Big Data, Analytics & Artificial Intelligence

The Future of Health Care is Here

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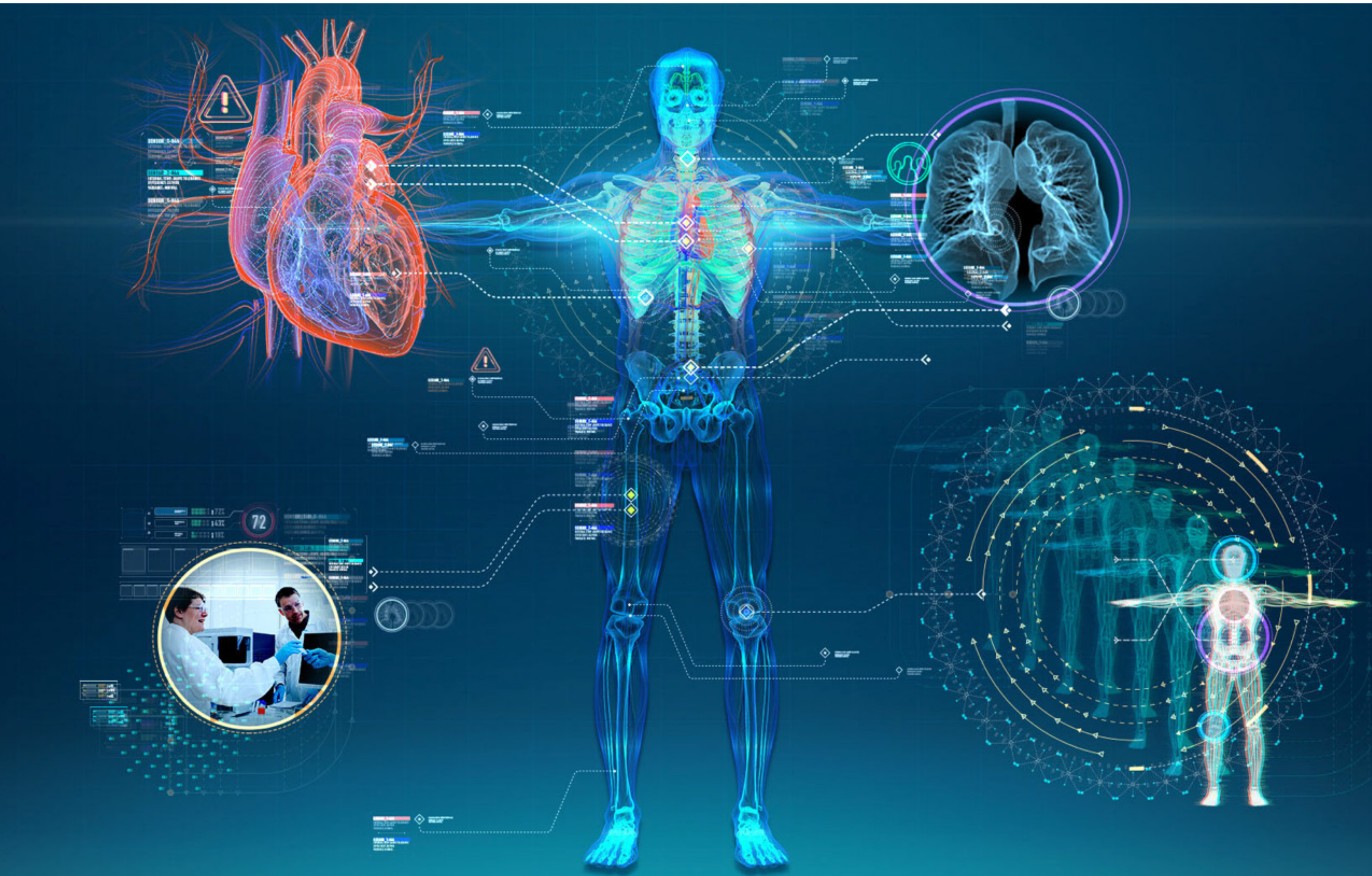
Preface



SOURCE: General Electric

The health care industry is a universe unto itself. Few other industries are as complex, expensive, and comprehensive as medicine. Yet it has been slow to embrace the potential of digital technology and recognize the power of data to improve outcomes.

Health care needs the transformative power of digital.

This white paper provides an overview of the future of digital health. It describes the skepticism and hype and what is needed for the medical community to embrace a world where data, machines, and analytics are employed to deliver higher quality, more efficient care. It also includes real cases that demonstrate the clinical and financial benefits of incorporating digital tools into the workflow and care of patients.

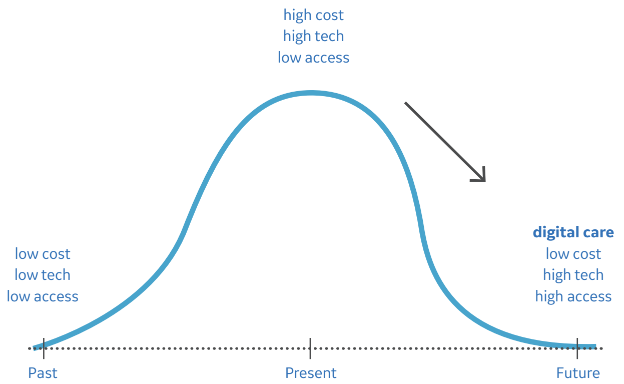
Introduction

Today's health care system, in the United States and throughout the world, is still entering the 21st century. Costs remain high, there are great inefficiencies, and, for a large percentage of the population globally, access to care is inadequate. Our health care enterprises tend to focus on treating acute illness rather than improving and maintaining the health and wellness of populations.

It is time to bring change to the health care industry.

The good news? A powerful catalyst for change in the health care system—digital health—*is* happening now (Figure 1).

Figure 1
Disruptive Innovation in Health Care



SOURCE: General Electric

And no, we are not talking about electronic health records (EHRs).

Today, "digital health" means advanced analytics based on multi-modal data; the "Health Care Internet of Things," which uses sensors, apps, and remote monitoring to provide continuous clinical information; and data in the cloud that enables clinicians to access the information they need to care for patients in their home, their office, or 300 miles away, and to collaborate with specialists in another country.

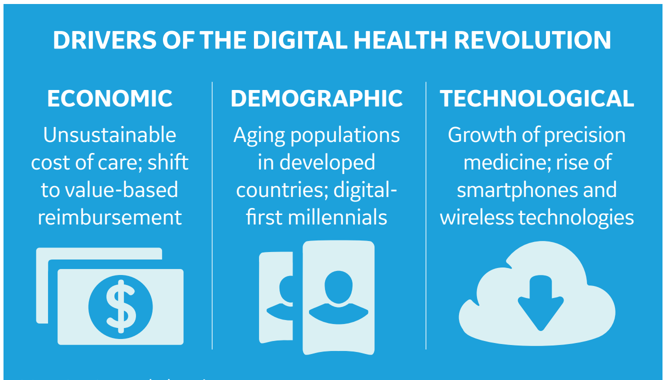
It means embracing the machine as an integral part of the health care team; automating routine procedures and processes so clinicians can focus on the most complex and critically ill patients; and using deep learning platforms to provide actionable tools at the point of care so clinicians can more efficiently and effectively diagnose and treat patients. It means automating billing, documentation, and regulatory processes so that the clinicians can focus on meeting every patient's needs.

Finally, digital health means caring for one patient at a time while also caring for millions of patients simultaneously. It means moving from sick care to wellness preservation, from "me health care" to "we health care," from individual health to population health.

Only then will we realize the goal of the 'Triple Aim' that underpins everything in health care today: Improved patient experience, improved health of populations, and reduced costs.[1]

Reimagining Medicine

Today, a perfect storm of economic, demographic, technological, and environmental factors has ignited the digital revolution in health care. These include the unsustainable cost of care; a shift to value-based reimbursement, in which outcomes and efficiency drive compensation; the desperate need for improved access to care; and the growth of precision medicine.



SOURCE: General Electric

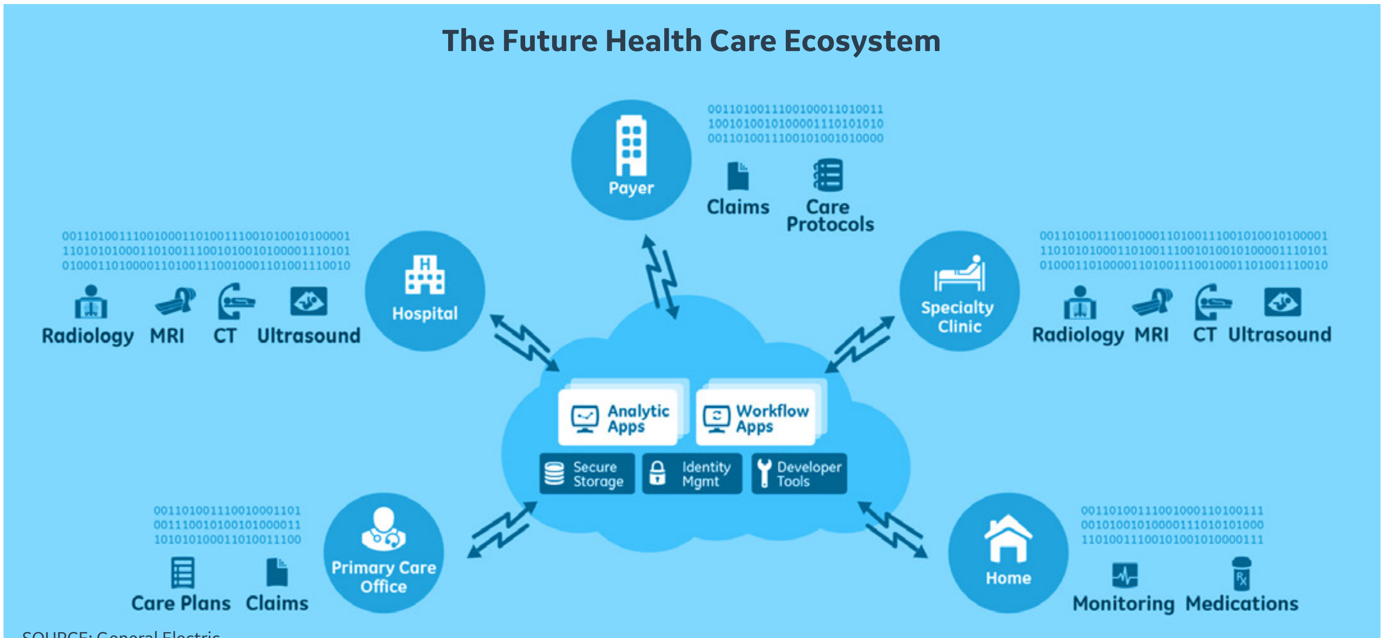
Demographically, aging populations in most developed countries will require more medical services even as the health care workforce shrinks. Meanwhile, millennials who were raised in a digital world are demanding a health care system that is as simple to navigate, predictive, and interactive as Amazon.[i] The rise of smartphones and wireless technology means health care delivery can occur anywhere, anytime, a concept that is particularly relevant in countries like India and China, which are just beginning to build the enormous health care infrastructure their growing middle class demands.

Finally, the U.S. and other countries are facing a significant shortage of physicians in many specialties, as clinicians retire and fewer people go to medical school.[2-4]

Meeting these challenges is impossible without a digital infrastructure that is transformative, globally accessible, and capable of delivering real-time, actionable results.

With data and analytics, we can reimagine medicine.

Imagine, for instance, computers that can mine genetic, genomic, laboratory, health history, and other data to predict an individual patient's likelihood of an adverse drug event, stroke, or heart attack; analyze the thousands of data points that make up a single patient's disease to forecast the disease trajectory and enable tailored treatment; and use sophisticated analytics to monitor the heart rates of premature infants for subtle changes that may presage infection.[5] These are not some futuristic fantasies but areas under active research today.



SOURCE: General Electric

[i] All third party trademarks are the property of their respective owners.

Just consider the implications in radiology, one of the first specialties to move to digital. Today, hospitals store hundreds of millions of digital images, their numbers growing as we become better at capturing thinner and thinner slices of the body via medical equipment such as CT and MRI. Massachusetts General Hospital, for instance, has a database containing more than 10 billion medical images.[6]

There is simply no way humans can turn that much data into useful information.

But machines can. The more scans they review, the more patterns they find, and the more quickly they can alert radiologists to those that are emergencies. This, in turn, will enable the delivery of more timely, higher quality care.

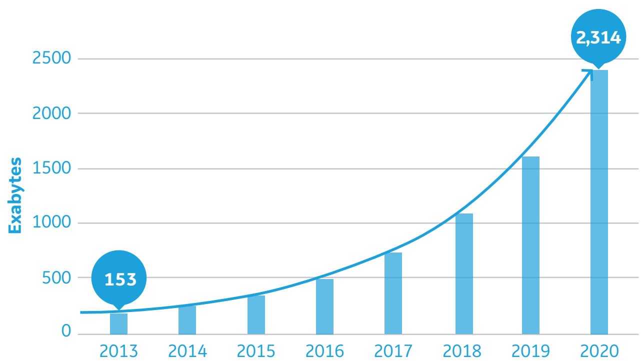
The potential of the digital revolution has drawn non-traditional companies into the market with devices and sophisticated analytics they promise will deliver financial and clinical benefits by mining metadata.

Clearly, the worlds of technology and health care are colliding at rocket speed.

Massive Amounts of Data Driving Digital Transformation

The amount of data the health care industry collects is mind-boggling. A 2014 report from consulting company EMC and research firm IDC put the volume of global health care data at 153 exabytes in 2013 (an exabyte equals one billion gigabytes; five exabytes is equal to the all the words ever spoken by humans). If you stored all that data on tablet computers, the authors noted, the stack would reach nearly 5,500 miles.[7,8]

Volume of Global Health Care Data Collected



SOURCE: EMC and IDC

The report projected a 48 percent annual growth rate, meaning that figure would reach 2,314 exabytes by 2020, enough to stack those tablets nearly a third of the way to the moon.[7]

The volume of data has been growing exponentially in the past decade as health care providers turned to EHRs, digitized laboratory slides, and high-resolution radiology images and videos. Add to that the petabytes of data stored in health insurance company claims databases and pharmaceutical and academic research archives, and the trillions of data points streaming from wearable sensors—activity trackers, continuous glucose monitoring devices, and implantable defibrillators.

Veterans Health Administration: More Than 16 Billion Bits of Data a Day

To make the numbers around health care data more understandable, consider the Veterans Health Administration (VHA), which serves nearly nine million people in its 150 hospitals and 1,200 outpatient facilities.[9] In a single day, the VHA creates more than 16 billion clinical entries, one million text-based notes (such as progress notes and discharge summaries), 1.2 million electronic orders, 2.8 million images, and one million vital signs.[10]

Its Corporate Data Warehouse, a repository for patient-level data aggregated from across its health delivery system, has 4,000 central processing units, 1.5 petabytes of storage, 20 million unique patient records, 1,000 separate data tables, 20,000 columns, and 80 billion rows.[10]

Because it has been collecting patient data for much longer than most health care systems, the VHA was one of the first to recognize the value within data. Today it uses the vast warehouse to drive clinical decisions. For instance, clinicians can calculate patient risk for hospitalization based on demographics, diagnoses, vital signs, medications, lab results, and prior use of health services, generating a score. More than 1,200 providers a month access those scores, which feed directly into a web-based application for the care team who then create individualized care plans and make referrals.[10]

Integrating Big Data, Analytics, Artificial Intelligence, and Machine Learning in Medicine

Case Study: A Library of Deep Learning Algorithms to Advance Care Globally

At the University of California San Francisco (UCSF), clinicians are working in partnership with GE Healthcare to develop a library of deep learning algorithms to revolutionize the speed at which scans are interpreted and patients receive care.

The collaboration is initially focused on high-volume, high-impact imaging to create algorithms that reliably distinguish between what is considered a normal result and what requires follow up or acute intervention. One early example of an algorithm under development screens X-rays for pneumothorax, or a collapsed lung, which can be a life-threatening condition. The algorithm will be focused on teaching machines to distinguish between normal and abnormal scans so clinicians can prioritize and more quickly treat patients with pneumothorax, which could result in better outcomes, reduced costs, and better patient experience.

Over the course of the partnership, GE Healthcare and UCSF will expand their focus to integrate data not only from a variety of imaging technologies such as CT, MR, ultrasound, and X-ray, but will also incorporate clinical data sets from the EHR, patient reported data, sensor data, environmental exposure data, genomics, and other sources to enrich the algorithms' sophistication and impact. Deploying the algorithms via the GE Health Cloud will enable the solutions and insights to become smarter, more robust, and more widely accessible over time.

Once such algorithms are deployed globally as applications on the GE Health Cloud and smart GE imaging machines, clinicians around the world will have virtual access to the associated clinical expertise and workflows used to create the algorithms.

SOURCE: General Electric

Machine learning refers to a process in which computers use algorithms to analyze large data sets in non-linear ways, identify patterns, and make predictions that can be tested and confirmed. Deep learning is a subset of machine learning. It uses artificial neural networks that mimic human brain connections that, over time, become "trained" to provide answers to questions with near 100 percent accuracy. It is what makes driverless cars possible. It is also what makes it possible for a machine to read an MRI scan with far greater accuracy than a human.[11]

We are already discovering the potential of machine and deep learning:

- Software company Apixio is developing a cognitive computing platform that can use data mining, pattern recognition, and natural language processing to evaluate quality of care. For instance, it can look back at years of records and determine if a patient with diabetes has been properly treated.[12]
- Stanford University researchers developed an algorithm that identified thousands of objective features from pathology images of lung cancer tissue, then trained a computer software program to evaluate the samples. The computer accurately predicted the prognoses of the cancer patients from the slide pathology in a fully automated method that the researchers suggested "could provide rapid and objective survival prediction for numerous patients."[13]
- Penn Medicine and University of Pennsylvania researchers are developing and testing algorithms to predict adverse health events in individual patients, including in-hospital surgical and post-discharge complications, as well as high morbidity health conditions such as heart disease, chronic lung disease, and stroke. Clinicians have already piloted metadata algorithms to detect heart failure and sepsis at their earliest stages.[14]
- UCSF, a coauthor of this paper, is using big data from more than one million people over 10 years as part of its eHeart study to identify predictive patterns for heart disease, identify causes of atrial fibrillation, reduce heart failure hospitalizations, and determine the effects of social media. Data feeds into computers in real time via sensors that participants wear, mobile applications, social media, and a dedicated web portal.[15]

Reaping the Value of Analytics Today

A survey from the technology company CSC of 590 information technology executives in 23 large companies found that about 75 percent are investing heavily in big data that can use sophisticated algorithms to assess treatments, identify patients for targeted interventions, and drive innovation. The executives said they believed analytics has the power to drive a productivity transformation in health care, primarily in better clinical outcomes, patient satisfaction, and profitability. Overall, 90 percent say that big data is already positively impacting productivity.[16]

In another survey of 150 health care decision makers, 82 percent of those using data analytics reported improved patient care; 63 percent reported reduced readmission rates; and 62 percent reported improved overall health outcomes. About half said analytics improved their hospital operational performance, financial reporting capabilities, and management decision making.[17]

Reimagining the Hospital of the Future

The digital revolution enables a rethinking of the traditional hospital, one in which much of the charting and monitoring is automated, leaving the care team to focus on the patient.

In Seine-Saint-Denis in France, for instance, the 668-bed Robert Ballanger Intercommunal Hospital has become a completely paperless facility with all vital signs fed directly into the EHR from monitoring devices.[18] In Dubai, emergency medical technicians used Google Glass with real-time video to communicate with on-site clinicians while on the way to the ER, which allowed the in-house team to prepare for the patient's arrival and the EMT to provide earlier care.[19]

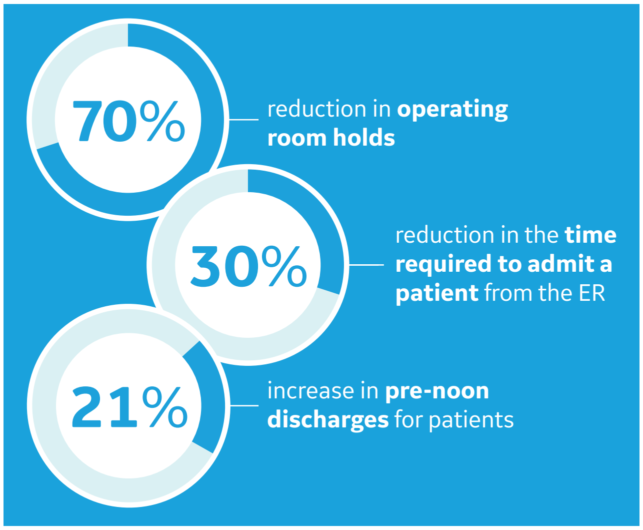
In Toronto, the $1.59 billion Humber River Hospital, which opened in 2015, bills itself as North America's first all-digital hospital. Patients check in on digital monitors, which alert staff that they have arrived; they and staff wear real-time tracking devices; robots mix and deliver medications and supplies; and 75 percent of its non-clinical functions, including pharmacy, laundry, and food delivery, is automated. Those tracking devices are more than just locators. They can tell providers if patients are ambulatory – and help them find those who are not supposed to wander. They also let family see when their loved one is out of surgery. An added bonus? No more annoying overhead paging.[20]

In Baltimore, The Johns Hopkins Hospital runs a NASA-like command post in the center of its campus that uses predictive analytics to run the hospital more efficiently. There, 22 high-resolution screens line the walls, providing a continuous stream of real-time images and data from 14 different sources. That data enables command center staff to sense risk, prioritize activity for the benefit of all patients, and trigger interventions to accelerate patient flow.

One program uses a digital twin of the hospital to predict patient activity for the next 48 hours. Another algorithm tells the staff which room turn or patient discharge would reduce wait time. Yet another senses when staffing levels have dropped to dangerously low measures and can alert administrators. Eventually, the system may be able to monitor risks that can lead to hospital-acquired conditions such as falls and infections.

The command center, staffed around the clock, doesn't change the care itself, just the delivery of the care so patients are seen earlier and clinicians can focus on patients rather than logistics. Since opening the center in February 2016, the hospital has seen a 70 percent reduction in operating room holds; a 30 percent reduction in time required to admit a patient from the ER; and a 21 percent increase in pre-noon discharges.

The Capacity Command Center at The Johns Hopkins Hospital



SOURCE: The Johns Hopkins Hospital

Digital Health and the Precision Medicine Revolution

It cost $100 million in 2001 to sequence a single human genome.[21] Today, that cost has plummeted to nearly $1,000, and experts predict it will be below $100 within the next 10 years, if not sooner.[22]

The dramatic drop in cost coupled with significantly faster and improved techniques is driving the precision medicine revolution. President Obama recognized its potential when he announced the $215 million Precision Medicine Initiative (PMI) during his 2015 State of the Union speech.

While precision medicine is primarily thought of as a means of providing individualized treatment, some of its greatest potential lies in mining the data generated when millions of people's genomes are sequenced. For instance, part of the PMI, the Cancer Moonshot will use deep learning and big data to discover why the same cancer responds differently to the same treatment. To do so, computers will sift through vast databases of genetic, clinical, and other data to identify the underlying genetic, molecular, immune, and cellular mechanisms that contribute to treatment success or failure.

It's already happening in Denmark, where researchers mined the medical records of more than 110 million EHRs in the U.S. and Denmark to identify genetic abnormalities strictly from the statistical analysis of medical conditions. They were able to generate a comorbidity code for complex diseases, finding, for instance, that schizophrenia, bipolar disorder, autism, and depression were all associated with four genes.[23]

Reaching the Triple Aim: The Role of Digital Health

The Triple Aim—improved patient experience, improved health of populations, and reduced costs—is the Holy Grail of health care today.[1] Success requires a previously unheard of reliance on data and the ability to deliver health care anywhere, at any time, in the most efficient manner possible. It requires a digital backbone.

Improved Patient Experience

Since the 1999 report *To Err is Human* from the Institute of Medicine (IOM) brought to light the toll of medical errors on Americans, despite tremendous industry and governmental effort, progress in improving safety has been slow and uneven.[24] Indeed, a recent report found that medical errors were the third leading cause of death in the U.S.[25]

Many of those errors are diagnostic, including missed diagnoses, misdiagnoses, and diagnoses that were never given to the patient. Most Americans will experience at least one in their lifetime, often leading to tragic results, with an estimated 10 percent of those deaths attributed to diagnostic errors.[25,26] There are numerous reasons for the high diagnosis error rate, but about a third is due to a lack of access to images and other data required for an accurate diagnosis.[27]

Medical error is the **third highest cause of death** in the U.S., accounting for

SOURCE: The BMJ

Yet, as a 2015 IOM report noted, health information technology, including alerts from the EHR, algorithms that scan the EHR for potential diagnostic errors, and better clinical decision support at the point of care can reduce the risk of errors. For instance, Kaiser Permanente's SureNet System scans the EHR to identify patients with gaps in care. In one example, the system searched 3.86 million patient records for patients who had not been screened for abdominal aortic aneurysm (recommended for most men ages 65 to 75). Screening resulted in 2,062 new diagnoses of aneurisms, 87 of which required surgery, and slashed the percentage of unscreened patients from 51.7 to 20 percent.[28]

The system also identified 12,396 patients over five years who had an elevated creatinine blood test but never had a repeat test. Of the nearly 7,000 who went on to have the repeat test, half had chronic kidney disease that may otherwise have been undetected or diagnosed at a later stage.

There are many other ways in which digital health will improve the patient experience, including rapid return of test results; greater clinician collaboration; improved workflow; and a more patient-centered approach to care.

Improved Health of Populations

Population-based health is "an approach to care that uses information on a group of patients within a primary care practice or group of practices to improve the care and clinical outcomes of patients within that practice."[29]

It is at the core of alternative payment models such as accountable care organizations (ACOs) and capitation. Such approaches, done well, currently require a tremendous amount of staff time, with one estimate finding an average of 138 minutes of staff time per patient. This, in turn, requires data analysis to identify and measure care gaps; cloud-based medical records and test results to stimulate coordination among clinicians; and personalized information and automated communications for patients.[30]

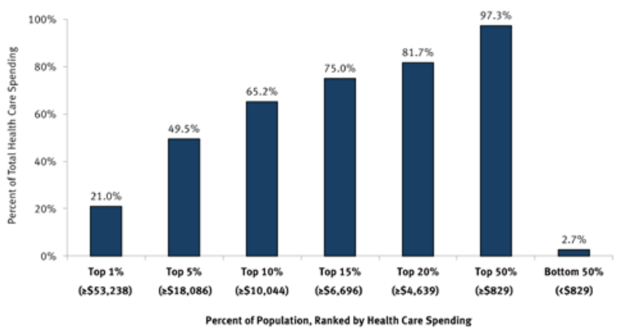
It also requires identifying so-called "super utilizers," the 5 percent of the population that is responsible for half of all health care spending (Figure 2). Mining patient and claims data with sophisticated algorithms can identify these individuals and enable early intervention that can keep them out of the ER and hospital, saving billions.[31]

That's what Maryland is doing. In the state, acute-care hospitals share data on hospital admissions and ER visits. When data showed that 5 percent of patients accounted for 70 percent of readmissions, they began working with 24 local health departments to identify opportunities to better manage these patients and keep them out of the hospital.[32]

Digital health is being used in developing nations like Ghana and India to improve rates of successful hypertension management among the population. In Ghana, the Community Hypertension Improvement Project (ComHIP) digitally delivers adherence support and lifestyle education to the patient's phone. It also shifts screening and care delivery from the health care system to local pharmacies and community nurses, all connected by digital health to facilitate coordinated patient care. And in India, health professionals are using innovative software to aid in the evaluation, risk stratification, drug management, and lifestyle interventions for hypertension patients, with the program showing substantial blood pressure improvement.[33]

Figure 2

Concentration of Health Care Spending in the U.S. Population, 2010



SOURCE: Kaiser Family Foundation. Concentration of Health Care Spending in the U.S. Population, 2010. 2010; http://kff.org/health-costs/slide/concentration-of-health-care-spending-in-the-u-s-population-2010/. Accessed November 1, 2016.

Reduced Costs

Shifting the cost curve in medicine requires more than simply lowering prices. It requires new approaches designed to deliver health care with different providers, in different settings, with different technology. Why should patients with diabetes have to see a physician every three months to test their blood glucose when they could get the test at the drugstore, transmit the results to their EHR, and follow up via email or a video conference with a nurse practitioner? Imagine the cost savings.

Researchers in Singapore did. They estimated that extending the use of telemedicine to screen for diabetic retinopathy could save the health care system more than $29.4 million.[34]

Or consider a device currently under investigation that sits under a cardiac patient's mattress in the hospital and collects information on their movements, respiratory rate, and pulse. The information is transferred to a server and put through an algorithm that determines if the patient is getting worse. If they are, it sends an alert to a caregiver's cell phone.

A published study found that the device could predict a worsening of the patient's condition 50 percent of the time compared to cardiac telemetry's 5 to 10 percent of the time. In that study, the system reduced the number of ICU days that patients required by 47 percent compared to those who did not use the device.[5,35] This represents substantial savings given that care delivered in the ICU costs $56.6 billion to $81.7 billion a year, representing 13.4 percent of hospital costs and 4.1 percent of national health expenditures.[36]

Additional cost savings, an estimated $30 billion a year, could come just from increasing the interoperability of medical systems so they can talk to each other.[37] McKinsey and Company predicted in 2013 that using big data to drive value-based care could reduce U.S. health care spending between $300 and $450 billion a year; 12 to 17 percent of the $2.9 trillion spent that year.[38]

Using **big data** to drive value-based care could **reduce health care spending** in the U.S. between

$300-450 BILLION A YEAR,

or 12-17% of the $2.9 trillion spent that year

SOURCE: McKinsey and Company

Mobile Technology: The Internet of Things

When refrigerators can monitor their contents and create grocery lists; thin rubber bracelets can track steps, heart rate, and sleep patterns; and a small speaker-like device on your kitchen counter can translate your verbal instructions into action, we have entered the Internet of Things.

Now the Internet of Things is coming to health care. In fact, it is already here.

It currently manifests as remote patient monitoring designed to prevent acute exacerbations of disease and other conditions that lead to high-cost medical care and readmissions; telehealth, in which medical care is delivered via computer; and behavioral health, in which apps and texts motivate patients to take their medication, exercise, and manage their health, among other things.

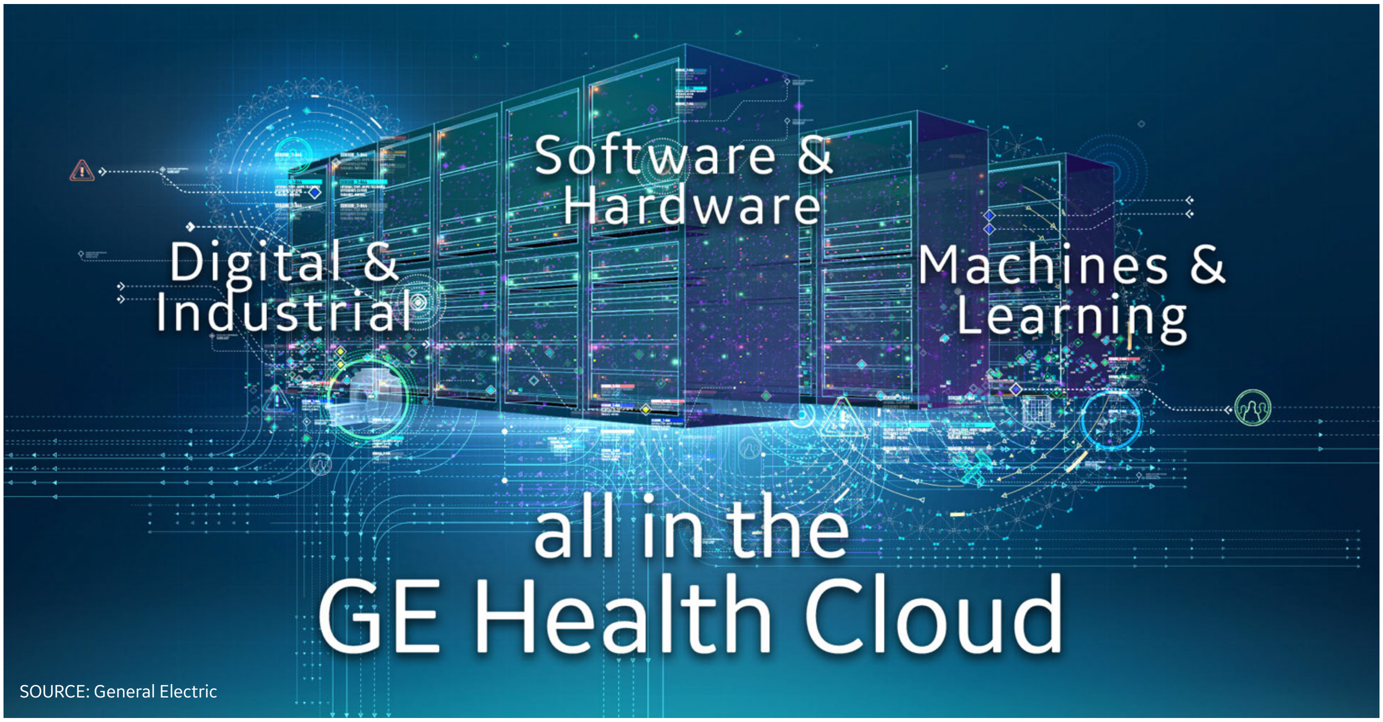
One example is the BodyGuardian Remote Monitoring System from Preventice Services in Rochester, Minnesota. Patients wear the cardiac monitoring technology, which feeds real-time data into a cloud-based health platform physicians can access. The monitor has three functions: mobile cardiac telemetry, event monitoring, and Holter monitor. It is FDA-cleared for the monitoring of non-lethal arrhythmias in ambulatory patients.[39]

In rural hospitals, which often don't have access to specialists in the ER, telehealth enables providers in other institutions to oversee the complicated procedure of intubating a patient, improving the rate of successful intubations.[40]

With the Internet of Things, a cell phone can be used as an EKG and a hand-held ultrasound, enabling high-tech care in low-resource environments. Cardiac defibrillators, insulin pumps, and Holter monitors all work wirelessly now and can feed data directly into the EHR.

A 2015 report from Goldman Sachs estimates health savings of digital health technologies related to the Internet Of Things of $305 billion, $200 billion of that related to improved prevention and management of chronic diseases, particularly heart disease, asthma, and diabetes.[41]

The cloud combines digital and industrial, software and hardware, and machines and learning.



SOURCE: General Electric

Facing the Challenges of Digital Health

For all its promise, the world of digital health care faces numerous hurdles.

Skeptical Providers

The promise of digital health has been oversold in the health care space for so many years that many stakeholders are, understandably, skeptical about its potential. "From ineffective electronic health records, to an explosion of direct-to-consumer digital health products, to apps of mixed quality—it's the digital snake oil of the early 21st century," American Medical Association CEO James Madara, MD, told the organization during its 2016 annual meeting.[42]

Barriers include a lack of rigorous study around the outcomes of touted technologies; technology development by engineers who did not understand the unique challenges of health care; and fears among providers that an app, machine, or algorithm may one day replace them.

Legal and Regulatory Issues

At some point, regulatory agencies like the Food and Drug Administration will likely become involved in regulating the use of artificial intelligence in medicine, particularly if machine and deep learning are used to drive diagnoses and treatments. There is concern that FDA regulation could be a hurdle given the agency's very deliberate pace in approving computer-aided diagnosis for mammography.

Other legal issues center around patient privacy, ownership of medical data, and even malpractice. For instance, if the machine makes the wrong decision, and a patient is harmed, who is at fault? The physician? The hospital? The company that built the machine?[11] Or, is a provider or health system responsible for a patient's actions and outcomes after the patient downloads their health data from the provider's portal into an app and changes their therapy?

Security

Health care data has replaced financial data as the most valuable information to steal and sell on the black market. Hence the massive attacks against health care entities such as Anthem (more than 80 million records hacked) and UCLA Health System (4.5 million records). Other hospitals have had their systems held hostage for ransom, forcing them to return to a paper-based system and shut down CT scanners and laboratories at a cost of millions[44] and unknown harm to patients.[43] While health care executives are increasingly aware of the threat, their systems remain poorly protected against the ever more sophisticated cybercriminal attacks occurring today.[44,45]

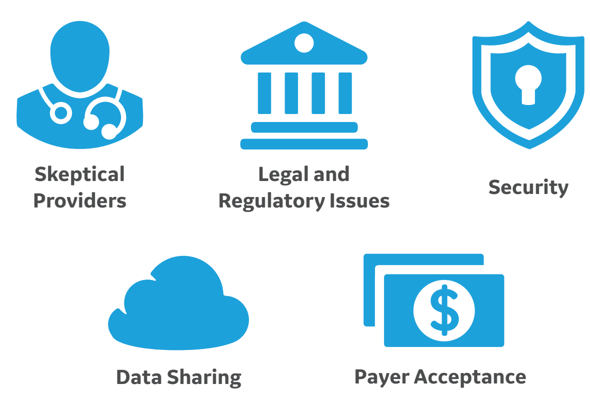
Data Sharing

Advanced analytics requires access to varied data from numerous sources, both within and among organizations, commercial entities, municipalities, and countries. Given the technical, regulatory, legal, privacy, and cultural complexities, convincing traditionally siloed systems to share data presents a significant hurdle.

Payer Acceptance

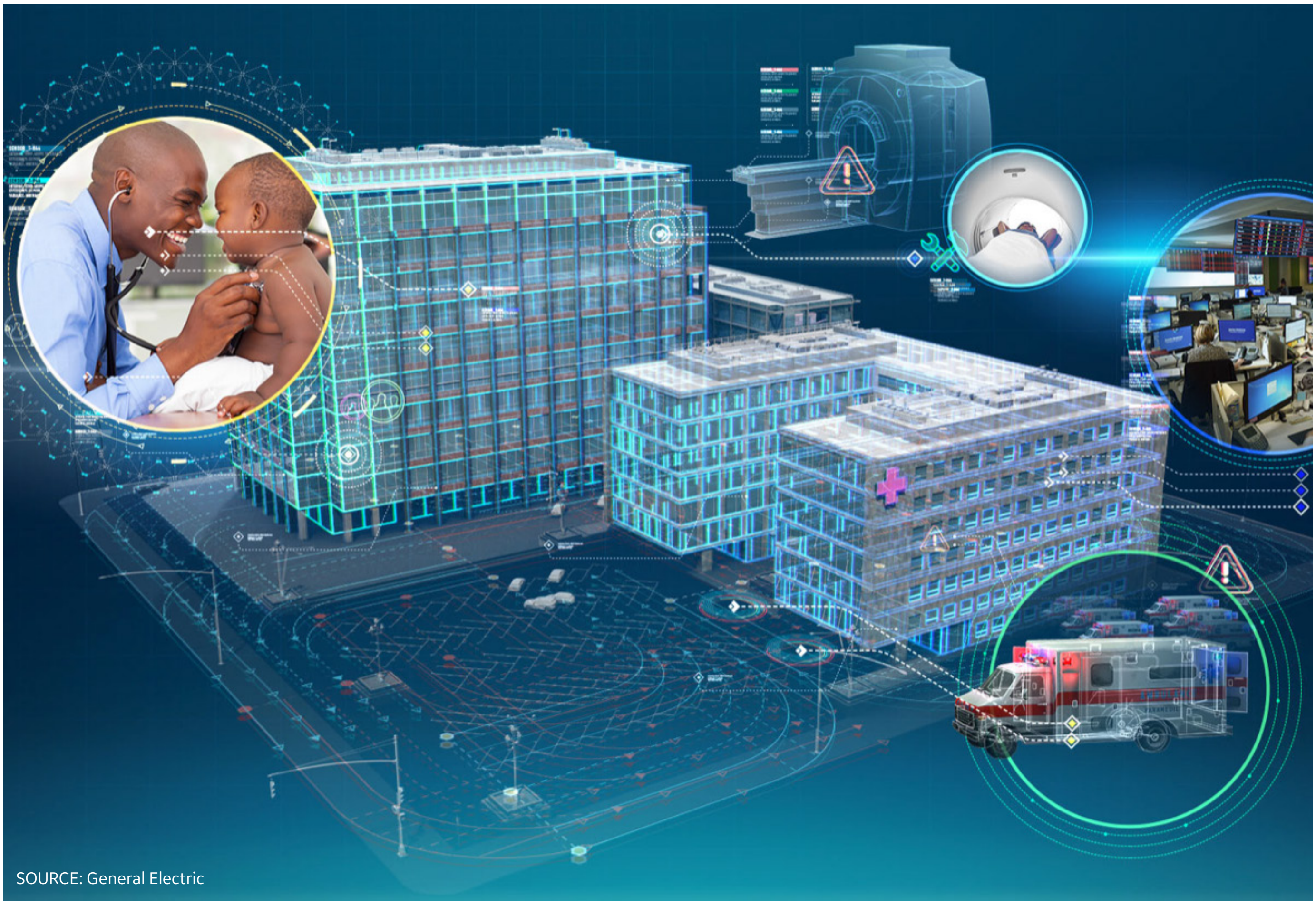
While digital health can improve efficiency and quality for the patient and reduce costs for the payer, providers and health systems still need to be compensated for their acquisition and use, particularly given the significant capital investment required. How will a smart machine or service that provides real-time clinical support algorithms that allow a physician to choose the right treatment for the right patient be reimbursed? Lack of clarity around payment models and the future of payment reform will continue to challenge the development and sustainability of digital health companies.

Challenges of Digital Health



SOURCE: General Electric

Conclusion



SOURCE: General Electric

We have entered the next era of medicine—an era of health care so futuristic that problems we didn't even know existed are being solved for. An era where we focus on health and wellness rather than disease. An era where technology not only makes care safer, more efficient, and higher quality, but also where it improves access to everyone.

Today, the technology exists—and is in use—to analyze the quadrillions of bits of data previously siloed and ignored.

Torn between the skepticism and the hype, it is incumbent on all of us to realize that the potential of digital health is already being realized. We are in the midst of the digitally-enabled health revolution, where the cloud connects people, data, and machines, and in which analytics has become a critical tool to delivering higher quality, more efficient care.

Minds working alongside machines equal lifesaving care, whether in the busiest emergency room in northern California or in the middle of Sub-Saharan Africa.

Big data. Analytics. Artificial Intelligence. Machine and deep Learning. This is the future of medicine. And if we are open to embracing it, the future is now.

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[1]Please refer to the UCSF case study on page 8 for more information.