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Author names: Wickramasinghe, N. , Bali, R. , Gibbons, C. , Choi, J.H.J. and Schaffer, J.L.
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A Systematic Approach

Optimization of Healthcare Operations with Knowledge Management

By Nilmini Wickramasinghe, MBA, PhD; Rajeev K. Bali, PhD; M. Chris Gibbons, MD; Capt. J.H. James Choi, USAF, MS; and Jonathan L. Schaffer, MD, MBA

KEYWORDS

Process engineering, knowledge management, optimization, data mining, effective healthcare delivery.

ABSTRACT

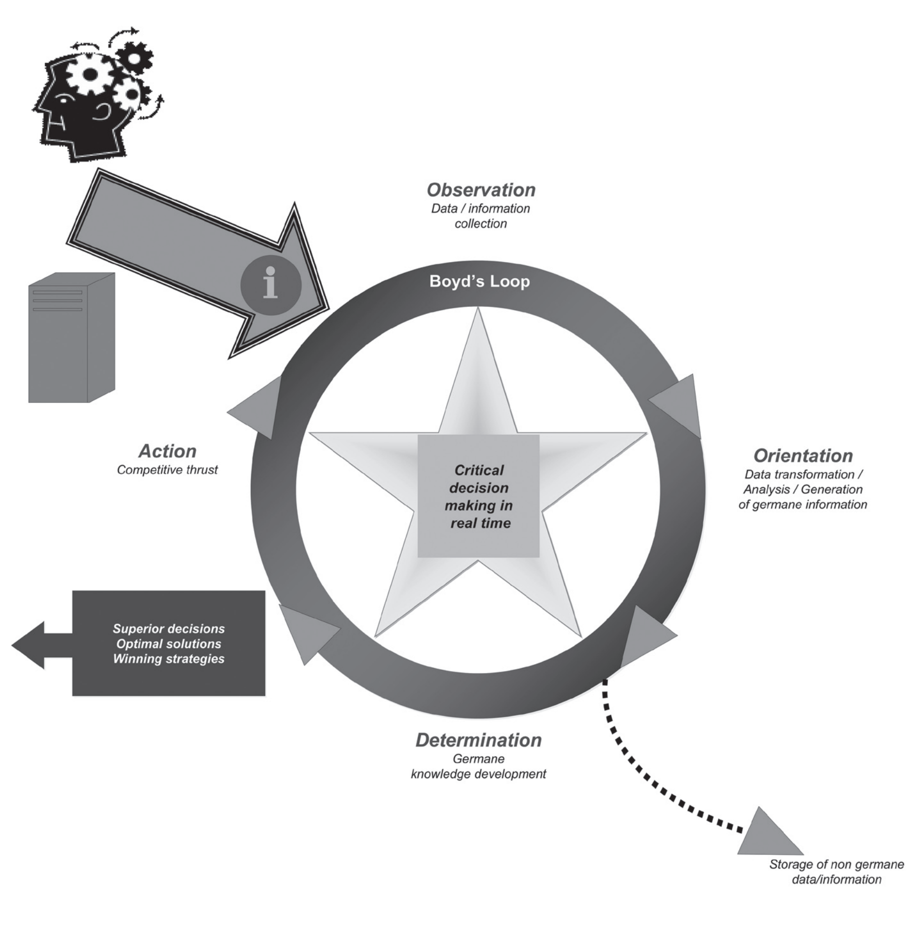
Effective decision making is vital in all healthcare activities. While this decision making is typically complex and unstructured, it requires the decision maker to gather multi-spectral data and information in order to make an effective choice when faced with numerous options. Unstructured decision making in dynamic and complex environments is challenging and in almost every situation the decision maker is undoubtedly faced with information inferiority. The need for germane knowledge, pertinent information and relevant data are critical and hence the value of harnessing knowledge and embracing the tools, techniques, technologies and tactics of knowledge management are essential to ensuring efficiency and efficacy in the decision making process. The systematic approach and application of knowledge management (KM) principles and tools can provide the necessary foundation for improving the decision making processes in healthcare. A combination of Boyd's OODA Loop (Observe, Orient, Decide, Act) and the Intelligence Continuum provide an integrated, systematic and dynamic model for ensuring that the healthcare decision maker is always provided with the appropriate and necessary knowledge elements that will help to ensure that healthcare decision making process outcomes are optimized for maximal patient benefit. The example of orthopaedic operating room processes will illustrate the application of the integrated model to support effective decision making in the clinical environment.

As the population ages, an increasing number of people will experience debilitating degenerative arthritis of the knee and hip joint. In degenerative arthritis, the articular, gliding surface of the joint becomes worn and exposes the underlying bone of the joint. This is a painful condition for which patients seek medical care to decrease their pain and increase their functional status. In fact, the number of persons age 65 or older is expected to double between the year 2000 and the year 2040.[1] One of the most successful procedures in the treatment of knee and hip arthritis is to replace the worn surfaces with the metal and plastic components of a hip or knee joint replacement. This procedure is completed in a hospital's operating room; the patient stays in hospital for a few days to start their recovery and is then discharged to home or a rehabilitation facility for further rehabilitation. Within the next twenty years, domestic demand for joint replacements is expected to increase by 174 percent for hips and 673 percent for knees.[2] The demands on the healthcare system for effective decision making in this patient population will be staggering.

CHALLENGES

Once the patient's arthritis is end-stage and the articular cartilage is worn away, patients with painful degenerative arthritis will

Fig. 2: Boyd's OODA Loop.



accurate and optimal and minimizing the effect of late cancellations that lead to lost opportunity costs. Additionally, the healthcare system must provide sufficient hospital resources so that patients can efficiently move from the operating room to the recovery room to their nursing floor bed and then to either a rehabilitation hospital bed or home with the provision of home care services such as physical therapy.

The entire process can initially be represented by three distinct phases: preoperative, intraoperative and postoperative. (Fig. 1) Each of these phases is dependant on a previous state or event and the capture of the data from that previous state is important to the optimization of the next phase. Many surgeons focus their practice on joint replacement surgery and will attest that their methods and procedures don't change significantly from operation to operation. While this statement may be disputed to some extent by the operating room personnel, every joint replacement follows a very similar pattern of events. The surgeon's performance of a joint replacement is fairly similar across hundreds of procedures but the most significant difference between each of the operations is the substrate changes, i.e. each patient is different. Successful execution of the processes in the operating room is dependent on the preoperative, intraoperative and postoperative processes that comprise the spectrum of orthopaedic care.

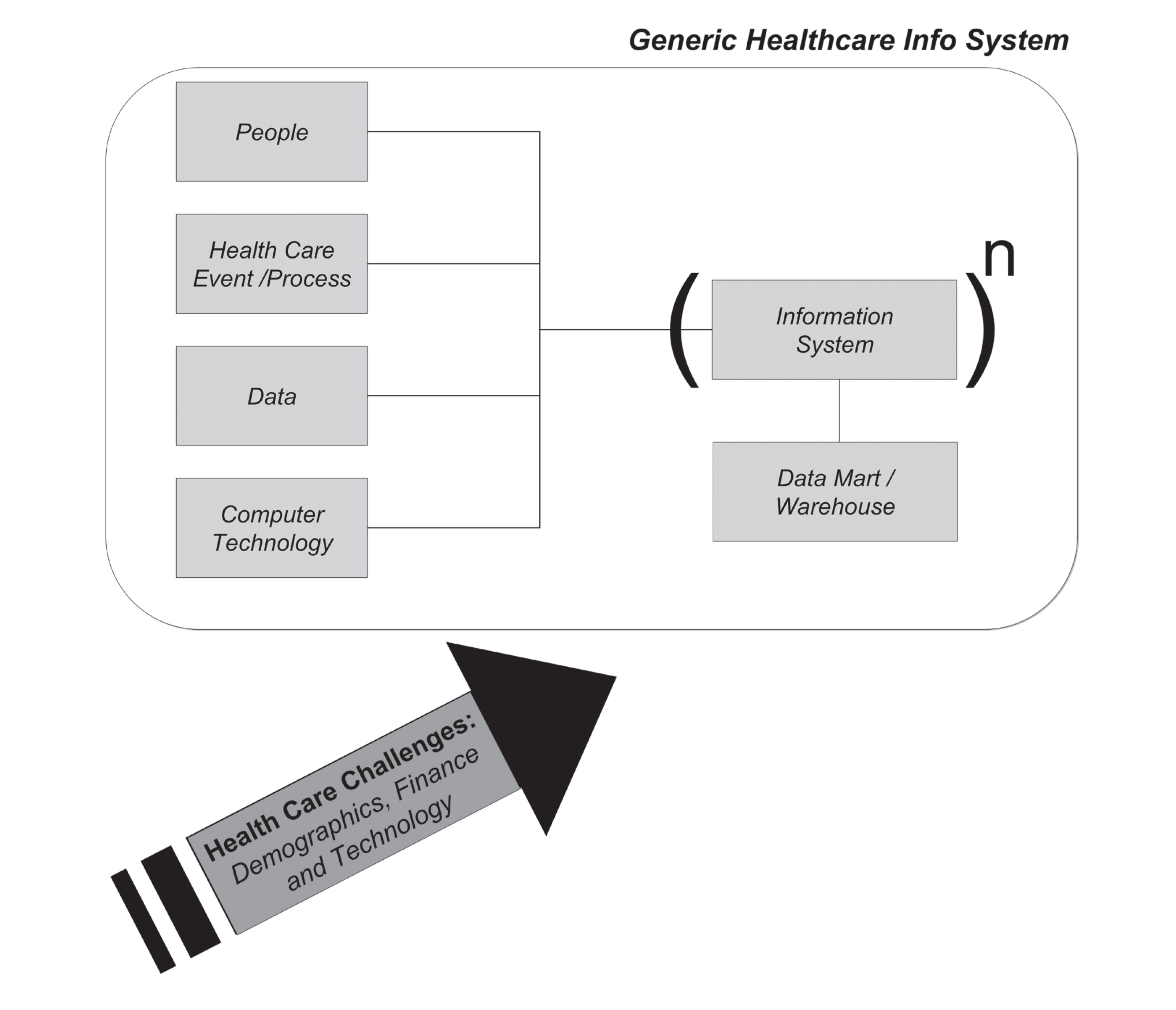
seek the expertise of an orthopaedic surgeon. Replacement of the degenerative surfaces of the hip and knee joint has become one of healthcare's most successful procedures in terms of providing the patient with pain relief and improved function. These operations are performed by the surgeon in a hospital in which the surgeon has been credentialed and has privileges to admit their patients and perform operations in which the surgeon has expertise. As the population requiring medical care increases, hospitals worldwide are being challenged to provide sufficient resources, including operating rooms, for these patients. There is also more pressure on the hospitals to decrease their cost structure in the face of increasing volumes while the introduction of newer medical technology, including new and presumably more advanced implants complicates the situation.

Patient preparation for a hip or knee replacement is dependant on their surgeon's evaluation and treatment plan as well as the preoperative evaluation to clear a patient for surgery by anesthesia and/or internal medicine providers. In many cases, a medical evaluation is also needed to ensure that the operative procedure is done in the safest manner possible. Ensuring that patients are optimally prepared for the day of surgery is critical to keeping both the surgeon's schedule and an operating room schedule

STAKEHOLDERS AND OBJECTIVES

The process stream begins with a patient experiencing pain and decreased function sufficient to present with their complaints to an orthopedic surgeon. Once the decision is made to proceed with the procedure, the patient is scheduled for the necessary preoperative evaluations and the surgery is scheduled at the hospital. The surgeon will also indicate their preference for a specific implant system and the hospital will ensure that those implants and the instruments used for their insertion are present for the surgery. In further preparation for the day of surgery, the sterilization and supply teams at the hospital are charged with assembling all of the necessary materials, the operating room nursing team sets up the sterile instruments and equipment and the operating room and the anesthesia team is tasked with providing the patient with a safe and pain-free operative experience. The surgeon and their assistants then can complete the operative procedure as scheduled. The postoperative recovery room nursing team provides the next step in the process by helping the patient recover from the

Fig. 3: Generic healthcare information system with healthcare challenges.



operative episode. Then the patient will go to the most appropriate nursing floor to start their recuperation with the assistance of the nursing team, the physical and occupational therapists, the surgical team and when necessary, various medical consultants. Once specific surgeon and institutional milestones have been reached, the patient is discharged to a rehabilitation nursing facility or to home where further physical therapy is provided. In all over 250 people and over 435 individual processes are involved with a single patient's operative procedure.[3] Each entity, hospital and surgeon's office has specific fixed and variable expenses that are greatly influenced by every process in the patient's care.

TECHNOLOGY

Hip and knee implants are undergoing a constant state of innovation and improved technology. While the benefits of these purported improvements are not always proven in a stringent or conclusive examination, the implant manufacturers are under immense pressure to improve their market share and profitability. As technologic advances in implants evolve in the marketplace, the implant companies are challenged to maintain pricing levels that provide the desired financial margins. As with all products, as the time from initial introduction increases, the products are seen as a commodity and the downward pricing pressures increase. In many cases, the hospital bears the increased costs of the new technology that the surgeons want to use while the margins of the implant companies increase. In the last 10 years, additional developments in implant insertion methodologies have included computerized navigation systems, newer instrument sets, new bearing surfaces and newer imaging based custom insertion instrument development. While direct to consumer marketing efforts have attempted to influence and pressure the surgeon's behavior through the demands of the consumer, the market has not been significantly influenced[4] Additionally, the value of these newer technologies has not yet been conclusively demonstrated.

Many hospitals are also involved in the implementation of electronic medical records systems to document and make available for dissemination the details of the care processes through nursing and physician notes and provide clinical decision support and computerized order entry processes. Hospital supply chain management and human resource teams have also been implementing electronic systems to improve the scheduling of personnel and the stocking, ordering and billing reconciliation of supplies and implants. The incremental costs of implementing these electronic systems have been borne by hospitals and doctor's offices while the payers' "reimbursement" for services rendered have been consistently decreasing.

The systematic approach and application of knowledge management (KM) principles and tools can provide the necessary foundation for improving the decision making processes in healthcare.

CREATING VALUE FROM KNOWLEDGE

As in the context of the orthopaedic operating room, in most healthcare activities, a critical function in the care process is decision making. While providers strive to bring order and structure to the care process, most decision making processes are more typically complex and unstructured. Unstructured decision making requires the gathering of multi-spectral data and information if the decision maker is to make a prudent choice.[5] Unstructured decision making in dynamic and complex environments is challenging and the decision maker is always at a point of information inferiority[6] as the decision maker is almost always missing information. It is in such situations that the need for germane knowledge, pertinent information and relevant data are critical (ibid) and hence the value of knowledge and the tools, techniques, technologies and tactics of KM are most beneficial.

Hierarchically, the gathering of information precedes the transformation of information into useable knowledge.[7,8] Hence, the rate of information collection and the quality of the collected information will have a major impact on the quality and usefulness of the generated knowledge.[9] In the dynamic and, to a large degree, unpredictable world of global healthcare, "action space awareness" (or synonymous "competitive space awareness") and information superiority.[10,11] have become the key factors to all successful operations. Such awareness however, can only be enabled through the extraction of multi-spectral data.

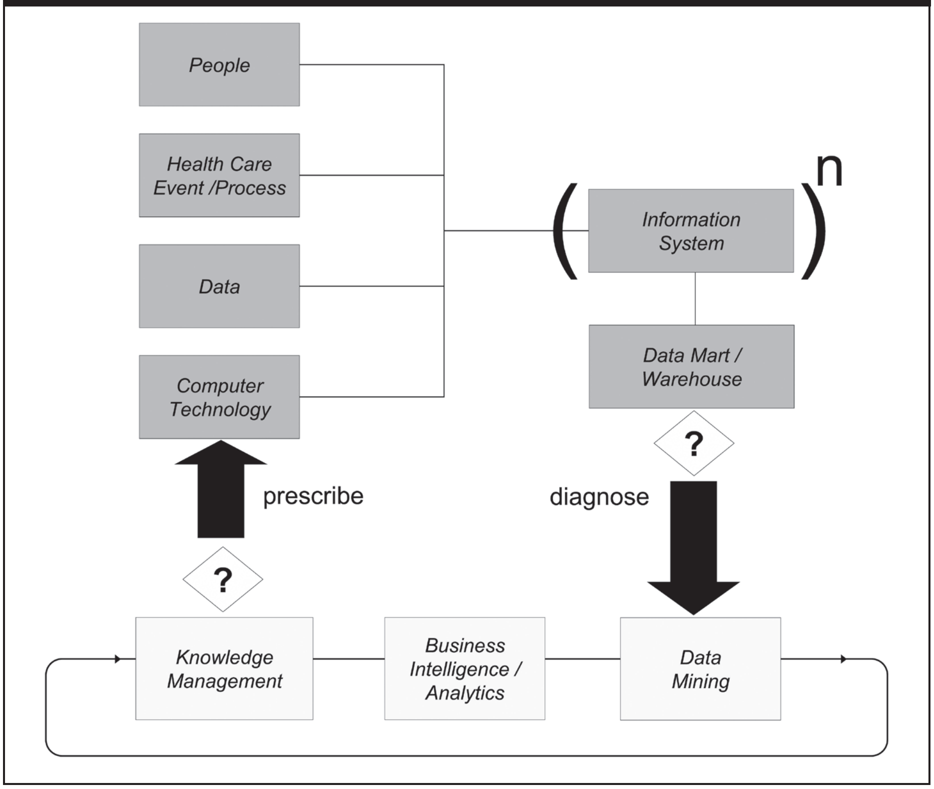
Boyd's OODA Loop (Fig. 2) provides a formalized analysis of the processes involved in the development of a superior strategy[11,12,13,14,15] and a suitable model to facilitate the organizing of germane knowledge. Boyd created the OODA loop to describe air warfare systems and has been credited as a predecessor and influencer of many management programs. The OODA Loop is based on a cycle of four interrelated stages revolving in time and space: Observation followed by Orientation, then by Decision, and finally Action. At the Observation and Orientation stages, multi-spectral implicit and explicit inputs are gathered (Observation) and converted into coherent information (Orientation). The latter determines the sequential Determination (knowledge generation) and Action (practical implementation of knowledge) steps. The outcome of the latter affects, in turn, the character of the starting point (Observation) of the next revolution in the forward progression of the rolling loop. The Orientation stage specifies the characteristics and the nature of the "center of thrust" at which the effort is to concentrate during the Determination and Action stages. Hence, the OODA Loop implicitly incorporates the rule of "economy of force," i.e., the requirement that only minimum but adequate (containment) effort is applied to insignificant aspects of competitive interaction. The Loop exists as a network of simultaneous and intertwined events that characterize the multidimensional action space (competition space), and both influence and are influenced by the actor (e.g., an organization) at the centre of the network. Moreover, the events provide the context and search criteria for extracting germane knowledge.

THE INTELLIGENCE CONTINUUM

Currently, the healthcare industry is contending with relentless pressures to lower costs while maintaining and increasing the quality of service in a challenging environment.[5,16] It is useful to categorize the major challenges facing today's healthcare organizations in terms of demographics, technology, and finance.[17] Demographic challenges are reflected by longer life expectancy and an aging population; technology challenges include incorporating advances that keep people 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, access—caring for anyone, anytime, anywhere; quality—offering world class care and establishing integrated information repositories; and value—providing effective and efficient healthcare delivery.[18] 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 and to 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.

To understand the role of the intelligence continuum, an examination of a generic healthcare information system is necessary. (Fig. 3) 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 within any one organization, multiple such systems could exist. To this generic system, we add the influences of healthcare challenges; i.e. the challenges of demographics, technology and finance. As

Fig. 4: The impact of the intelligence continuum on the generic healthcare system.



baby boomers age, the incidence of people over the age of 65 is projected to increase for the next forty years.[1] 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 while also ultimately enduring 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.[19]

Addressing these challenges is best approached through a closer examination of the data generated by the information systems and stored in the larger data warehouses and/or smaller data marts. 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.

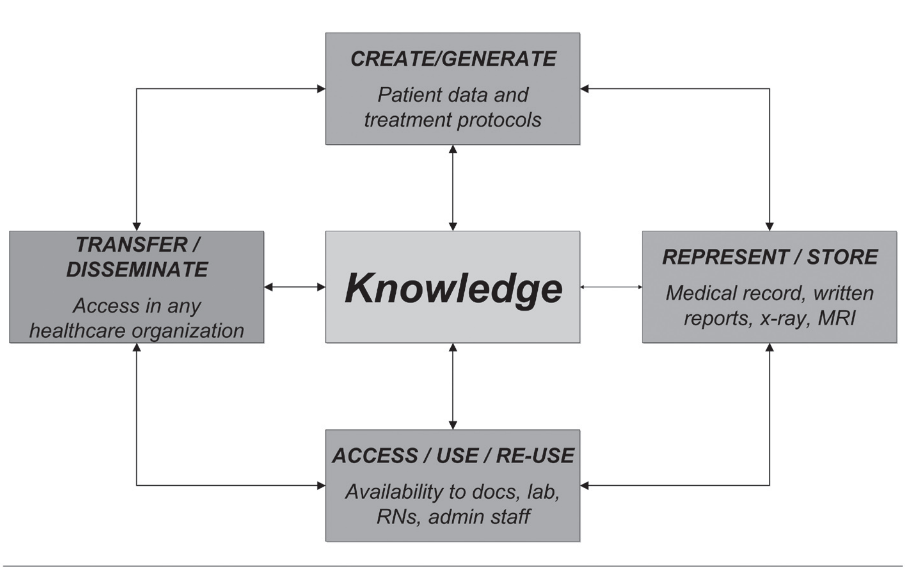
The Intelligence Continuum[17] is a representation of the collection of key tools, techniques and processes of today's knowledge economy; i.e. including but not limited to data mining, business intelligence/analytics and knowledge management. Taken together they represent a very powerful system for refining the data raw material stored in data marts and/or data warehouses and thereby 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. (Fig. 4)

In today's context of escalating costs in healthcare, managed care in the US, 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.[20] 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 becomes daunting even to the most experienced healthcare researcher or manager.[21] 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.[22,23] Figure 5 highlights important aspects of knowledge in essential healthcare operations.

RETURNING TO THE ORTHOPAEDIC OPERATING ROOM

The orthopaedic operating room represents an ideal environment for the application of a continuous improvement cycle that

Fig. 5: The key steps of knowledge management.



is dependant on and can benefit from the Intelligence Continuum. For those patients with advanced degeneration of their hips and knees, arthroplasty of the knee and hip represent an opportunity to alleviate pain and 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 tests and consultations. Keeping the process moving for each patient and maintaining a full schedule for the surgeon and the hospital are challenges that require accurate and timely information for successful process completion and achieving the goals for each patient, surgeon and the hospital simultaneously. 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 patients' 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 and the processes involved in 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.

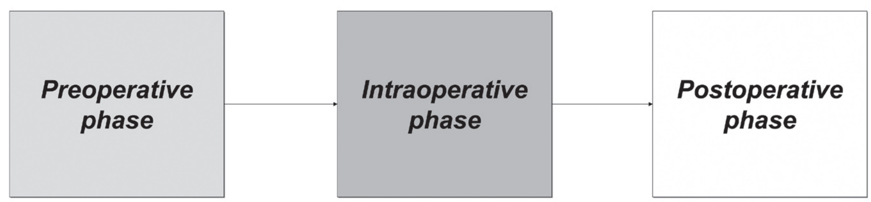
The entire process of getting a patient to the operating room for a surgical procedure can be represented by three distinct phases: preoperative, intraoperative and postoperative (Fig. 1). In turn, each of these phases can be further subdivided into the individual yet interdependent processes that represent each step on the surgical trajectory. As each of the individual processes is 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 set and the re-engineering of each of the deficient processes will then lead to increased efficiency. For example, many patients are allergic to the penicillin family of antibiotics that are often administered preoperatively in order to minimize the risk of infection. For those patients who are allergic, a substitute drug requires a 60 minute monitored administration time as opposed to the much shorter 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.[24]

CONCLUSIONS

To improve the efficiency and efficacy of patient care especially for those patients requiring hip or knee replacement, every healthcare process on the pathway from evaluation to operation to recovery should be optimized – the inputs, transformation and outputs should be measured against specification for process time, scheduling, expenses, personnel, etc. Each individual in the long chain of processes has tacit knowledge that increases with each day of experience while the explicit knowledge in the institutional or surgeon's policies and procedures manual are infrequently updated. The opportunity to improve the knowledge spiral and use the Intelligence Continuum to capitalize on realizing the full value of the system is unparalleled. The inherent limitations of organizational structure must be overcome to make these improvements.

The first steps in a process improvement project include the identification of each knowledge point, i.e. the process map-

Fig. 1: The phases of care and processes for patients undergoing joint replacement.



ping for joint replacement procedures with the goal of improving performance and predictability while minimizing variances, decreasing "waste" and increasing value while minimizing costs. The generation, representation, storage, transfer and transformation of knowledge are key steps in making the desired improvements in clinical and management practices and incorporating continuous innovation. The current state is that the daily volume data that is generated and accumulated is often lost, further increasing the gaps between data collection, comprehension and analysis. Boyd's OODA loop model of observation, orientation, decision, and action can organize the inputs and provide a structure for improvement. More patients with degenerative knee and hip arthritis will need joint replacement. Surgeons and hospitals with successful clinical outcomes will use process engineering tools to identify critical path processes and the stakeholders to optimize process efficiency, efficacy, productivity, safety and satisfaction. **JHIM**

Nilmini Wickramasinghe, MBA, PhD, s a professor at the School of Business Information Technology, RMIT University, Australia. She is internationally recognized and well published in the area of healthcare and knowledge management.

Rajeev K. Bali, PhD, is a Reader in Healthcare Knowledge Management at Coventry University (UK). His research interests lie in clinical and healthcare knowledge management.

M. Chris Gibbons, MD, is Associate Director, Johns Hopkins Urban Health Institute and an Assistant Professor at Johns Hopkins Schools of Medicine and Public Health.

James Choi, USAFR, MSC, is currently a fourth year medical student at Case Western Reserve University and has been a research associate in the Advanced Operative Technology Group at Cleveland Clinic.

Jonathan L. Schaffer, MD, MBA, is Managing Director, eCleveland Clinic Information Technology Division and Program Director of the Advanced Operative Technology Group, Orthopaedic and Rheumatologic Research Center at the Cleveland Clinic.

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