribute, and receive. The frequency (by time and/or quantity) and method (by e-mail or Web page) are important parameters that should be set up by the users.

The *integrated search* function is designed to reduce the information overload and usefulness of search results to the users. Integrated search across all repositories are performed by default but users can also identify the repositories they want to search such as Web pages, e-mails, and discussions. This function should also provide the ability to automate indexing and to crawl frequently to keep the index current.

The *categorization* function allows users to browse, create, and manage knowledge categories. It establishes a process and guidelines for authoring and publishing knowledge categories by the users. Business groups or departments or divisions are made responsible for creating and managing their own subject area taxonomies.



Documents	Knowledge Warehouses/Marts	Applications	Best Practices	Discussions
• Patient Admission • Billing & Payments • Health Administration • Medical Research Literature • Drug References	• Patient Record • Providers' Clinical Log • Medical Procedures • Hospital Operations	• Knowledge Mining & Analysis – Clinical, Financial & Administrative • Decision-Support • Quality Assurance	• Procedure & Care Management • Disease Diagnosis & Test • Pharmacy, Emergency & Nursing Practice • Claims Processing	• Cost Reduction • Fraud & Abuse Prevention • Performance Measurement • Coordination of Care

Knowledge Sources

Fig. 2. Knowledge management capabilities for health care management systems.

The *integration* function ensures seamless and consistent navigation among and between the above functions and knowledge sources such that all individuals can use the organization's combined knowledge and experience in the context of their own roles.

4. E-health

Executives in leading health care organizations are increasingly recognizing that in order to maintain or gain competitive advantages, organizational knowledge not only need to be managed for, but also integrated with their corporate e-business systems, which we call *e-health*. Organizations, therefore, require capabilities and infrastructure to ensure that the right knowledge is available in the right forms to the right people and to the right e-health applications.

The e-health design must contain two major components, customer-oriented and business-oriented activities, both of which must be supported by a huge technical infrastructure consisting of a variety of technologies to provide all the necessary capabilities for an overall solution. Fig. 3 provides the e-business capabilities and infrastructure for health care management systems.

The infrastructure design of e-health is guided by two major goals: to deliver great value to the customer and, to achieve operational efficiencies for the enterprise. The first goal is incorporated in the design by providing provisions for seamless connectivity across the extranets and intranet and for greater data interoperability between and among the organizations and their different units through the extranets and intranets. The second goal is incorporated in the design by providing provisions for interoperating core services across the business processes—clinical, financial, and administrative.

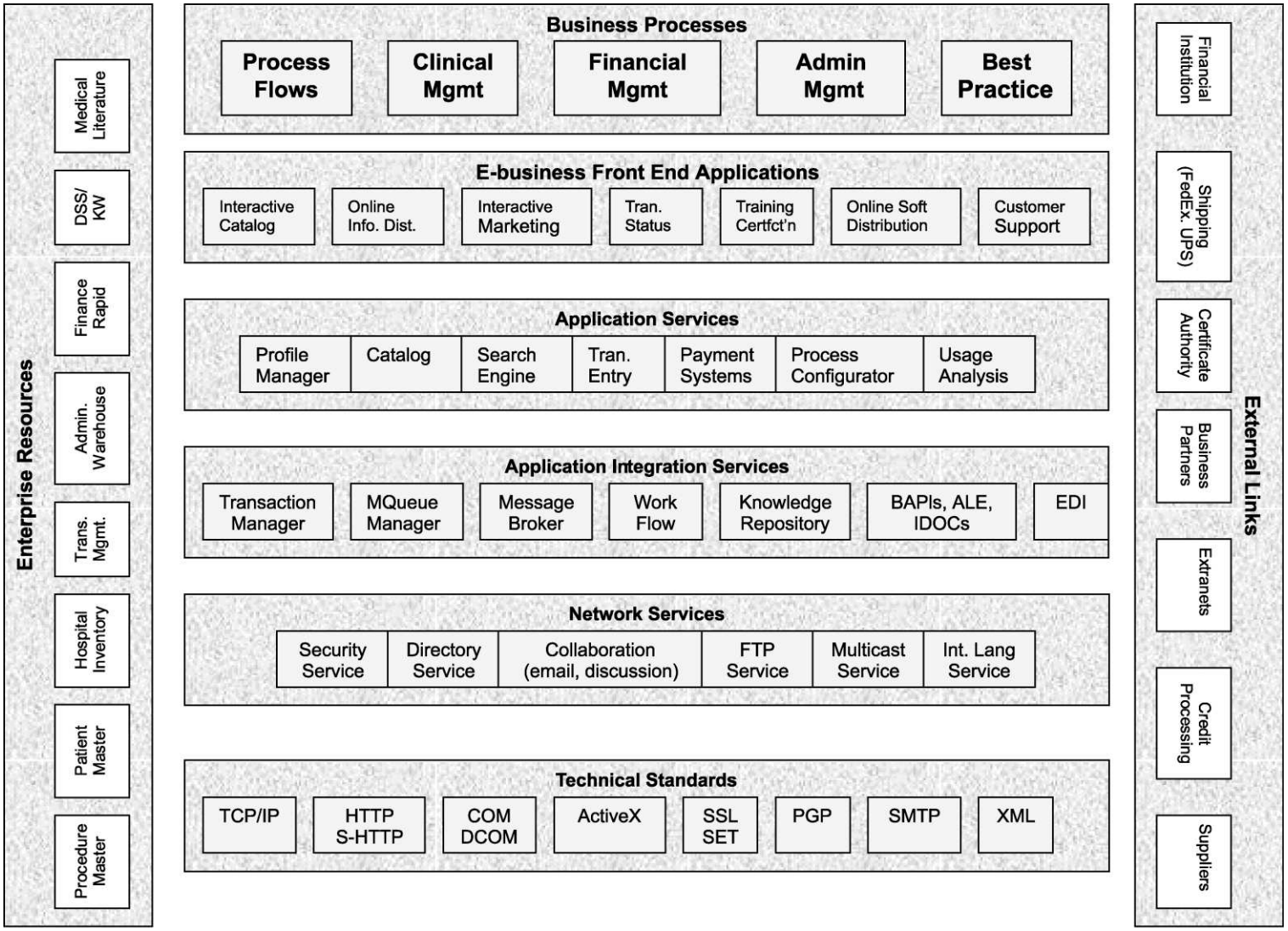


Fig. 3. E-business capabilities and infrastructure for health care management systems.

The typical e-health capabilities would include: adaptive marketing and promotions based on customer and partner; customer and partner profiling; catalog-navigation, product info, pricing, availability, searching; price quote; order entry, acknowledgement, and status; payment acceptance—secure storage of customer financial information; transaction processing; secure links to multiple payment systems; enterprise applications and data integration—order processing, inventory, finance, warehouse, shipping/fulfillment, tax, etc. communication with customers and partners—email, broadcast, discussion; customer and partner support; and training/certification.

5. Proactive knowledge based decision-support

As mentioned earlier, health care organizations suffer from the problem of systems and knowledge integration. Two types of problems originate from it. The first problem is knowledge management related. The knowledge is fragmented, not shared, thus inconsistent. E-health requires a better DSS repository to have access to and to analyze the enterprise-wide knowledge for business intelligence. In addition, the knowledge is not being used to strategic advantage (the quality of decisions by the users is directly related to the quality and availability of knowledge). The second problem is technical in nature. The multiple knowledge bases used in different environments make sharing of knowledge more complex (inflexibility from format incompatibility and reduced ease of use) and it therefore introduces complexity in developing DSS front ends.

The solution strategy to the above integration problem is to design and develop a logical enterprise knowledge warehouse (EKW) that use common knowledge architecture which will ensure consistency in the knowledge warehouse containers and use common metaknowledge repository that contains metaknowledge from all sources and containers in the knowledge warehouse architecture. The key objective of such an EKW in health care management is to provide access by authorized users to the relevant health care knowledge related to the clinical, administrative, and financial processes in desirable forms of outputs regardless of the location of the sources of input knowledge or how they are used to generate the outputs. The EKW would require knowledge to be pieced together from various systems and sources, merged into a cohesive whole, and made available to all those who need it. The EKW is therefore a managed knowledge base in which the knowledge is subject-oriented, integrated, time-variant, and non-volatile.

The design architecture of the EKW and its corresponding decision support for health care management systems is shown in Fig. 4.

EKW is designed to contain a broad range of DSS knowledge that is shared across the enterprise and built to meet the needs of multiple users belonging to multiple organizational units. It integrates shared knowledge across multiple business processes and the derived knowledge (e.g. billing) is designed to be computed by standard business rules to ensure consistency of results regardless of which application delivers it to the user. In addition, EKW is designed to provide consistent knowledge for DSS to the knowledge marts and DSS applications.

The operational knowledge store (OKS) consolidates knowledge from multiple source systems and is used as a source of cleansed, rationalized knowledge for other knowledge containers. The dependent knowledge marts contain subset of enterprise-shared knowledge for a segment (e.g. group, business process, etc.) and the contents of these marts must remain consistent with EKW to ensure consistency of reports (populated directly from the EKW). Furthermore, these marts must be designed to match the type of analysis required by target users—online analytical processing (OLAP), ad hoc, querying, etc. The independent knowledge mart is the same as dependent knowledge marts except that contents are or may be fed directly from source, or from any knowledge containers, but is not required to remain consistent with the EKW.

The access tools provide the means for business intelligence through ad hoc and managed query environment, OLAP support, statistical analysis tools, knowledge mining (answers that lead to new questions), and access to DSS applications at all levels.

The knowledge mining tools, in particular, identify patterns and relationships in the knowledge that may be useful for building models that aid decision-making or predict behavior (Goebel & Gruenwald, 1999). These tools enhance the decision-making process by providing new knowledge that users would not otherwise have been able to access on a timely basis. The newly extracted knowledge needs to be inserted into one or more knowledge bases to keep them continuously up-to-date for the practice of evidence-based medicine. Data visualization techniques that ease the interpretation process of new knowledge can be used in conjunction with the knowledge warehouse (Fayyad, Grinstein, & Wierse, 2001).

Knowledge mining has a wide range of applications in health care: market analysis and management, risk analysis and management, fraud detection and management, etc. The frequently mined knowledge by these applications are associations, classes (groups with particular profiles), clusters (groups of instances with the same characteristics), sequences (events linked over a period of time), exceptions (unusual knowledge), forecasts (estimations of future values of attributes), text (e-mails, news) and Web documents. In health care, the mining of knowledge to help identify costs, patient populations, emergency center utilization, lab utilization, operating room utilization, and patient flow have been used.

In summary, the benefits that can be derived from EKW may be directly reflected in the ease of knowledge access and operational efficiencies. However, the indirect benefits

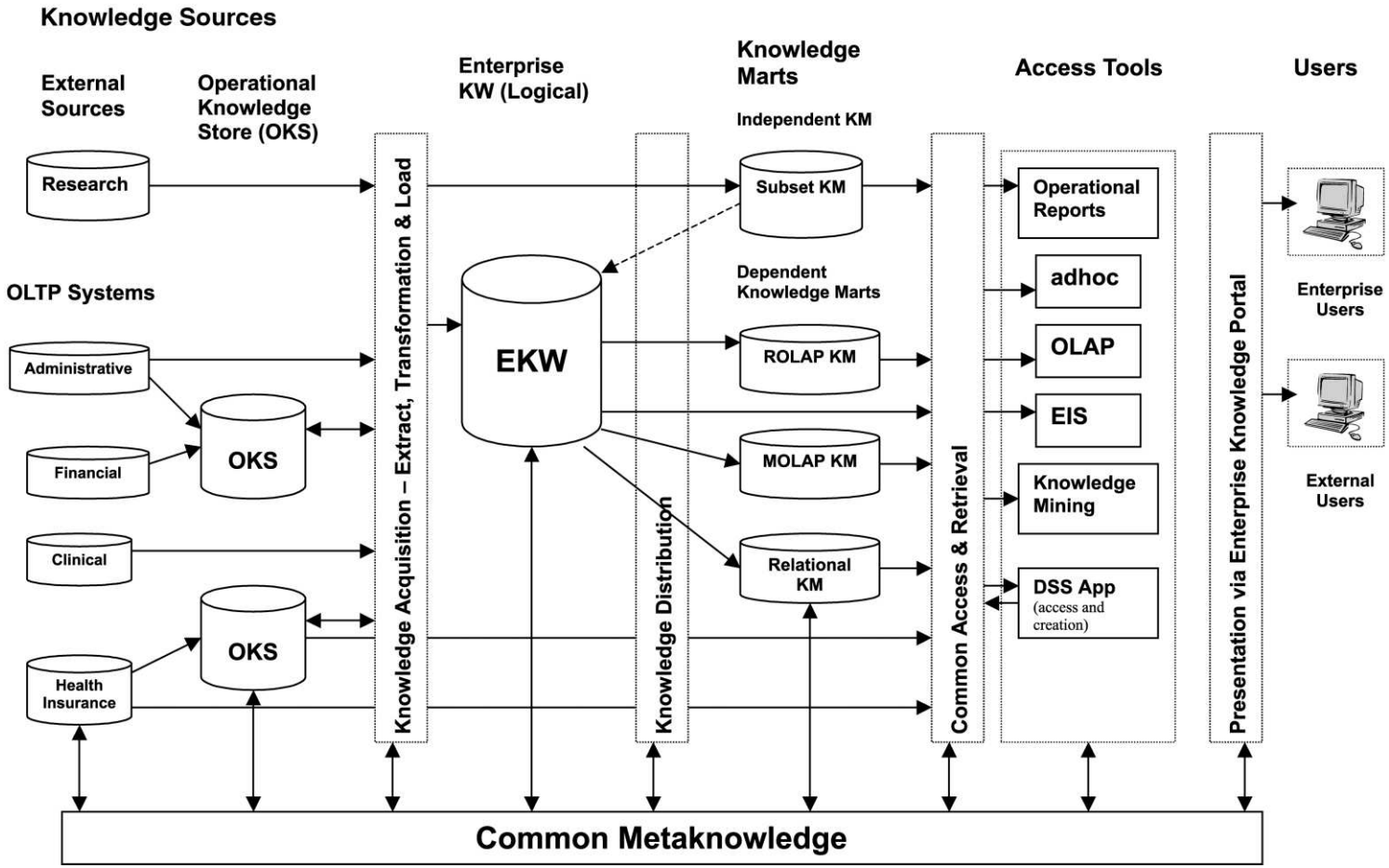


Fig. 4. Knowledge-based decision—support architecture for health care management systems.

are associated with improved customer focus and satisfaction, enhanced knowledge interpretation, and dissemination of knowledge to DSS users (both internal and external) and DSS applications may be the strongest contributions to competitive advantage. Several types of analysis can be performed using the DSS, in particular, the analysis of historical knowledge on populations, defined by the audience, not only will be of benefit in the administration of care to an individual patient but will also help in the formulation of programs on utilization management, medical management, and disease management.

6. Health care management system interface

The users of the health care management system would be using an enterprise knowledge portal (EKP) as the system interface that could be personalized to their needs and preferences. An EKP, simply and broadly, means a secure, Web-based interface that provides a one-stop (single point) interaction with appropriate intellectual capital, applications, expertise, and services for all people involved in the enterprise—including employees, partners, suppliers and customers. Fig. 5 shows a snapshot of the EKP that is envisioned for the health care management system. The features of the EKP are briefly described below.

Integration. In many ways the EKP is an amalgamation of business software programs within the enterprise (ERP, CRM, Web sites, Knowledge Warehouses, etc.) and knowledge and services external to enterprise—all of which are accessed from a single Web-based interface.

Personalization. Customization of content and 'look and feel'. Users should be able to choose what appears on their window to the enterprise—within certain role-defined constraints. This includes subscription and notification capabilities wherein users can opt to have knowledge or applications delivered to their desktops—controlling when it is delivered and how it is presented.

Content management. Requires directory and indexing capabilities to automatically manage the knowledge residing in knowledge warehouses, Web sites, ERP systems, etc. Using metaknowledge to define types of knowledge, the content management serves as the backbone for EKW and the corresponding DSS described in Section 5.

Search. Includes easy navigation of and access to corporate knowledge (organized by the content management system), providing the ability to drill down through knowledge to get to the information required by the user.

Publishing. For workers in the enterprise to put business knowledge into the system. It must support all the main knowledge types defined in the system and give users the ability to classify access to the knowledge being published according to defined roles or individuals within the enterprise.

Business intelligence. Provides access to DSS tools and applications that perform knowledge mining, OLAP, statistical analysis, decision-support sessions, etc. This feature contributes the most toward turning the business knowledge into competitive advantage.

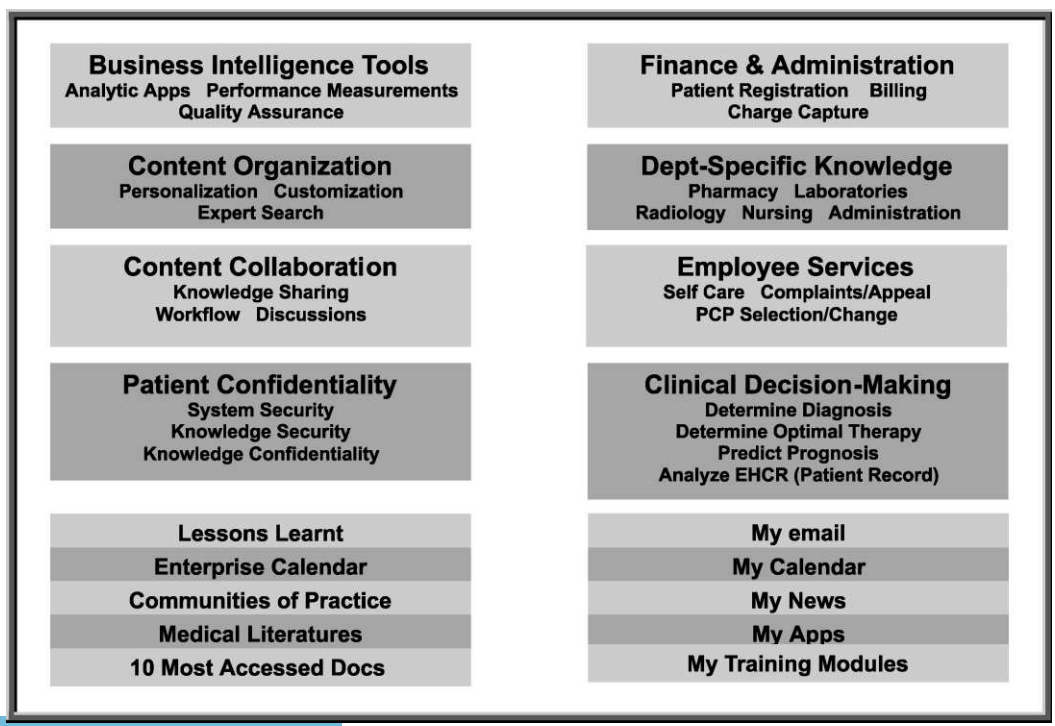


Fig. 5. Personalized EKP—a snapshot.

Security. Granular access controls for groups and individuals.

Collaboration. Share and collaborate on content to increase workflow productivity and interaction between and among employees, partners and suppliers. Collaborative functionality can range from tracking e-mail to developing workplace communities.

In summary, with a focus on integrating applications, services and knowledge, the EKP provides users both a manageable window to the enterprise and a powerful tool for making the decisions that will keep the enterprise competitive.

7. Future research

At the heart of the application of IT in health care is EHCR in which medical data about the patient is recorded. The development of industry-wide standard for EHCR is a major research issue that is currently being undertaken by several leading researchers. The Institute of Medicine has defined the EHCR as an "electronic patient record that resides in a system designed to support users through availability of complete and accurate data, practitioner reminders and alerts, CDSS, links to bodies of medical knowledge, and other aids".

A computer-based patient record system includes all the elements that facilitate the capture, storage, processing, communication, security, and presentation of computer-based patient record information. The linking of EHCR to clinical guidelines and protocols is essential if best practice is to be fully embedded as an integral part of health care delivery process. The insertion of clinical data into the EHCR irrespective of its source (information system, manual entry, monitoring device, and so forth), maintaining and building it, and then making the EHCR available to those who need it, are obvious issues to be dealt with for developing the uniform standard.

Related to the development of uniform standard of EHCR as well as critical to the success of evidence-based medicine is a need for further research to bring a resolution to the issues regarding agreement on messaging formats, system architectures, and clear articulation of the needs of the target user or customer of health care delivery system. If standard uniform data were captured at the point of care, clinicians would benefit from the capability to retrieve and exchange clinical data critical for clinical reports, statistics, and clinical outcomes analysis.

Research on privacy and confidentiality issues of health care knowledge including the lifetime health care record of patients is fundamental to the widespread adoption of health care management system. Significant privacy and confidentiality issues emerge when knowledge from widely disparate sources are brought together and made available in electronic form. There is an inherent tension between the clinician's need to have relevant knowledge easily available and the patient's legal and ethical right to have control over the dissemination of highly personal clinical information. Research on this topic should focus on three aspects. First, on *system security* or measures taken to keep computer-based information systems safe from unauthorized access and other harm; second, on *knowledge security* or measures taken to protect knowledge from accidental or intentional disclosure to unauthorized persons and from unauthorized alteration; and finally on *knowledge confidentiality* or measures taken to keep sensitive knowledge from being disclosed to unauthorized persons.

8. Conclusion

The dramatic transformation of health care organizations from independent local entities into regional and national integrated health care delivery enterprises has forced a reevaluation of the role of information systems. There is a growing realization that more widespread use of information technologies to increase efficiency and to enable changes in health care delivery processes could do much to improve the performance of health care systems, within the bounds of appropriate measures to protect the confidentiality of private health information. This research presented the capabilities, the technical infrastructure, and the decision support architecture of a knowledge management-enabled health care management system.

Decision-making is a knowledge-intensive activity with knowledge as its raw materials, work-in-progress, by-products, and finished goods (Holsapple, 2001). The design of EKW with its ability to provide better access to knowledge for decision-making would make it possible for the enterprise to enhance quality of patient care and deliver more responsive customer service while reducing the costs of health care.

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