The Role of Healthcare System of Systems and Collaborative Technologies in Providing Superior Healthcare Delivery to Native American Patients

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Abstract

Healthcare delivery throughout the United States occurs at varying standards of quality. One segment of the community that continues to suffer from issues pertaining to poor access and low quality is the American Indians and Alaska Natives (AI/AN) population. Such a situation is clearly untenable, especially given the plethora of tools, techniques, technologies and tactics afforded by today's knowledge economy. In this paper, we proffer a model incorporating a system of systems approach in order to provide better healthcare delivery to native American patients. We first discuss the role of collaborative technologies in healthcare system of systems. Then we describe the role of healthcare system of systems and collaborative technologies in healthcare delivery to native American patients.

Key words: Healthcare Delivery, Native American Patient Care, Knowledge Management, Healthcare Information Systems, Healthcare System of Systems, Intelligence Continuum

1. Introduction

The Indian Health Service (IHS), an agency within the Department of Health and Human Services, is responsible for providing federal health services to American Indians and Alaska Natives. The provision of health services to members of federally-recognized tribes grew out of the special government-to-government relationship between the federal government and Indian tribes. This relationship, established in 1787, is based on Article I, Section 8 of the Constitution, and has been given form and substance by numerous treaties, laws, Supreme Court decisions, and Executive Orders. The IHS is the principal federal health care provider and health advocate for Indian people, and its goal is to raise their health status to the highest possible level. The IHS currently provides health services to approximately 1.5 million American Indians and Alaska Natives who belong to more than 557 federally recognized tribes in 35 states [1]. While most IHS services are provided on or near reservations, approximately one percent of the budget is used to provide services to Indian people living in urban areas, even though most recent census data shows the majority of Native Americans are urban. Clients of the Urban Indian program commonly experience barriers in accessing basic health services due to a multiplicity of reasons mostly connected with poor data, bad information and minimal knowledge. Figure 1a and 1b provide schematics of the current system. We contend that such a situation can benefit from the application of the intelligence continuum and a system of systems approach [2].

2. The Intelligence Continuum

To effectively and efficiently apply the techniques of data mining and strategies of knowledge management to healthcare, Wickramasinghe and Schaffer developed the Intelligence Continuum model [2]. Succinctly stated, the Intelligence Continuum (IC) is a collection of key tools, techniques and processes of today’s knowledge economy (figure 2); 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 the creation of superior outcomes and processes.

An understanding of the role of the intelligence continuum begins with an examination of a generic healthcare information system. 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.

In order to address these challenges a closer examination of the data generated 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 that 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 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.

As can be seen from figure 2, data mining, business intelligence/analytics and knowledge management form the key components of the intelligent continuum so they will now be discussed briefly in turn.

**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 [2-6]. 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, it leads to knowledge discovery [6].

**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 [2-6]. 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 "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 from 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 [2].

**Knowledge Management:**
Knowledge management is aimed at solving the current business challenges to increase efficiency and efficacy of core business processes while simultaneously incorporating continuous innovation. Broadly speaking, knowledge management involves four key steps of creating/generating knowledge, representing/storing knowledge, accessing/using/re-using knowledge, and disseminating/transfering knowledge [2]. The captured knowledge can take the form of either tacit knowledge (know how) or explicit knowledge (know what), furthermore it is possible to transform tacit knowledge to explicit knowledge and vice versa by invoking specific knowledge transformations. [2]. In the context of AI/AN populations both tacit and explicit knowledge is essential to facilitate patient centric superior healthcare delivery thereby making KM an integral component to facilitating better healthcare delivery in this context. Furthermore, it is the strategies of KM that become particularly important in ensuring that at all times relevant data, pertinent information and germane knowledge permeate systems at all times and the extant knowledge base continually grows in a meaningful and useful fashion.

The concept of Intelligence Continuum then can be applied to several healthcare issues related to the Native American population. However to ensure the full benefits of such an approach is realized it is necessary to take a system of systems perspective. To facilitate such an understanding and the appreciation of such an approach it is thus necessary to first discuss the web of healthcare players and how a systems of systems approach fits into the healthcare context. From this we will then discuss several case vignettes to illustrate the prudence of such an approach to be adopted in the specific context of the AI/AN population.

### 3. Brief Background of the Healthcare System in the US

The healthcare system in the United States is inherently complex in nature and serves to address the needs of several stakeholders. Key stakeholders include patients, providers (including physicians and nurses), healthcare facilities (such as hospitals and clinics), pharmacies, governmental agencies, funding agencies, payers (including insurance companies and employers), federal and state regulators, and funding agencies. Taken together they form the web of healthcare players [2]. Interests of these key stakeholders translate into multiple business rules that lead to heterogeneity in healthcare delivery and management. Some of the major processes and systems used by the web of healthcare players are briefly described below.

**Managed Care Companies:** Managed care companies have become popular in the last decade primarily because of their efforts to contain medical costs. PPOs (Preferred provider organizations) and HMOs (Health Maintenance Organizations) are examples of managed care companies. Managed care companies employ a variety of techniques to contain costs including gatekeeping (requiring mandatory authorization for hospitalization), capitation (payment of a fixed amount per member per month), generic drug substitution for brand name drugs [15]. A variety of information systems exist within managed care companies to enroll patients, maintain their claim records, audit claims and track physician services.

**Hospitals:** Hospitals are financed by a variety of sources including payments from managed care companies, Medicare and Medicaid programs. DRGs (Diagnosis related group) payments reimburse the hospitals based on the diagnosis and treatment. Hospital care in the US is characterized by technologies for diagnosis, treatment to electronic maintenance of patient health records.

**Physicians:** Groups of physicians often practice together serving patient needs. Physician groups work with managed care companies via insurance contracts, utilize hospitals for in-patient care and work with governmental agencies such as Veteran’s Administration hospitals, Medicare and Medicaid programs. Physicians utilize a number of technologies and information systems to diagnose and monitor patient’s health status.

**Clinics:** Clinics are utilized by physician groups for treating outpatients. Clinical information systems are utilized for managing patient health records to scheduling patient visits and billing managed care organizations for patient visits.
**Governmental Agencies:** Governmental agencies provide oversight of physicians, clinics, hospitals and nursing homes. Special units exist for dealing with veterans health and for administering programs such as Medicare and Medicaid.

Based on the above discussion, we next describe how healthcare systems fit into the definition of system of systems [16-20]. Healthcare systems exhibit the following properties.

**Operational and Managerial Independence:** It is clear each individual system --- from managed care systems to governmental systems --- exists on its own independent of the other systems. Together, they serve the patient needs, while operating independently. In addition, each has its managerial independence with the management structure ranging from governmental management to private sector management.

**Geographical Distribution:** Healthcare systems are inherently distributed with no central organizational structure. Clinical systems, hospital systems, regulatory systems are dispersed geographically. The negative effects of geographical separation of healthcare systems, even though an impediment, can be alleviated by technology mediation.

**Evolutionary Development:** Healthcare systems undergo evolutionary development. For example, pharmaceutical companies bring new drugs to the market after years of research, while hospital technologies are evolving to incorporate sensor based monitoring of in-patients. Again myriad technologies ranging from mobile technologies to electronic health records help evolutionary development.

**Emergent Behavior:** An example of emergent behavior is to track the quality of care using the data from the individual systems such as the clinical systems and the hospital systems. For example, insurance companies such as the United Health certify physicians on whether they meet the quality standards based on national averages on quality care obtained from information on physician treatment of patients across the nation. As another example, The Affordable Care Act signed into law by president Obama in March 2010 consists of dozens of individual changes, or provisions [23]. Each of these provisions has an impact on the web of healthcare players. Healthcare systems are exhibiting emergent behavior to respond to the changes mandated by this law.

Based on this discussion, it can be seen that health care is complex and can be categorized as system of systems. In the next section we explore the role of technology in healthcare system of systems (HSoS).

### 4. Collaborative Technologies in Healthcare

Table 1 shows the rise of healthcare expenditures in the US from 2000 to 2009 (latest available data is for 2009). Healthcare expenses have increased from $1.4 Billion in 2000 to $2.5 Billion in 2009, while their share as a percentage of GDP increased from 13.8% in 2000 to 17.6% in 2009. Further, the following is noted by the centers for Medicare and Medicaid services report on US healthcare expenditures [24]: Shares of total national health spending financed by businesses (21 percent), households (28 percent), governments (44 percent), and other private sponsors (7 percent) have remained relatively steady over time. Between 2008 and 2009, however, the federal government share increased significantly (from 24 to 27 percent), while the state and local government share declined (from 17 to 16 percent).

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2005</th>
<th>2009</th>
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<tr>
<td>National health expenses (in Billions)</td>
<td>$1,378</td>
<td>$2,021</td>
<td>$2,486</td>
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<tr>
<td>U.S. Population in Millions</td>
<td>283</td>
<td>296</td>
<td>307</td>
</tr>
<tr>
<td>GDP in Billions</td>
<td>$9,952</td>
<td>$12,638</td>
<td>$14,119</td>
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<tr>
<td>National Health Exp. Share of GDP</td>
<td>13.8</td>
<td>16</td>
<td>17.6</td>
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<tr>
<td>Per Capita national health expenses</td>
<td>$4,878</td>
<td>$6,827</td>
<td>$8,086</td>
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<td>Annual Percent Change</td>
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<tr>
<td>U.S. population</td>
<td>6.4</td>
<td>6.5</td>
<td>-1.7</td>
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In 2009, health spending by households decelerated, growing 0.2 percent in 2009 compared to 5.4 percent in 2008. Health spending by state and local governments declined 1.3 percent, and health spending by private businesses declined 0.5 percent in 2009.

Hospital spending increased 5.1 percent to $759.1 billion in 2009 compared to 5.2-percent growth in 2008. Growth in 2008 and 2009 was much slower than the trend between 1999 and 2007, when spending increased an average of 7.2 percent per year. The slower growth in 2009 was influenced by decelerating private health insurance spending and slower price growth. Partially offsetting these factors was an
increase in Medicaid spending, as Medicaid enrollment increased considerably in 2009.

Physician and Clinical Services: Spending on physician and clinical services increased 4.0 percent in 2009 to $505.9 billion, a deceleration from 5.2-percent growth in 2008. Slower growth in the use and intensity of services in 2009 was partially offset by increasing prices.

It should also be noted that the WHO predicts the US healthcare expenditure to increase to 20% of GNP by 2020 if unchecked [25]. To reduce healthcare expenses, technology mediation can play a significant role. For example, mobile technologies to monitor chronic diseases [26] can enable pervasive monitoring, thereby enabling patients to receive feedback on the readings related to chronic diseases (e.g. blood glucose readings for diabetes). This in turn may facilitate superior control of chronic diseases, reduce patient visits to hospitals and thus contribute to controlling healthcare expenses.

Technology mediated collaborations appears to be a worthy goal in order to address these escalating costs and deliver superior healthcare, and is currently being used in limited settings in the healthcare system of systems [28-29]. However, its widespread use in HSoS across different players requires overcoming of significant barriers. In the next section, we consider several scenarios/cases of this ontology and discuss how the collaboration is taking place now or can take place in future. We also indicate the significant benefits and barriers for these scenarios.

5. Collaborative Technologies to Facilitate Different Processes in HSoS

Scenario 1: Use of collaborative technologies by clinicians to communicate diagnosis information to patients.

Currently, the most prevalent means of communicating diagnosis information based on laboratory testing is by

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<th>Media</th>
<th>Purpose</th>
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<td>Nurse</td>
<td>Nurse</td>
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<td>PHR*</td>
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<td>Tele-medicine</td>
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Table 2: Ontology of collaborative technologies in health care. (Source: Mini-track chairs)
telephone. The results are either communicated by telephone or the patient is asked (via phone conversation) to come in for a follow-up visit to discuss the findings and lab results. Based on the ontology in Table 2, a future process could use email and/or mobile devices for communicating diagnoses. However, barriers to adopting new technologies include the following:

- Clinician time and effort
- Risk of communicating without using any kind of security, encryption

There are currently no incentives for physicians to communicate via email. They are not reimbursed by payers/patients for communicating results via email; this is very similar to them not being compensated for returning patient phone calls and providing prescription refills. This fact is reflected in recent survey findings by CompTIA [30]: only 21% of the responding physicians mentioned that they allow patients to email or text health-related questions, 12% said they email appointment reminders, and only 5% said they text appointment reminders. Also, abnormal test results and bad news in terms of diagnosis are best discussed face-to-face rather than via email. Also, communication via mobile devices will require additional mechanisms to comply with HIPAA regulations. In fact, the providers need to demonstrate to HIPAA (in case of an audit) that there are mechanisms to ensure integrity of data during Thus, communication via telecommunication is the significant mode of communication for abnormal test results.

Scenario 2: Communication of prescription information from clinician to pharmacy.

This scenario involves communication between two key players of HSoS --- providers, clinicians and pharmacies. The following discussion assumes that the ontology is further extended for communicating prescription information accurately between providers and pharmacies. Currently, prescription information is communicated by the clinicians to pharmacies either by hand-written prescriptions, telephone, or fax. However, as electronic health records (EHRs) get implemented at a sustained pace, prescription orders are electronically communicated using the Computerized Physician Order Entry (CPOE) component of EHRs. Electronic Health Records (EHR) is the most commonly accepted term for software with a full range of functionalities to store, access, and use patient medical information. EHRs contain longitudinal electronic record of patient health information generated by one or more encounters in any care delivery setting. CPOE is an automated order entry system that captures a physician’s instructions regarding the care of their patients. It is often implemented as a component of the EHR. It must be able to communicate orders to other connected systems within the EHR. Barriers to implementing EHRs include the following:

- Confusion due to complexity
- Cost of implementation
- Lack of standardization
- Lack of motivation in creating interoperability
- Uncertainties about the direct benefits
- Significant changes to clinical processes

EHRs allow direct sourcing and capturing of patient data. Hence, benefits of implementing EHRs include: Direct patient care, Continuing patient care, Research, Improving legal compliance, Cutting costs, Improving patient safety, and providing decision support.

In fact, to demonstrate the meaning use of EHRs for federal incentives, 15 core objectives need to be met by the healthcare facility implementing the EHRs. One of these 15 core objectives is related to providing the CPOE functionality of EHRs [19].

Core Objective: Use computerized physician order entry (CPOE) for medication orders directly entered by any licensed health care professional who can enter orders into the medical record per state, local and professional guidelines.

With the increased prevalence of EHRs, CPOE may become the predominant mode of communication for prescriptions in future years. In the next section, we apply these concepts to healthcare delivery for native American patients.

4. Applying SoS and the IC to Healthcare Delivery in Native American Population

In Fiscal Year 2006, Urban Indian health is funded at $33 million. Urban Indian health organizations also typically leverage funding in order to maximize service provision. IHS provides about half of all funding available to these organizations. Other major funding agencies include Medicaid, State and local programs, and other Federal programs separate from IHS. Services provided vary from outreach, referral and case management to comprehensive care, including: ambulatory medical care; dental services; community
education (health education, transportation, patient advocacy); alcohol and substance abuse prevention, treatment and counseling; AIDS and STD information; mental health counseling; and social services.

Some of the key issues related to native American health as identified by Wickramasinghe et al [15] include the following:

- Barriers to quality healthcare due to factors such as poverty and lack of insurance.
- Misclassification of native Americans as either Whites or Hispanics. This misclassification leads to unreliable data on the incidence of diseases (such as cancer) in the native American population, which in turn leads to misconceptions about the immunity of native Americans to diseases such as cancer.
- Lack of cultural awareness on the part of physicians.
- Limited federal funding. IHS funding from federal government was approximately $33 million for FY 2006, which translates to $210 per user. In contrast, the per capita national health expenses were $7,198 in 2006 (see Table 1).
- Disparity between funds allocated to Indian health services on reservations versus the Indian health services in urban regions. Most recent census data from 2000 showed that 61% of the native Americans live in urban regions. However, only 1 percent of the budget is allocated to native American health services in urban regions.

While some of these issues require policy changes from the federal government for their resolution, other issues can be resolved by effective management of data and knowledge related to native Americans. For example, funding the Indian Health Centers adequately can be accomplished by congressional action during budget negotiations. However, data required to track the health issues of native American population can be accomplished by using information systems that can effectively capture specific data relevant to native American population. Nevertheless before the tools, techniques, technologies and tactics of Knowledge Management can be successfully applied it is first useful to conceptualize this context as a healthcare system of systems.

5. Collaborative Technologies and System of Systems Approach for Healthcare Delivery to AI/AN Population

Given the barriers such as limited funding to IHCs and poverty of AI/AN population, it is difficult to utilize the full extent of collaborative technologies for AI/AN population. Under-funding of IHCs may dissuade providers (physicians, nurses) to communicate with patients using technologies such as email and mobile devices. Further, IHCs may not have fully implemented EHRs that facilitate seamless communication among providers, hospitals, pharmacies and other key players in HSoS. In this section, we take the example of cancer diagnosis in native American patients and describe the current process versus the desired process using collaborative technologies for AI/AN patients. We selected cancer because it is often misreported in AI/AN population, thus making cancer incidence rates in AI/AN population appear lower than the actual incidence rates [11]. Figure 3 shows a simple process for cancer diagnosis in AI/AN population. An American Indian/Alaskan Native patient is first seen by a primary care physician (PCP). If the PCP suspects cancer, he/she refers the patient to a specialist who conducts further tests. If the cancer diagnosis is confirmed, the patient follows up with appropriate physicians for treatment. In the ideal scenario, the specialist (or the administrative staff) who diagnoses cancer also registers the cancer case with the state cancer registry. If cancer is ruled out, the patient follows up with the primary care physician for future visits. In this process, communication of information, diagnosis and data occurs between primary care physician (PCP), specialist, patient, and the stage agencies tracking cancer (if cancer is diagnosed in the patient). The current process for this communication is paper-based and manual. For example, the specialist reports are delivered to PCP by paper and the communication of diagnosis to the patient occurs face-to-face. It is possible to utilize EHRs and mobile devices for communication involving the PCP and the specialists by applying an appropriate ontology. Similarly, it is possible to utilize web-portals to communicate cancer diagnosis to state agencies. The key barriers such of lack of EHR implementations can be overcome if better funding and governmental incentives are provided to the Indian Health Centers.

6. Concluding Remarks

Few would disagree that healthcare delivery in the US is at a cross roads [2, 29-31]. Costs are escalating and quality is too often a growing concern. In order to address effective and efficient patient-centric healthcare delivery, it is necessary to focus on how to provide value. In the Information age this is only feasible by embracing technology to enable superior healthcare delivery.
One of the areas where healthcare delivery is embarrassingly inadequate in the US is the delivery of care to AI/AN segments of the community[13-15]. The preceding has served to proffer an approach that serves to potentially rectify this untenable situation. Specifically we have proposed the adoption of a system of systems conceptualization coupled with the introduction of the intelligence continuum in order to systematically and appropriately apply the tools, techniques, technologies and tactics of the knowledge economy to this context.

By introducing the intelligence continuum model, it is possible to generate better data and information which then can be extracted and utilized to support enhanced decision making to facilitate superior diagnosis and thereby better treatment. An added benefit of the IC model is that it is continuous and hence the extant knowledge base is always built upon with each iteration so that the future state is always better than the current state in terms of having more data and information from which to make critical decisions. Moreover, the IC model also captures and utilizes vital tacit and explicit knowledge. We have illustrated this approach with preliminary data from an ongoing research project focusing on cancer and healthcare delivery in the AI/AN community.

Providing quality healthcare for all Americans is a priority on the government’s agenda. In order to realize this vision for the AI/AN segment of the community, it is imperative that pertinent data and relevant information are appropriately analyzed in order to support the necessary and consequent decision making required. This can only occur if a rigorous and systematic approach is adopted making it an imperative to take a system of systems approach coupled with the IC as the preceding has described. Only then will it be possible to provide the necessary patient-centric quality healthcare that is incumbent on the US healthcare system for AI/AN segments of the community.

7. References


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Figure 3: A simplified process for cancer diagnosis and tracking AI/AN cancer


[27] WHO http://www.who.int/en/


