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The Promises and Challenges of Innovating Through Big Data and Analytics in Healthcare

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How IT Can Transform Healthcare

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The Promises and Challenges of Innovating Through Big Data and Analytics in Healthcare

by Donald E. Wynn, Jr., and Renée M.E. Pratt

In 1969, Herbert Simon argued that we were entering an "information-rich" era in which information was being produced at unprecedented rates.[1] However, we didn't have the capacity then to utilize all the information that was available. Updating this essay in 1988,[2] Simon advocated the use of computers as "managerial decision aids" that have (1) access to information inside and outside the organization, (2) sophisticated capabilities for filtering and analyzing this information, and (3) natural language capabilities in addition to numerical capabilities.

Today, the rate of information flow in virtually every industry is even more unprecedented. The amount of information and data available within the healthcare industry is growing exponentially due to the rapidly increasing availability of a number of medical devices, enterprise software systems such as electronic health record (EHR) systems, and other technologies. For example, one estimate is that the amount of global digital healthcare data will explode from 500 petabytes in 2012 to 25,000 petabytes in 2020.[3]

The technological capabilities of 1969 and 1988 were not sufficient to fully exploit Simon's ideas. Today, organizations have access to an avalanche of data management and data analysis tools, which we collectively designate as "big data" and "analytics" technologies, respectively. The combination of these tools and the amount of data available has led to golden opportunities for hospitals, public health departments, and corporations to develop and deploy a wide variety of business intelligence and analytic applications to support multiple organizational objectives.

Through the use of business intelligence and analytical tools, this newly acquired capacity for analyzing detailed data enables healthcare providers and other data owners to pursue a myriad of clinical, operational, and financial innovations,[4] some of which we outline below. However, the many promises attributed to these innovations may never be realized without the establishment of cultural, organizational, and technological policies that are aligned in such a way as to enable members of the healthcare industry to collectively share and utilize this data effectively. In this article, we present the promises and challenges of big data and analytics (BD&A) in healthcare, informed by our observations of and interviews with healthcare providers in the US and European Union (EU). We then provide a set of recommendations for capitalizing on the extraordinary innovation opportunities available through big data.

BD&A IN THE HEALTHCARE INDUSTRY

There is a wide variety of definitions for big data, but we can generally define it in terms of not only the amount, but the complex nature of the data being used. Ultimately, the quality and utility of this data depend on the manner in which an organization manages the "Four Vs" — volume, variety, velocity, and veracity — identified by IBM as attributes of big data:

- **Volume.** By any standard, the sheer volume of data in healthcare will increase dramatically over the next few years. According to a 2012 report, a hospital attempting to go paperless will generate 60 gigabytes of data per bed each year, which is over 6 terabytes of data per year for the average hospital.[5] Another study predicts that the amount of data stored by the average hospital will jump from 168 gigabytes in 2010 to 665 gigabytes in 2015.[6]
- **Variety.** Consistent with societal and technological innovations in the marketplace, the variety of data available to healthcare organizations (HCOs) has also shifted dramatically. Data is now generated by small devices (e.g., personal health and fitness monitors) as well as large agencies (e.g., the US Centers for Disease Control and Prevention).
- **Velocity.** In addition to the daily flow of clinical and financial data, hospitals must also contend with a high velocity of data from medical equipment, personal health monitors, and other sources. For example, a hospital may have several thousand medical devices, each streaming one reading per second,

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which equals 86,400 data points per machine per day to be stored.

- **Veracity.** HCOs must also be concerned with veracity, which is the degree of uncertainty and precision of the data. To utilize the data in a reliable manner, the organization must be able to trust that a medical device is not malfunctioning and that unstructured data, such as a physician's handwritten notes, is being translated correctly.

Analytics is "the scientific process of transforming data into insight for making better decisions."[7] Applied to a business context, analytics seeks to transform data from past business decisions and practices, customer information, and environmental conditions to improve business decision making and increase business value through cost reductions, increased revenues, or both. For organizations that adopt an analytics program, the benefits can be tremendous. One study found that organizations adopting analytics as part of their decision-making processes were twice as likely to "substantially outperform" their industry peers compared to firms that were less dependent on analytics.[8]

THE PROMISES OF BD&A

As in many industries today, the potential use of these new tools and techniques promises to introduce several significant benefits for the healthcare industry. Advocates of BD&A in healthcare are quick to point out the many clinical, operational, and financial improvements available to users of these applications (see Table 1). We explore several of these promises here, along with some examples to illustrate the extraordinary advances they represent for patient care, operational systems, and financial practices.

Clinical Benefits

Clinically, the application of analytics tools and techniques to clinical data has yielded impressive examples of improved patient care. Specifically, analytics has been used to address clinical objectives such as improved quality of care, patient safety (including reduced medical errors), wellness, prevention, disease management, and patient satisfaction and retention.[9]

IBM, Epic Systems, and Carilion Clinic took six months to develop a system that combined over 200 health, social, and living arrangement factors from existing electronic medical records on 350,000 patients. Using both structured and unstructured data, they were able to identify 8,500 patients at risk for developing congestive heart failure, with an 85% accuracy rate.[10, 11] This included 3,500 patients that otherwise would have been overlooked. Similar examples exist for other organizations, such as the University of Florida Health network, which used public health data and geographic/population data to adjust its mobile care units to serve three counties that were identified as underserved for breast cancer screening.[12]

Eventually, physicians will have the opportunity to present specific, tailored clinical options for individual patients. This includes the possibility of using a patient's individual genetic makeup and a complete longitudinal medical history (see Figure 1[13]) to prescribe highly personalized medical treatments, as opposed to "cookbook medicine."[14]

Table 1 — Potential Benefits of BD&A in Healthcare (Source: Cortada et al.)

Category	Specific Benefits
Clinical	Improved quality of care
	Improved patient safety (including reduced medical errors)
	Improved wellness, prevention, and disease management
	Individualized medical treatment
	Improved physician comparison and evaluation
Operational	Improved supply chain and inventory management
	Improved speed and efficiency of operations
	Efficient utilization of resources
Financial	Improved claims processing and payments
	Improved accounts receivable
	Reduced billing errors
	Reduced fraud and abuse
	Reduced financial risk for accountable care organizations (ACOs)

Operational Benefits

BD&A can help reduce an HCO's operational costs by finding new ways to provide the right treatment and the right prescriptions to the right patient at the right time. By applying these tools to issues such as inventory or supply chain management, organizations can realize speed and efficiency improvements. In turn, these may also lead to improvements in patient safety, quality of care, and patient satisfaction.

Many of these operational changes will become increasingly necessary in the US, as hospitals deal with changes introduced by upcoming regulatory mandates. For instance, hospitals must reduce the rate at which patients are readmitted for treatment of specific diseases or risk lower Medicaid reimbursement rates. Without a corresponding reduction in the costs of operating a facility, many of these hospitals will find themselves in a financial bind. The University of Pittsburgh Medical Center uses analytics to identify incoming patients that have a significant risk of readmission, targeting them for subsequent interventions such as home visits instead of waiting for them to show up at the hospital later.[15] Also, by deploying analytics toward the efficient utilization of their resources (including operating rooms, emergency rooms, and medical equipment), these hospitals may be able to find other ways to protect their bottom line.

Financial Benefits

Organizations have been able to apply BD&A to their revenue cycle management processes, which include medical claims, payments, record keeping, and accounts receivable. As an example, Duke University Health System was able to identify and reduce errors in the billing processes for its pediatric intensive care unit. Its efforts resulted in a shift from a US $2.1 million loss to a $400,000 profit, along with an additional $12 million in revenues that resulted from correcting and resubmitting prior billing statements.[16] Analytics can also help identify sources of fraud and abuse within an organization, including improper or excessive claim filing and unnecessary medical tests or procedures.

Additional financial benefits may arise from the emergence of accountable care organizations (ACOs), which are groups of practitioners and hospitals that combine forces to provide coordinated care for a particular patient population. The intent is to entice ACOs to share the financial risk for their patients, encouraging them to focus more on improving the quality of the care they provide than on generating revenues. In return, they are compensated in proportion to the size and composition of the population itself, less any medical costs incurred by the patients. ACOs can use BD&A to uncover ways to reduce the costs of specific treatments and hospital

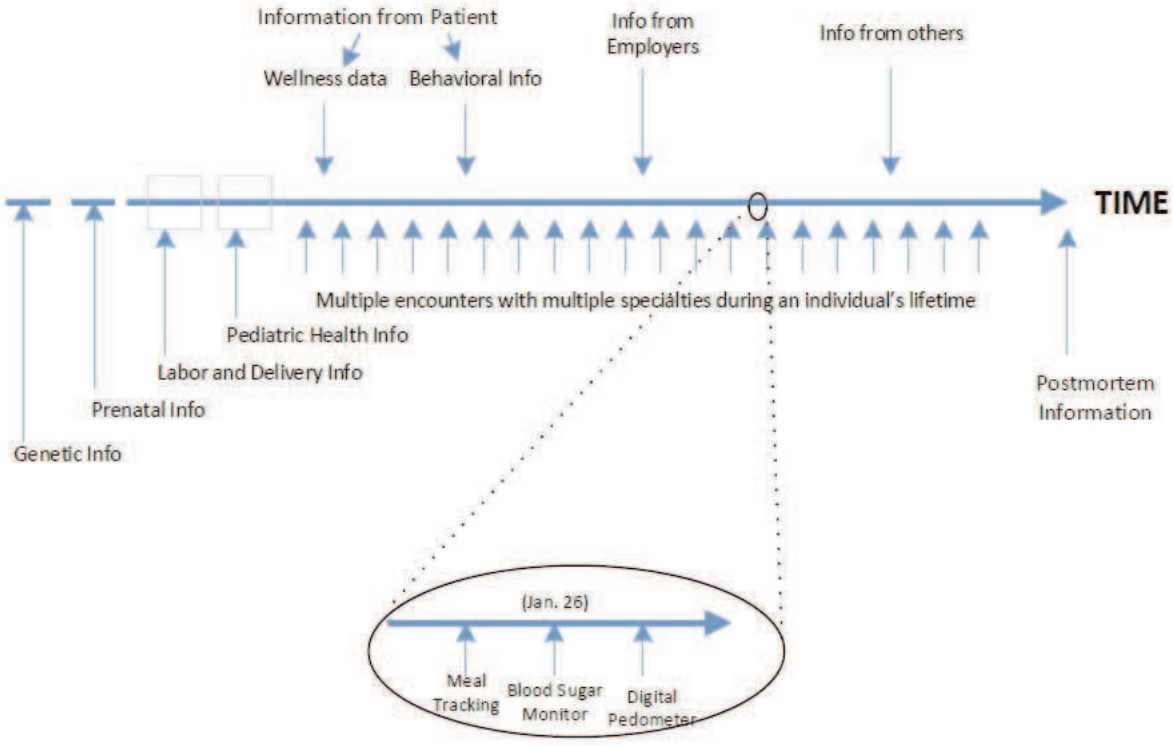

Figure 1 — The sum of all health data: a longitudinal perspective on healthcare data. (Source: Murphy, Hanken, and Waters.)

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visits and predict population-level treatment rates in an effort to lower their overall costs.

CHALLENGES IN THE BD&A PROCESS

For all the promises offered by healthcare analytics, the challenges it presents are equally numerous. IT departments, medical records staffs, and administrative teams must take a number of issues into account in order to take advantage of BD&A's many benefits. We examine these challenges in the context of four stages in the analytics process: data collection, storage and extraction, statistical processing, and output generation (see Figure 2).

Data Collection

The primary challenges of data collection lie in finding the data, managing access to it, and dealing with its volume and velocity. The prudent HCO will find ways to access and incorporate even more data from sources such as wearable devices, patient logs, and physicians' notes, as well as data from government agencies and other external sources (see Figure 3). With the large amount of data, it is also necessary to assess and manage the data quality in terms of veracity. The classic adage "garbage in, garbage out" remains true, especially for data-driven practices such as analytics. It therefore becomes important to take steps during the selection and collection of these data sets to ensure that they are

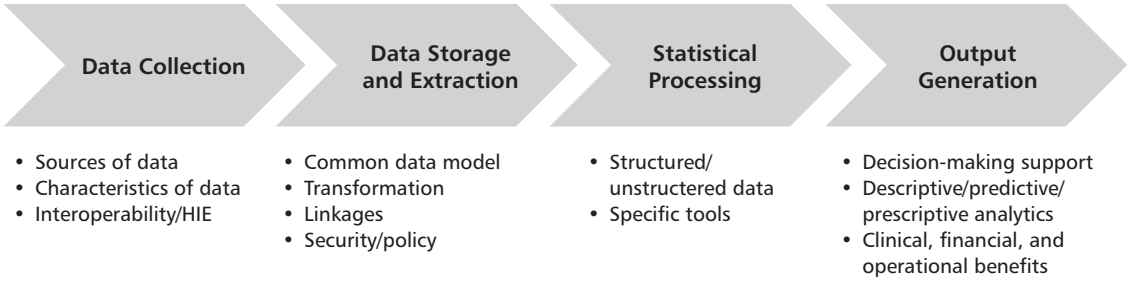

Figure 2 — Four stages in the analytics process.

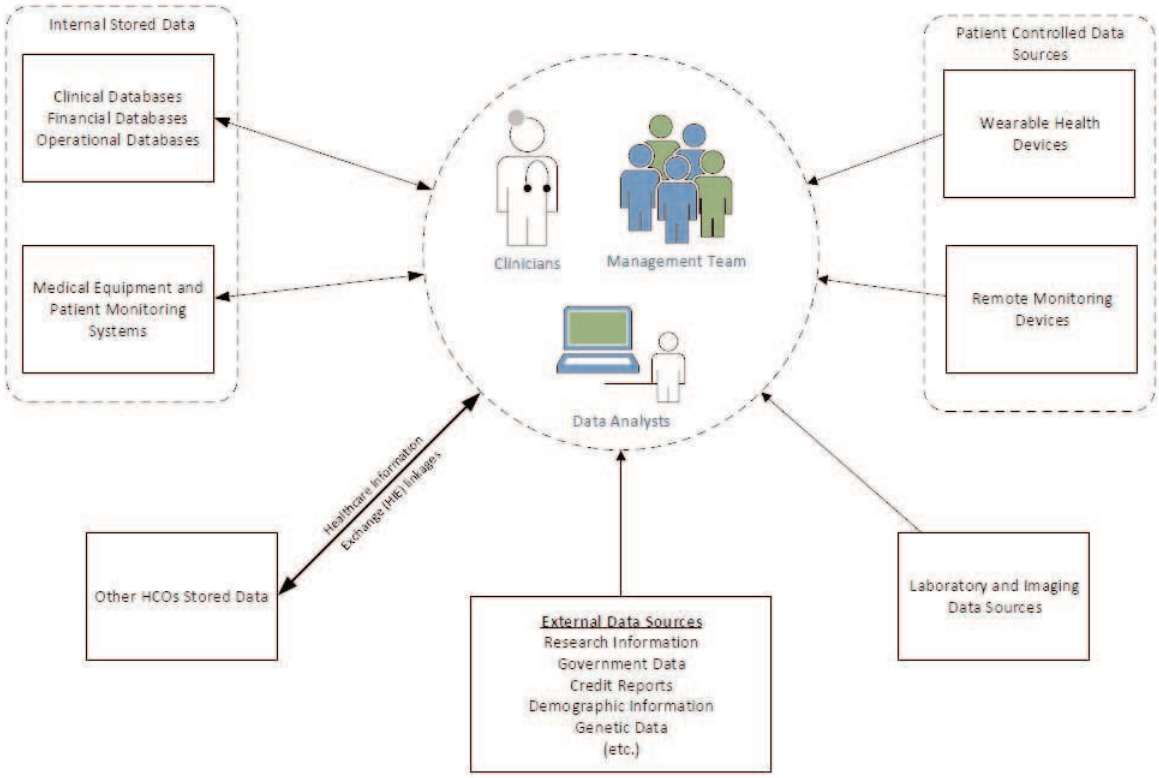

Figure 3 — Data sources available to HCOs.

valid, accurate, and appropriate for subsequent analytical use.

With the advent of regulations and policies such as "meaningful use" standards[17] in the US, the EU directive on cross-border healthcare, and efforts by the EU and US to exchange medical records between the two continents, clinicians will require access to data stored at multiple facilities. Currently, many providers participate in one or more health information exchanges to share electronic patient data on a regional basis. In time, this will become nearly universal as providers across the world gain access to patient data and other information.

Perhaps the most important responsibility for HCOs is protecting acquired and stored data from unintentional access and dissemination.

Data Storage and Extraction

Unfortunately, as the number of data sources increases, so do potential issues with respect to the variety of data and the effort required to enforce standards. The data must be standardized and normalized in such a way as to enable applications and analysts to fully use the entire spectrum of accessible data. Transforming the data into a common data model will allow analytics users to utilize and connect a wide range of data in their analysis to develop a complete picture of the patient's medical history. Whereas this is not so difficult for structured data such as weight, prescriptions, and other components, unstructured data such as physicians' notes and medical research literature are more difficult.

Perhaps the most important responsibility for HCOs is protecting acquired and stored data from unintentional access and dissemination. Government regulations (such as HIPAA in the US and Articles 81 and 83 of the EU's General Data Protection Regulation) impose significant penalties for organizations that do not protect sensitive data appropriately. But this presents several unique dilemmas for using and sharing data. For instance, some patient data needs to be accompanied by identification information in order to contact the patient for treatment, while other uses for the data may not require such identification, such as demographic studies. The task of the organization is to ensure that the correct level of privacy protection is provided, whether the data is being accessed internally or exchanged with other parties. Aside from the legal and regulatory concerns, the main issue may be one of trust between HCOs and the patients or customers that rely on these organizations to protect their personal information. Organizations that violate this trust may find themselves subject to patient uprisings, legal action, and/or regulatory punishments.

Statistical Processing

Healthcare data comes in a wide variety of structured and unstructured formats. For structured numeric data, statistical analysis is most appropriate. However, there is a lot of useful information stored as unstructured data, such as text-based notes, imaging files, and more. Using this unstructured data correctly requires additional techniques. For instance, IBM's Watson supercomputer has been redirected to the healthcare field in an effort to more readily use the vast amount of unstructured data (along with structured data) toward the diagnosis and prevention of health concerns. Of course, not every organization can afford a supercomputer to deal with the same volume of data as IBM's Watson. There are less expensive tools such organizations can use to analyze unstructured data, but these less powerful tools may not be able to realize the full value from the available data.

Output Generation

Getting useful insights from analytics requires a team of skilled people to ask the appropriate questions, conduct the correct analysis, and interpret the statistical analysis and results for nontechnical users. These individuals guide the efforts to utilize descriptive, predictive, or prescriptive analytics[18] to generate the relevant insights to resolve the organization's issues. It is through the use of these insights as part of the organization's decision-making process that the clinical, operational, and financial benefits of BD&A can be achieved. The difficulties arise in trusting the outputs to be valuable even if they contradict traditional or expected results and finding ways to incorporate these insights.

CAPITALIZING ON BD&A

To achieve the benefits of BD&A while meeting the corresponding challenges, we offer several recommendations for HCOs seeking to improve the value of their analytics platform and succeed in this new arena (see Table 2).

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Table 2 — Recommendations for Succeeding with BD&A in Healthcare

Action Item	Detailed Recommendations
Changing organizational structure	• Select appropriate location for analytics team (centralized or decentralized) • Hire chief analytics officer to lead analytics efforts • Establish analytics leadership team
Creating an analytics mindset	• Work to overcome resistance by users • Incorporate data-driven practices throughout organization (even for physicians)
Hiring data scientists and analysts	• Hire sufficient numbers of different types of analysts • Situate analysts throughout the organization
Training users on capabilities	• Make users aware of data and tools available to encourage innovation
Improving security and privacy awareness	• Monitor patient privacy relentlessly • Monitor sharing and interfaces between organizations
Investing in capabilities	• Spend on capabilities and opportunities • Value intangible assets (e.g., data) accordingly
Achieving ROI	• Gather the right metrics • Validate insights suggested by analytics • Incorporate insights into key decision-making practices across the organization

Changing Organizational Structure

Just as there is a need to align business and technology, there is a similar need to align business and analytics to ensure that the questions being asked and the insights generated match the needs of the organization. The IT department should retain responsibility for the administration and operation of the technological infrastructure itself. However, the information-handling responsibilities — including data governance, data analysis, and the integration of predictive and prescriptive outputs into the decision-making practices of the firm — need to be situated elsewhere for best results. One structural solution to consider is to establish an analytics leadership team that consists of analytics specialists and representatives from each of the functional areas. This team may be centralized within a separate department or decentralized in teams spread throughout the organization. Regardless of which approach is chosen, the key for this team is to ensure that the analytics efforts match the overall mission and strategy of the organization. Oversight of this team should fall under a new position called the "chief analytics officer," or CAO, who is responsible for the application of analytics toward improved business decision making and processes for the organization.

Creating an Analytics Mindset

Beyond the structural changes, converting the organization to an analytics mindset may be the toughest challenge of all. To date, there has been a limited application of analytics-based practices to organizational and personal routines in healthcare, but this is slowly changing. The implementation of an analytics culture in healthcare introduces a new means of practicing medicine that relies on not only a physician's knowledge and intuition, but the prescriptive analysis of both deep patient-specific and broad cross-sectional population data. This will be especially important for independent physicians. These small-practice physicians will need to be included in this new revolution as it continues to evolve. Furthermore, the availability of data leads to opportunities to compare doctors' results and practices that did not exist previously. For instance, one hospital used its EHR data to identify a physician who had been prescribing a given drug significantly more than his peers. After this was pointed out, the physician was able to reduce the prescription rate to a level more consistent with the status quo. If not introduced carefully, this type of data-driven oversight can lead to resistance on the part of physicians and other practitioners accustomed to existing ways of practicing medicine. Overcoming this resistance requires the organization to be careful in setting and monitoring practitioners' expectations with regard to the purpose for such monitoring.

Hiring Data Scientists and Data Analysts

Further down the organization, there continues to be a need for increasing numbers of data scientists and analysts. There are several types of analysts, ranging from data analysts focused primarily on the technical aspects of the medical and clinical data to informaticians focused on the development and interpretation of statistical models to analyze this data. In addition, there is a need for business analysts who use their knowledge of healthcare processes, roles, and workflows to help functional areas identify opportunities to use analytics to solve specific problems. Organizations must be willing to hire several of each type of analyst to enable the various departments and facilities to capitalize on the BD&A capabilities.

Everyone from C-suite executives to laboratory technicians should be confident enough to suggest ways to use the existing data and tools to improve clinical, financial, and operational practices.

Training and Users' Capabilities

Entire organizations need to be encouraged and empowered to look for opportunities to take advantage of their analytics capabilities in ways that may not be apparent when the systems are implemented. Everyone from C-suite executives to laboratory technicians should be confident enough to suggest ways to use the existing data and tools to improve clinical, financial, and operational practices. To accomplish this, training should be provided to every member of the organization, not just the data scientists or analysts. This training should include familiarity with the data sets, tools, and techniques available, as well as the possibilities that exist based on successes within the organization or elsewhere.

Improving Security and Privacy Awareness

Clearly, there is a balance to be struck between valid use of patient data by parties with legitimate reasons to do so and protection from illegitimate access of this data. Article 81 of the EU's General Data Protection Regulation specifically discusses this balance, protecting a patient's fundamental privacy rights versus the needs of health professionals to use the data for medical diagnosis, preventive medicine, or the provision of treatment and care. This requires HCOs to ensure that the privacy of shared patient data is carefully guarded. Individuals and organizations responsible for managing information security and patient privacy must be more aware of not only the source and protection of any data they have stored, but also the management of any external interfaces they have established with other data sources, as these may be pathways for hackers to enter.

Investing in Capabilities

Clearly, new infrastructure, data storage, analysis software, and staffing requirements arise when an organization implements a functional BD&A program. Unfortunately, this runs counter to many HCOs' focus on cost containment and other defensive strategies with regard to IT spending, especially when it can be rather difficult to determine the tangible benefits attributable to an analytics program. For instance, how do you assign a pecuniary value to patient satisfaction or faster emergency room service? It's not easy. Instead, there must be a shift to a more offensive spending model in which the goal is to invest in *opportunities* to introduce innovations in the HCO's business practices and revenue generation models. In addition, intangible assets such as the various data sets being used by the organization need to be evaluated for their potential value, which may not be recognized immediately.

Achieving ROI

Once the systems are implemented, the organization must use the BD&A program to its full potential to achieve the desired ROI. According to a 2013 Accenture report, there are three main reasons why BD&A do not generate expected returns: (1) measuring the wrong metrics, (2) not identifying and validating the insights and actions suggested by analytics, and (3) not embedding these insights into key decision-making processes and business outcomes across the organization.[19] HCOs that focus on the validation and incorporation of the insights generated by analytics techniques can increase their chances of achieving a positive return on the sizable investments they must make in these technologies.

CONCLUSIONS

There are interesting times ahead for physicians, administrators, insurers, and other members of the healthcare industry. BD&A have the potential to revolutionize the industry through innovations in the business models, operations, and clinical practices currently being used.

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But these changes will not be easy to achieve without significant changes and additions to the organization's structure, culture, data, and technology. A comprehensive set of best practices for BD&A in healthcare is in its infancy, but the recommendations offered above will be useful for moving HCOs toward positive returns on their investments in these systems.

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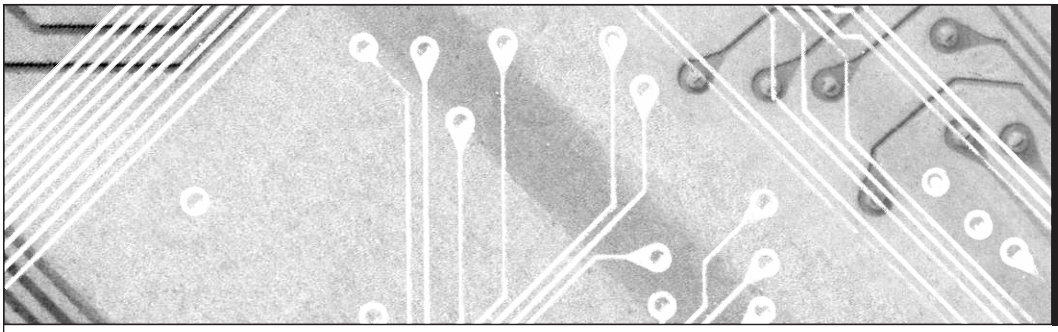

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Cutter Consortium's philosophy is that there is no single right solution for all enterprises, or all departments within one enterprise, or even all projects within a department. Cutter believes that the complexity of the business technology issues confronting corporations today demands multiple detailed perspectives from which a company can view its opportunities and risks in order to make the right strategic and tactical decisions. The simplistic pronouncements other analyst firms make do not take into account the unique situation of each organization. This is another reason to present the several sides to each issue: to enable clients to determine the course of action that best fits their unique situation.

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The Cutter Business Technology Council was established by Cutter Consortium to help spot emerging trends in IT, digital technology, and the marketplace. Its members are IT specialists whose ideas have become important building blocks of today's wide-band, digitally connected, global economy. This brain trust includes:

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