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Cutting Through the Gordian Knot of Inefficient Healthcare Processes with the IC

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ABSTRACT
Medical science has made revolutionary changes in the past decades. Contemporaneously however, healthcare has made incremental changes at best. One area within healthcare that best exemplifies this is the OR. The growing discrepancy between the revolutionary changes in medicine and the minimal changes in healthcare processes is leading to inefficient and ineffective healthcare deliver and one if not the significant contributor to the exponentially increasing costs plaguing healthcare globally. Significant quantities of data and information permeate the healthcare industry, yet the healthcare industry has not maximized this data resource by fully embraced key business management processes or techniques (such as knowledge management, data mining, business intelligence or business analytics) to capitalize on realizing the full value of this data/information resource to re-engineer processes. The construct of the intelligence continuum, a Möbius of sophisticated tools, techniques and process provides a systematic mechanism for healthcare organizations to facilitate superior clinical practice and administrative management, is introduced. Further, the case example of the orthopedic OR is used to illustrate the power of the intelligent continuum (IC) in effecting more efficient and effective healthcare processes to ensue and thereby enabling healthcare to make evolutionary changes.

THE KNOWLEDGE ECONOMY
The world has witnessed three distinct ages so far – the Agrarian Age (or agricultural economy), the Industrial Age (or industrial economy), and now the Information Age (or knowledge economy). In today's knowledge economy, knowledge is now recognized as the driver of productivity and economic growth, leading to a new focus on the role of information, technology and learning in economic performance. A key raw material for all organizations in the knowledge economy is data, as this resource can be refined into information and ultimately knowledge, the ultimate source of sustainable competitive advantage. Organizations generally have been slow to maximize the potential of this raw data asset but healthcare organizations have been particularly slow. This is ironic since healthcare is an area that generates large volumes of heterogeneous data in all its processes that have significant impact on treatment outcomes for patients, the discovery of new methods to treat diseases and the need to facilitate better administrative functions throughout the healthcare web between provides, insurers, payors and patients. We posit in this paper, that by embracing the tools and techniques of the knowledge economy; namely by embracing the intelligence continuum, healthcare organizations will be better placed to not only maximize their data raw material but also realize the solutions they are turning to in order to meet today's challenges

HEALTHCARE CHALLENGES AND SOLUTION STRATEGIES
Currently the healthcare industry in the US is contending with relentless pressures to lower costs while maintaining and increasing the quality of service in a challenging environment [2][3]. It is useful to think of the major challenges facing today's healthcare organizations in terms of the categories of demographics, technology, and finance. Demographic challenges are reflected by longer life expectancy and an aging population; technology challenges include incorporating advances that keep people younger and healthier; and finance challenges are exacerbated by the escalating costs of treating everyone with the latest technologies. Healthcare organizations can respond to these challenges by focusing on three key solution strategies; namely, 1. access - caring for anyone, anytime, anywhere; 2. quality – offering world class care and establishing integrated information repositories; and 3. value – providing effective and efficient healthcare delivery. These three components are interconnected such that they continually impact on the other and all are necessary to meet the key challenges facing healthcare organizations today. Given the interdependent nature of these elements, the relationship can be defined as the AQV Möbius (figure 1). In order to fully actualize the AQV Möbius and thus best meet the current healthcare challenges, it is imperative that healthcare organizations embrace the tools, techniques and processes of today's knowledge economy; namely, incorporate the intelligence continuum into the generic healthcare information system.

THE INTELLIGENCE CONTINUUM
To understand the role of the intelligence continuum, an examination of a generic healthcare information system is necessary (figure 2). The important aspects in this generic system include the socio-technical perspective; i.e. the people, processes and technology inputs required in conjunction with data as a key input. The combination of these elements comprises an information system and in any organization multiple such systems could exist. To this generic system, we add the healthcare challenges; i.e. the challenges of demographics, technology and finance. As the baby boomers age, the incidence of people over the age of 65 is projected to be increased for the next forty years. Moreover, as people age, improved healthcare is providing those people over the age of 65 a longer lifespan and the ability to tell about it but also ultimately endure many complicated medical problems and diseases. Certainly technology is helping to keep everyone alive and younger and in better health but the cost to do so is escalating exponentially [3].

In order to address these challenges and actualize the AQV Möbius a closer examination of the data generate by the information systems and stored in the larger data warehouses and/or smaller data marts is necessary. In particular, it is important to make decisions and invoke the intelligence continuum; apply the tools, techniques and processes of data mining, business intelligence/analytics and knowledge management respectively. On applying these tools and techniques to the data generated from healthcare information systems, it is first possible to diagnose the "as is" or current state processes in order to make further decisions regarding how existing processes should be modified and thereby provide appropriate prescriptions to enable the achievement of a better future state; i.e. improve the respective inputs of the people, process, technology and data so that the system as a whole is significantly improved.

COMPONENTS OF THE INTELLIGENCE CONTINUUM

The Intelligence Continuum is defined as a collection of key tools, techniques and processes of today's knowledge economy; i.e. including but not limited to data mining, business intelligence/analytics and knowledge management. Taken together they represent a very powerful system for refining the data raw material stored in data marts and/or data warehouses and their by maximizing the value and utility of these data assets for any organization. The first component is a generic information system which generates data that is then captured in a data repository. In order to maximize the value of the data and use it to improve processes, the techniques and tools of data mining, business intelligence and analytics and knowledge management must be applied to the data warehouse. Once applied, the results become part of the data set that are reintroduced into the system and combined with the other inputs of people, processes, and technology to develop an improvement continuum. Thus, the intelligence continuum includes the generation of data, the analysis of these data to provide a "diagnosis" and the reintroduction into the cycle as a "prescriptive" solution (Figure 3). Each of the components of the intelligence continuum is now explored in more detail.

Data Mining

Due to the immense size of the data sets, computerized techniques are essential to help physicians as well as administrators understand relationships and associations between data elements. Data mining is closely associated with databases and shares some common ground with statistics since both strive toward discovering structure in data. However, while statistical analysis starts with some kind of hypothesis about the data, data mining does not. Furthermore, data mining is much more suited to deal with heterogeneous databases, data sets and data fields, which are typical of data in medical databases that contain numerous types of text and graphical data sets. Data mining also draws heavily from many other disciplines, most notably machine learning, artificial intelligence, and database technology.

Data mining then, is the non-trivial process of identifying valid, novel, potentially useful, and ultimately understandable patterns from data [4]. Clinicians accomplish these tasks daily in their care of patients using their own "personal CPU"; however, the enormous amounts and divergent sources of information coupled with time constraints limit any clinician's ability to fully examine all issues. Data mining algorithms are used on databases for model building, or for finding patterns in data. When these patterns are new, useful, and understandable, we say that this is knowledge discovery [5]. How to manage such discovered knowledge and other organizational knowledge is the realm of knowledge management [6].

Data mining then can also be considered as a step in the broader context of the knowledge discovery process that transforms data into knowledge [5]. It is essential to emphasize here the importance of the interaction with people; namely, medical professionals and administrators who always play a crucial and indispensable role in any knowledge discovery process in facilitating prediction of key patterns and also identification of new patterns and trends. This is particularly true when we take into consideration features that are specific to the medical databases. More and more medical procedures employ imaging as a preferred diagnosing tool. Thus, there is a need to develop methods for efficient mining in databases of images and associated clinical data, which is inherently more difficult than mining in numerical databases. Other significant features

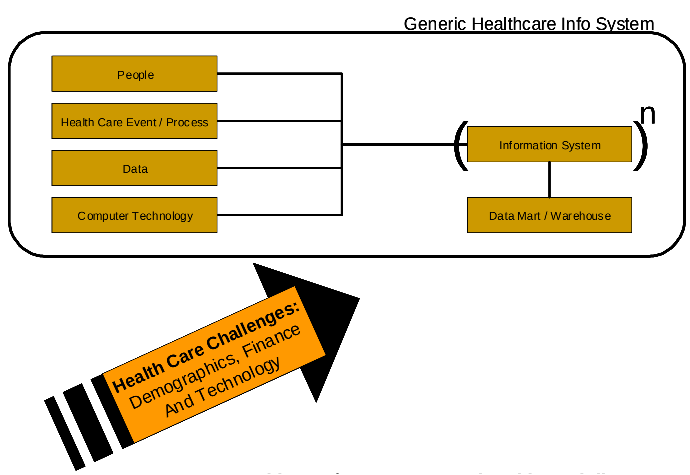
Figure 1. AQV Möbius

include but are not limited to security and confidentiality concerns and the fact that the physician's interpretation of images, signals, or other clinical data, is written in unstructured English – which is also very difficult to mine [7]. Some important data issues that data mining is most useful in helping organizations wrestle with include but are not limited to huge volumes of data, dynamic data, incomplete data, imprecise data, noisy data, missing attribute values, redundant data, and inconsistent data. Furthermore, data mining offers a wide variety of models to capture the characteristics of data and to help knowledge discovery; including, summarization, clustering/segmentation, regression, classification, neural networks, rough sets, association analysis, sequence analysis, prediction, exploratory analysis, and visualization. Figure 4 depicts 1) the evolution of knowledge from data through information and then to knowledge itself the primary product of data mining, 2) the key steps involved in the knowledge discovery process and 3) the two major types of data mining; exploratory and predictive..

Business Intelligence/Analytics

Another technology-driven technique, like data mining connected to knowledge creation is the area of business intelligence and the now newer term of business analytics. The business intelligence (BI) term has become synonymous with an umbrella description for a wide range of decision-support tools, some of which target specific user audiences [8][9]. At the bottom of the BI hierarchy are extraction and formatting tools which are also known as data-extraction tools. These tools collect data from existing databases for inclusion in data warehouses and data marts. Thus the next level of the BI hierarchy is known as warehouses and marts. Because the data come from so many different, often incompatible systems in various file formats, the next step in the BI hierarchy is formatting tools, these tools and techniques are used to

Figure 2. Generic Healthcare Information System with Healthcare Challenges



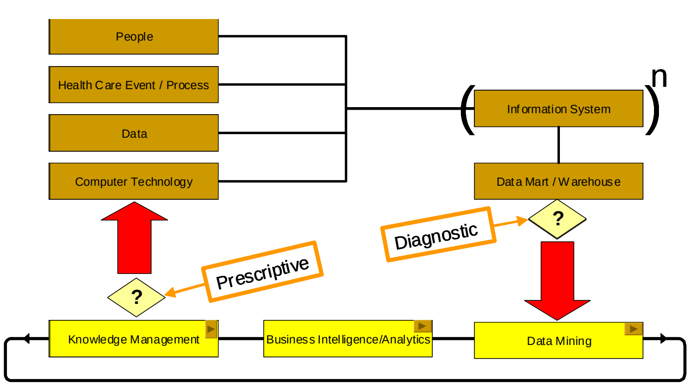
"cleanse" the data and convert it to formats that can easily be understood in the data warehouse or data mart. Next, tools are needed to support the reporting and analytical techniques. These are known as enterprise reporting and analytical tools. OLAP (on-line analytic process) engines and analytical application-development tools are for professionals who analyze data and do business forecasting, modeling, and trend analysis are some examples. Human intelligence tools form the next level in the hierarchy and involve human expertise, opinions, and observations to be recorded to create a knowledge repository. These tools are at the very top of the BI hierarchy and serve to amalgamate analytical and BI capabilities along with human expertise. Business analytics (BA) is a newer term that tends to be viewed as a sub-set of the broader business intelligence umbrella and specifically focuses on the analytic aspects within BI [8].

Knowledge Management

Knowledge management is an emerging management approach that is aimed at solving the current business challenges to increase efficiency and efficacy of core business processes while simultaneously incorporating continuous innovation. Specifically, knowledge management through the use of various tools, processes and techniques combines germane organizational data, information and knowledge to create business value and enable an organization to capitalize on its intangible and human assets so that it can effectively achieve its primary business goals as well as maximize its core business competencies [10][11]. The premise for the need for knowledge management is based on a paradigm shift in the business environment where knowledge is central to organizational performance [12]. Broadly speaking, knowledge management involves four key steps of creating/generating knowledge, representing/storing knowledge, accessing/using/re-using knowledge, and disseminating/transferring knowledge [6] (figure 5).

In today's context of escalating costs in healthcare, managed care, regulations and a technology and health information savvy patient, the healthcare industry can no longer be complacent regarding embracing key processes and techniques to enable better, more effective and efficient practice management. The proliferation of databases in every quadrant of healthcare practice and research is evident in the large number of isolated claims databases, registries, electronic medical record data warehouses, disease surveillance systems, and other ad hoc research database systems. Not only does the number of databases grow daily, but even more importantly, so does the amount of data within them. Pattern-identification tasks such as detecting associations between certain risk factors and outcomes, ascertaining trends in healthcare utilization, or discovering new models of disease in populations of individuals rapidly become daunting even to the most experienced healthcare researcher or manager [13]. Yet these tasks may hold the answers to many clinical issues such as treatment protocols or the identification across geographic areas of newly emerging pathogens and thus are important. Add to all of this, the daily volumes of data generated and then accumulated from a healthcare organization administrative system, clearly then, the gap between data collection and data comprehension and analysis becomes even more problematic. Information technology (IT) tools coupled with new business approaches such as data mining, business intelligence/analytics and knowledge management should be embraced in an attempt to address such healthcare woes [14][7].

Figure 3. Impact of the Intelligence Continuum on the Generic Healthcare System



CLINICAL EXAMPLE: OPERATING ROOM

The orthopaedic operating room represents an ideal environment for the application of a continuous improvement cycle that is dependant on the Intelligence Continuum. For those patients with advanced degeneration of their hips and knees, arthroplasty of the knee and hip represent an opportunity to regain their function. Before the operation ever begins in the operating room, there are a large number of interdependent individual processes that must be completed. Each process requires data input and produces a data output such as patient history, diagnostic test and consultations. From the surgeon's and hospital's perspective, they are on a continuous cycle such as depicted by the AQV Möbius. The interaction between these data elements is not always maximized in terms of operating room scheduling and completion of the procedure. Moreover, as the population ages and patient's functional expectations continue to increase with their advanced knowledge of medical issues; reconstructive Orthopaedic surgeons are being presented with an increasing patient population requiring hip and knee arthroplasty. Simultaneously, the implants are becoming more sophisticated and thus more expensive. In turn, the surgeons are experiencing little change in system capacity, but are being told to improve efficiency and output, improve procedure time and eliminate redundancy. However, the system legacy is for insufficient room designs that have not been updated with the introduction of new equipment, poor integration of the equipment, inefficient scheduling and time consuming procedure preparation. Although there are many barriers to Re-Engineering the Operating Room such as the complex choreography of the perioperative processes, a dearth of data and the difficulty of aligning incentives, it is indeed possible to effect significant improvements through the application of the intelligence continuum.

The entire process of getting a patient to the operating room for a surgical procedure can be represented by three distinct phases: preoperative, intraopertive and postoperative. In turn, each of these phases can be further subdivided into the individual yet interdependent processes that represent each step on the surgical trajectory. As each of the individual processes are often dependant on a previous event, the capture of event and process data in a data warehouse is necessary. The diagnostic evaluation of this data, and the re-engineering of each of the deficient processes will then lead to increased efficiency. For example,

Figure 4. Key Steps of Data Mining

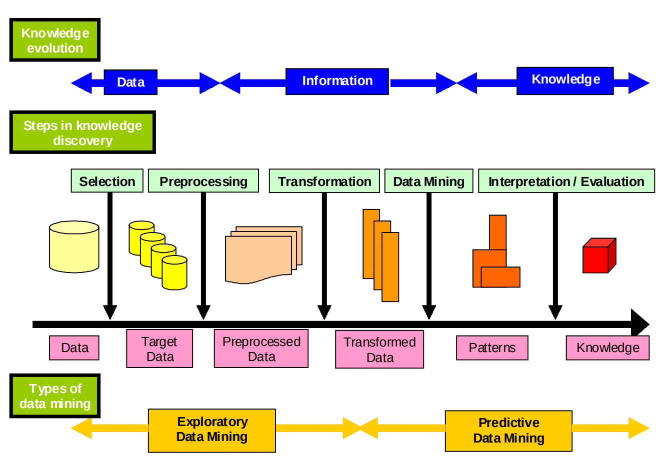
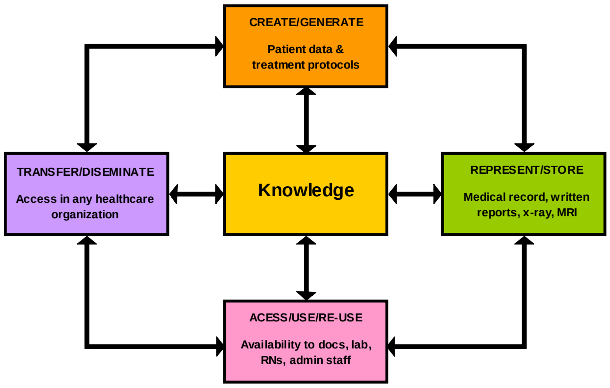


Figure 5. Key Steps of Knowledge Management



many patients are allergic to the penicillin family of antibiotics that are often administered preoperative in order to minimize the risk of infection. For those patients who are allergic, a substitute drug requires a 45 minute monitored administration time as opposed to the much shorted administration time of the default agent. Since the antibiotic is only effective when administered prior to starting the procedure, this often means that a delay is experienced. When identified in the preoperative phase, these patients should be prepared earlier on the day of surgery and the medication administered in sufficient time such that the schedule is not delayed. This prescriptive reengineering has directly resulted from mining of the data in the information system in conjunction with an examination of the business processes and their flows. By scrutinizing the delivery of care and each individual process, increased efficiency and improved quality should be realized while maximizing value. For knee and hip arthroplasty, there are over 432 discrete processes that can be evaluated and reengineered as necessary through the application of the Intelligence Continuum [15].

DISCUSSION AND CONCLUSION

The discussion about the intelligence continuum has served to highlight the significance and key role for knowledge management, business intelligence/analytics and data mining in healthcare. Specifically, this was done by discussing some of the major challenges facing healthcare today in terms of demographics, technology and finance. Next, the benefit of incorporating the intelligence continuum in order for healthcare to actualize the AQV Möbius was presented before each of the key components of the intelligence continuum was defined in turn. Finally, an example of how beneficial the incorporation of such a perspective is in redesigning the current state of the OR to a future state of the OR was given. Taken together then, this paper serves to under score the importance of taking a holistic approach to addressing the challenges currently faced by healthcare. Furthermore, by focusing on diagnosing the current state and then finding appropriate solutions so it is possible to prescribe strategies to make the key inputs into the healthcare information system more effective and efficient it will then be possible to realize the value proposition for healthcare; namely effect the AQV Möbius. While medical science has made revolutionary changes, healthcare in contrast has made incremental changes at best. The disparity between these two is one of the major reasons why today's healthcare industry is faced with its current challenges. By embracing the intelligence continuum it will be possible for healthcare to make evolutionary changes and thereby meet patients great expectations.

REFERENCES

[1] Wickramasinghe, N. and S. Sharma forthcoming 2005 *The Fundamentals of Knowledge Management* Prentice Hall, Upper Saddle River.

[2] Pallarito, K. 1996 "Virtual Healthcare" *Modern Healthcare* pp. 42-44 Mar.

[3] Wickramasinghe, N. and J.B. Silvers 2003 "IS/IT The Prescription To Enable Medical Group Practices To Manage Managed Care" Health Care Management Science vol. 6 pp-75-86.

[4] Krzysztof J. Cios, editor; "Medical data mining and knowledge discovery"; Physica-Verlag, 2001.

[5] Fayyad, Piatetsky-Shapiro, Smyth, "From Data Mining to Knowledge Discovery: An Overview", in Fayyad, Piatetsky-Shapiro, Smyth, Uthurusamy, Advances in Knowledge Discovery and Data Mining, AAAI Press / The MIT Press, Menlo Park, CA, 1996.

[6] Wickramasinghe, N., A. Fadlalla, E. Geisler and J. Schaffer 2003 "Knowledge Management and Data Mining: Strategic Imperatives for Healthcare" proceedings of the 3rd Hospital Of the Future Conference.

[7] Marianne Kolbasuk McGee; "High-Tech Healing"; Information Week, September 22, 1997.

[8] Kudyba, S. & R. Hoptroff 2001. Data Mining and Business Intelligence: A Guide to Productivity, IGP, Hershey.

[9] Dhar, V. and R. Stein 1997 Seven Methods for Transforming Corporate Data into Business Intelligence, Prentice Hall, Upper Saddle River.

[10] Swan, J., H. Scarbrough & J. Preston 1999 "Knowledge Management – The Next Fad To Forget People?" Proceedings of the 7th European Conference in Information Systems.

[11] Davenport, T & L. Prusak, 1998 Working Knowledge, Harvard Business School Press, Boston.

[12] Drucker, P. 1993. Post-Capitalist Society. New York, Harper Collins.

[13] Holmes, J. P. Abbott, P. Cullen, RN, L. Moody, K. Phillips, B. Zupan; "Clinical Data Mining: Who does it, and what do they do?"; AMIA 2002 Symposium, Nov. 9-13, 2002.

[14] Berinato, S; CIOs at the Heart of Health-Care Change; CIO Magazine Jun 15,2002.

[15] Schaffer, Steiner, Krebs and Hahn; Orthopaedic Operating Room of the Future, 2004, unpublished data.

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