The New **Innovation Agenda**

Eight clinical technologies with the potential to transform health care delivery

**Look inside for:**

- Overview of innovation functions at health systems
- Emerging clinical technologies poised to detect new indicators of disease, power evidence-based decisions, and deliver precise clinical care
- Implications of emerging technologies on hospitals and health systems
Emerging and disruptive technology

WHAT YOU’LL LEARN

• How innovation has evolved at health systems, as well as business challenges that clinical innovations in the pipeline pose for health care providers
• Which emerging clinical technologies could potentially transform the future of health care delivery
• What remaining barriers must new clinical technologies overcome to reach the health care marketplace
• What are the major implications of emerging clinical technologies for health care providers

BEST FOR
Hospital executives, innovation and strategy leaders

READING TIME
45 min.
The New **Innovation Agenda**

Eight clinical technologies with the potential to transform health care delivery
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If “population health” was last decade’s must-acquire competency for hospitals and health systems, “innovation” is the one that most are reaching to cultivate today. New competitors, payment models, and consumer demands require acute care providers to become more agile and proactive—anticipating threats and opportunities and systematically acting to position the organization to thrive in the new reality. Executives agree on the imperative, but it is difficult to identify a starting point in the vast field that “innovation” encompasses. For example, “innovation” can mean revenue diversification, cultural shifts, delivery system reinvention, or emerging IT and clinical breakthroughs. It is worthwhile for executives to zero in on one innovation category at a time—starting, in this study, with clinical technology innovations—and to become conversant in the landscape, general mechanics, and range of business cases for innovations that are most relevant to acute care providers. For much of the past decade, the function of tracking and assessing new technologies lived in service line planning. Today, hospital and health system leaders are confronted with a much wider set of clinical technologies, many of which have the potential to dramatically transform the future of health care delivery. Many hospital and health system leaders are unprepared to evaluate the next generation of clinical innovations. Building business cases to support new technology adoption is always challenging because emerging innovations often have immature economic and operational models. However, the sheer diversity of new technologies emerging today makes it particularly difficult for executives to determine where to invest time and resources and how to ensure that innovations maximize returns for the health system.

In order to see beyond the headlines and mitigate distractions, executives need a compass for identifying the most important innovations; leaders should focus their attention on three overarching categories of clinical innovation.

• First, a range of technologies are helping providers detect new indicators of disease—especially at the genetic and molecular levels.
• Second, advancements in analytics, namely artificial intelligence (AI), are helping power evidence-based decisions with speed and scale.
• Third, a collection of groundbreaking technologies—ranging from gene editing to 3D printing—are enabling providers to deliver more precise, tailored clinical care.

New means of detecting indicators of disease range from gene- and molecular-based tests to patient-generated data captured through internet-enabled devices. Gene and molecular-based tests enable earlier, more accurate, and less invasive identification of disease risk and occurrence. The challenge is building scalable, affordable systems to administer these tests and protocols for acting on their results. Patient-generated data captured through internet-connected devices enables providers to prevent escalations of known health issues on an ongoing basis, and ideally, in real-time. The challenge with these technologies is leveraging them in ways that are not merely window dressing, and using only the information that could change the course of clinical care and improve outcomes.

Developments in AI technologies can support clinicians in making efficient, evidence-based treatment decisions. AI-based computing systems will be crucial aids in processing the ever-expanding volume of diagnostic results, patient-generated data, and academic literature that will otherwise overload clinical teams, or simply go unused. The challenge with AI is to narrow in on high-impact business cases. Many of these business cases concern productivity, efficiency, and cost avoidance, but there is also a world of possibility around raising quality—using AI to better predict risk and tailor care plans to specific patients for better outcomes.

In order to keep pace with the evolving standard of care, providers must explore—and in select cases adopt—new clinical interventions that allow treatments to be more targeted and customized to individual patients. Health care’s pioneers are offering access to life-changing treatments that may cure otherwise terminal diseases, especially cancer, and address systematic shortcomings, such as organ supply shortfalls. While many of these technologies are far from widespread adoption, executives should have a general sense of where the major disruptions may come from, and how they could transform diverse parts of the delivery system—from acute interventions to ongoing care management—in the long term.
**Introduction**

The Innovation Imperative

The concept and focus of innovation in health systems have evolved significantly across the past decade. Ten years ago, the term largely referred to technology assessment and service line planning, particularly around imaging, technology, and surgical techniques. The most frequently requested topic covered by the Advisory Board’s “Innovation Center” of the mid-2000s concerned investments in CT scanners.

**Technology Assessment in Advisory Board’s “2008 Clinical Technology Investment Guide”**

- **Laggard**: Spiral CT
- **Late Majority**: 4-slice, 8-slice
- **Early Majority**: 40-slice, 64-slice
- **Early Adopter**: Dual-source, Dual-energy, 256-slice
- **Innovator**: 320-slice

Today, the term ‘innovation’ has drastically expanded. The current health industry market has pressured hospitals and health systems to invest in evolving the entire delivery system. Providers face disruptive competitors in the ambulatory space, new payment models, increasingly powerful forces of consumerism (performance transparency, ‘shopping’ infrastructure, and rising consumer cost exposure), as well as heightened margin pressure.

Combine those business pressures with a flourishing landscape of new technologies (particularly IT and analytics) and clinical breakthroughs (such as in precision medicine), and it’s no wonder that hospitals and health systems are scrambling to build a systematic response. To take only one example, recent years have seen a boom in dedicated innovation centers; nearly three-quarters of hospitals over 400 beds reported they either already have some form of such a center, or will have one by mid-2018.

**Hospitals/Health Systems with Internal Innovation Centers**

*AHA/Avia Survey, 2016; (Includes Existing Centers and Those Planned to Launch by June 2018)*

n=300 (hospital/health system leaders)

- **29%** All Hospitals
- **50%** AMCs
- **72%** Hospitals Over 400 Beds

**Innovation Focus Areas**

*Advisory Board Interviews, 2017*

n=40 (innovation and strategy executives)

- Accessibility, retail, urgent care models
- Digital Health, telemedicine
- Patient experience, customer service
- Clinical IT, analytics, interoperability
- Population health, payment reform
- Personalized medicine models
- Venture capital, start-ups
- R&D, commercialization
The Innovation Landscape

While a range of providers seek to be on the cutting edge of innovation, hoping to find compelling business cases among emerging technologies and ways to evolve the delivery system, it is always challenging to assess the business case for new-in-kind ways of delivering care. The incredible noise and hype across anything and everything new in health care make it even more difficult to wrap one’s head around which types of innovation to invest in—and in what way—so as to advance the strategic objectives of a hospital or health system.

This publication is designed as an orientation to the most important features in the landscape of clinical technology innovation, specifically from the acute care provider’s perspective. Innovations are organized by “vector”—overall categories of clinical technology transformation, each of which includes many types of specific technologies (and each of those, many potential vendors).

While delivery system innovations such as virtual visits, concierge medicine models, and extended-access clinics are not the focus of this study, Advisory Board has a wealth of information on these topics, especially those that have been adopted widely enough to have a business case track record. Please see the appendix on page 32 for Advisory Board resources on delivery system innovations not covered in this study or contact your Advisory Board relationship manager to request resources on your topic of interest.

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Clinical Technologies Entering the Health Care Market

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<th>Existing Innovations</th>
<th>Pipeline Innovations</th>
<th>Innovations on the Horizon</th>
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<tbody>
<tr>
<td>Virtual Visits</td>
<td>Gene Editing</td>
<td>Bioelectronics</td>
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<tr>
<td>Digital Monitoring</td>
<td>Regenerative Medicine</td>
<td>Electroceuticals</td>
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<td>Genetic Screening</td>
<td>Artificial Intelligence</td>
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<td>Consumer Analytics</td>
<td>Point-Of-Care Analytics</td>
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<td>Robotics, Automation</td>
<td>Real-Time Risk Analytics</td>
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<td>Concierge Medicine</td>
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<td>Extended-Access Clinics</td>
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0-2 years 3-5 years >5 years

Source: Health Care Advisory Board interviews and analysis.
Business Challenges of Emerging Clinical Technology Innovation

It is worth better defining emerging clinical innovations from the provider perspective because, while it is always challenging to build pro formas around anything new, the clinical technologies in the pipeline today are particularly difficult for providers to fit into existing business planning frameworks. Many innovations promise to upend traditional provider economics, long-standing competitive dynamics among traditional players, or both. These challenges join the existing business planning complexities that providers already face, as they operate several different books of businesses simultaneously, each with distinct reimbursement models, in an environment of considerable uncertainty.

Nontraditional Innovators
Consumer interfaces pioneered by disruptive innovators with unclear (or contested) linkages to clinical care—often not reimbursed by insurers

Expensive Niche Treatments
Specialized treatments that apply to relatively narrow markets, carrying astronomical price tags and raising payment model dilemmas

Interdisciplinary, Cross-Service Line Transformation
Key innovation vectors apply across service lines; traditional service-line-oriented business planning models to fall short of perceiving the big picture

Significant Long-Term Demand Destruction
Certain clinical technology innovations on the horizon substantially reduce market for downstream services—including some cornerstones of the inpatient service portfolio

Methodology

To choose the most important clinical technology innovations, Advisory Board researchers sorted through the ocean of trade press and journal articles about innovation. We analyzed venture funding trends and researched FDA clinical trials to get a clear picture of the innovation pipeline. Our researchers interviewed health care executives, particularly those who lead dedicated innovation centers, and worked with both internal and external experts who specialize in planning, the major clinical services, and health care IT. Clear areas of innovation emerged from the research, each including multiple applications across service lines. This volume presents technologies in the three areas that will, in our view, drive the most transformation in health care across the next three to ten years.

The goal of the study is to help providers gain a more informed perspective of future innovation. Many of the profiled innovations are in the pipeline, some years from wide adoption. The Advisory Board will update and expand its guidance on specific cost, revenue, and feasibility considerations if or as they enter the market and establish even a preliminary business track record.

Learning Objectives:

- Become conversant in important innovation vectors, foundational concepts, and notable applications
- Learn emerging feasibility and business case considerations, both for the innovation itself and its impact on downstream services

Source: Health Care Advisory Board interviews and analysis.
Three Broad Vectors of Transformation, Encompassing Eight Technologies

When studying clinical technology innovations in a patient’s journey through the health care system, we found three broad categories of innovation, each of which encompasses many specific types of technologies.

1. **Detecting new indicators of disease:** Although the health care industry has made tremendous progress in diagnostic capabilities, many diagnoses still occur too late in the disease development cycle. Many tests are invasive or toxic to patients. Some tests are also not sensitive enough, resulting in duplicative tests and missed opportunities to tailor treatment for maximum effectiveness. Tomorrow’s diagnostic innovations will more proactively identify health risks, accurately diagnosis conditions, and manage and prevent escalations of diagnosed diseases.

2. **Powering evidence-based decisions:** A tidal wave of diagnostic, patient-generated, and academic data is just beginning—and already swamping health care providers. The data hold tremendous power to improve patient outcomes, but is limited by clinicians’ ability to practically manage and apply it in day-to-day workflows. Developments in artificial intelligence (AI)-based decision-making capabilities will allow health systems to drastically improve efficiency in this terrain, raising clinician productivity, boosting staff to top of license, and better tailoring care to individuals.

3. **Delivering precise clinical care:** As research advances, clinical interventions will remain in the spotlight of health care innovation. Tomorrow’s treatments offer increasing precision and customization, with less toxicity and fewer side effects. Armed with a wide array of related technologies, providers could address today’s unmet demands, such as potentially overcoming organ supply shortfalls and treating chronic conditions that are merely manageable today.

Eight Clinical Technologies with the Potential to Transform Care Delivery

Across the three vectors of innovation, we will explore eight specific clinical technologies, using case studies of transformation in provider sites today if they exist. Note that Advisory Board does not endorse any specific technology or vendor (some of which may succeed, others not). Our goal is to highlight the themes and trends for each innovation vector.

**Detecting New Indicators of Disease**

1. Polygenic Risk Profiles and Molecular Diagnostics
2. Real-Time Patient Data from “Internet of Things”

**Powering Evidence-Based Decisions**

3. AI-Guided Decision Support Platforms
4. Next-Generation Natural Language Processing

**Delivering Precise Clinical Care**

5. Molecular and Gene-Targeted Treatments
6. Engineered Organ Replacements
7. 3D Printer-Enabled Surgeries
8. Bioelectronic Device Implants

**Themes of Emerging Innovations:**

- Personalization
- Customized care
- Next-gen precision
- Efficiency gains

**Important Disclaimers**

1. The following innovations are not best practices. They are important themes and trends, with examples to show potential implications for hospitals and health systems. There is a possibility that some of these innovations will not materialize, but if they do, they will have a transformative impact on the health care industry. Advisory Board is not endorsing any particular application or company in the following examples.

2. This research report does not serve as an in-depth scientific explanation of clinical technologies. Health Care Advisory Board researchers are happy to have further discussions regarding specific details of the technologies.

Source: Health Care Advisory Board interviews and analysis.
Eight Technologies Transforming Clinical Care
1. Polygenic Risk Profiles and Molecular Diagnostics

**What are they?**
Polygenic risk profiles and molecular diagnostics analyze biomarkers at the gene or molecular level to detect health risk or disease occurrence in the human body.

**Why are they important?**
Many diseases are not detected early enough in the disease progression to be treated effectively, and some diagnostics are overly invasive or toxic to patients. Diagnostic tests are not always sensitive enough, resulting in duplicative tests, missed diagnoses, and missed opportunities to tailor treatment to an individual. Emerging polygenic risk profiles and molecular diagnostic technologies have the potential to overcome today’s diagnostic shortfalls and improve patient outcomes.

**Key Facts**
- 80% of cancer cases detected in the final third of disease stages are fatal, leaving a large opportunity to improve cancer outcomes with earlier detection
- 29K future cancer diagnoses may be linked to radiation from a single year of CT scans, indicating the industry needs less toxic diagnostic capabilities

**Biomarkers:** Indicators that can be objectively measured to accurately predict medical state

**Biobank:** A repository of bio-specimens, including blood, saliva, tissue samples, purified DNA, etc.

**Polygenic risk:** The effect of multiple genes on one’s susceptibility to health conditions or responsiveness to treatment

**Evergreen Challenges at the Start of the Patient Care Pathway**
- Proactively identify health risks
- Accurately diagnose conditions
- Manage and prevent escalation of diagnosed disease

When the human genome was first sequenced at the turn of the century, it set the foundation for precision medicine—but at a cost that made it impractical for widespread adoption. At that time, it cost over $1M to sequence one gene. As technology has evolved, the cost to sequence a gene has dropped to under $1,000 today.

New research has also revealed a wide array of ways to improve interventions based on one’s unique genetic profile. Pharmacogenomics, for example, allows providers to cater drugs and therapies to patients based on genetic profile, increasing drug effectiveness.

Although genetic screening has not yet fully penetrated the health care market, it holds great potential to tackle the evergreen challenges of detecting and diagnosing diseases earlier and more effectively.

**Cost to Sequence Human Genome**

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<tr>
<th>Year</th>
<th>'01</th>
<th>'03</th>
<th>'05</th>
<th>'07</th>
<th>'09</th>
<th>'11</th>
<th>'13</th>
<th>'15</th>
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<tr>
<td>Cost ($)</td>
<td>100,000</td>
<td>10,000</td>
<td>1,000</td>
<td>100</td>
<td>10</td>
<td>1</td>
<td>1</td>
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**Establishing the Foundation for Precision Medicine with Genomic Information**
- Identify biomarkers associated with disease
- Integrate research into biobank; create unique patient profile
- Consider polygenic, multi-factorial risk factors

Case Studies: Providers Using Polygenic Risk Profiles

Case in Brief: Rady Children’s
- 551-bed hospital in San Diego, CA
- Aims to sequence DNA of all NICU infants 4 months or younger with unexplained illnesses; to date, sequenced DNA of 100+ newborns
- Scaling rapid genetic-sequencing approach nationwide; 15 children’s hospitals will start sending DNA samples to Rady by 2018

50% Of patients receive a proper diagnosis after getting DNA sequenced
80% Of patients receive life-changing treatment as a result of the genetic diagnosis

Rady’s Solution
- Some infants have unexplained sickness, symptoms
  - Finds clues by sequencing genome; references database of known mutation links
- Genetic tests not reimbursed by payers, costs $8,500
  - Only sickest newborns in NICU without a diagnosis get DNA sequenced
- Saving infant life requires timely diagnosis and intervention
  - Holds world record for fastest diagnosis from DNA sequencing, 26 hours

Case in Brief: NorthShore University Health System
- Four-hospital health system based in Evanston, IL
- Built 30-question Genetics and Wellness Assessment tool to incorporate genetic testing into physician practices using recommended guidelines from NCCN¹ and ACMG²
- Providers suggest a curated collection of gene panels for patients; on average, patients pay no more than $500 out of pocket

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Some providers are realizing the clinical and financial benefits of incorporating genetic testing into clinical care, both for diagnostic and preventative aims. NorthShore has integrated genomic screening into all of its primary care and OB/GYN practices. To ensure value, NorthShore practices test only for genes that have clear follow-up clinical interventions.

The program is in its first year of operation, but has had great success in identifying patients that need clinical interventions and also appealing to consumers’ desire for proactive health engagement.

Patient Prompted to Complete Genetics and Wellness Questionnaire
- 30 questions to collect family and health history
- Algorithm determines applicable gene panel

PCP Discusses Next Steps with Patient
- Explains benefits of receiving certain genetic tests
- Provides referral to specialists if needed

Patient Receives Personalized Counseling Based on Genetic Profile
- Genetic susceptibilities and preventive strategies explained
- Potential adjustments to patient care plan or pharmaceuticals made by PCP

Care Team Integrates Data into Patient Profile
- Serves as reference for future episodes/interventions
- System hopes to eventually assess polygenic risk and influence of additional data (e.g., the microbiome)

For some conditions, the accuracy and timeliness of a diagnosis and treatment can be the difference between life and death. Recognizing the power of genomics as a possible solution, Rady Children’s now aims to sequence the DNA of the sickest newborns in the NICU who have unexplained symptoms and an unclear diagnosis to find clues that could save the newborns’ lives.

At this time, genetic testing for newborns is not typically reimbursed by payers. Rady has received several research grants to operationalize its program, and executives hope their program will prove the long-term clinical and financial value of newborn genomic screening.

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1) National Comprehensive Cancer Network
2) American College of Medical Genetics and Genomics


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Case Study: Emerging Molecular Diagnostic Technologies

Despite the power of genomic screening in detecting disease risks, a different strategy is needed to test for the actual occurrence of diseases for which the patient is merely at risk. One emerging method to test for disease occurrence is a blood-based screen, which has the capability to identify disease at the molecular level.

Case in Brief: GRAIL, Inc.
- Silicon Valley biotech startup that has raised $1.1 billion in funding
- Developing blood test to detect cancer in asymptomatic people; test reads circulating tumor DNA for 508 different gene mutations

Molecular diagnostics: GRAIL is a start-up company that aims to use "liquid biopsies" to detect signs of cancer in seemingly "healthy" patients. Blood is first extracted from asymptomatic patients and then tested to see if cancerous DNA is circulating in the bloodstream. The method is currently in clinical trials. It shows early signs of both accurately detecting the presence of cancer in those with malignant tumors and also in revealing mutations in the tumor that help clinicians to determine targeted treatments for the given cancer.

The blood test offers a less invasive method for active and early surveillance. GRAIL’s liquid biopsies are also more sensitive than many screening tests today and can detect multiple cancers, including advanced breast, prostate, and non-small-cell lung cancers. The capability to detect cancer at an early stage before symptoms appear, especially in patients that have a higher genetic risk, has the capability to dramatically decrease cancer mortality.

Detecting Cancer DNA in the Bloodstream Before Symptoms Develop

90%
Of patients who had at least one mutation detected in tumor tissue where the cancer could have been detected in the blood in an early study of 124 patients with advanced breast, prostate, and non-small-cell lung cancers

76%
Of circulating tumor DNA mutations detected by GRAIL were specifically associated with targeted treatments and considered “actionable”

Liquid biopsies can detect high-risk malignancies early in the disease development lifecycle. But new research has revealed a diagnostic method even less invasive than a blood draw: breathalyzers. An international consortium led by Technion, Israel’s Institute of Technology, made a nanoarray that uses artificial intelligence to analyze a person’s breath and identify and differentiate between 17 different diseases. The breathalyzer has the potential to be extremely valuable because it involves no injections or blood draw, generates instant results, is lower in cost than traditional blood tests, and has high levels of accuracy.

**Diseases Detected by Breathalyzer**
- Lung cancer
- Colorectal cancer
- Head and neck cancers
- Ovarian cancer
- Bladder cancer
- Prostate cancer
- Kidney cancer
- Gastric cancer
- Crohn’s disease
- Irritable bowel syndrome
- Multiple sclerosis
- Chronic kidney disease
- Ulcerative colitis
- Idiopathic Parkinson’s
- Atypical Parkinsonism
- Pulmonary arterial hypertension
- Pre-eclampsia

86% Accuracy of disease detection and discrimination between diseases in tests to date.

**Breath Analysis Process**
- Patient breathes into breathalyzer device with artificially intelligent nanotechnology sensors.
- Sensors detect and quantify pre-identified organic compounds in exhaled air.

**Benefits of Breathalyzer**
- No injections or blood draw
- Instant results
- Lower cost than traditional blood tests

**Implications of Polygenic Risk Profiles and Molecular Diagnostics for Hospitals and Health Systems**

1. **Genetic screening and new molecular diagnostics are growth opportunities**—both because consumers may demand them, and because systems can capture downstream revenue from associated follow-up treatments. While not a make-or-break business opportunity today, genomics will likely become a necessary part of care models in the future.

2. **First movers will have to pave their own path, figuring out immature economic and reimbursement models.** Despite the proliferation of diagnostic tests, providers must adopt only those that are supported by sufficient evidence regarding clinical utility and cost effectiveness—which are also the ones most likely to be covered by insurance.

3. **A growing body of research is revealing new actionable implications for specific genetic variants.** Armed with genetic data, providers can realize profound clinical benefits today, especially in the area of pharmacogenomics. In the future, providers could differentiate their services by considering the influence of multiple genes and other personal health indicators (microbiome, socioeconomic, etc.) on disease susceptibilities and treatment responsiveness.

4. **Having less-invasive ways to diagnose active conditions for which clinical interventions exist is a compelling proposition.** In addition, to the degree that non-invasive diagnostics detect the onset of diseases that genetic screens only predict, these two types of diagnostics work well together because they give providers a range of tools for active surveillance.

Source: Nakhleh et al., “Diagnosis and Classification of 17 Diseases from 1404 Subjects via Pattern Analysis of Exhaled Molecules,” ACS Nano, 2017; Health Care Advisory Board interviews and analysis.
2. Real-Time Patient Data from “Internet of Things”

Case Study: Provider Delivering Marked Outcome Improvement from the IOT

What is it?
The “internet of things” (IoT) refers to devices that send and receive data near instantaneously over the internet. Applied to health care, these devices can track health indicators in real time.

Why is it important?
Technological advancements are redefining what it means for providers to practice active disease surveillance. The ultimate goal is not just early identification of health issues, but rather real-time identification of dangerous health escalations. Real-time patient data through the IoT allows providers to collect and process data from the patient, which, in some cases can enable providers to anticipate health issues and deliver time-sensitive interventions.

Key Facts
- 97.6M wearable devices are expected to be shipped annually by 2021
- $163B of IoHT solutions in healthcare space are expected in 2020
- 38.1% CAGR of IoHT solutions in health care is expected from 2015-2020

Children’s Mercy Hospital is using real-time patient generated data for children with hypoplastic left heart syndrome through its Cardiac High Acuity Monitoring Program (CHAMP). The program equips parents with monitoring devices that submit data to the medical team. If a potentially dangerous indicator is recognized, providers can take immediate action to address the problem. Real-time monitoring of newborns in the CHAMP program has demonstrated incredible success, significantly decreasing pediatric interstage mortality.

Details of CHAMP Program

**Case in Brief: Children’s Mercy**
- 367-bed hospital based in Kansas City, MO
- Developed Cardiac High Acuity Monitoring Program (CHAMP) for children with hypoplastic left heart syndrome
- Indicators of cardiac health, including heart rate, weight, and oxygen saturation measurements, are instantly analyzed in the cloud after submission in the Mercy app

**CHAMP Program Eliminates Pediatric “Interstage” Mortality**

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<thead>
<tr>
<th></th>
<th>Before CHAMP</th>
<th>With CHAMP</th>
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<td><strong>20%</strong></td>
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<td><strong>0%</strong></td>
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1) Internet of healthcare things.
2) Compound annual growth rate.
3) Interstage is the time between the first and second surgeries for patients with hypoplastic left heart syndrome. Children’s Mercy has observed 0% mortality for all 62 patients using CHAMP.

Case Study: IOT-Enabling Platform

The internet of things has led to a proliferation of patient-generated data. Although many IoT devices are popular with consumers, patient-generated data must be integrated into clinical workflows to achieve real clinical utility.

Providence St. Joseph Health Ventures developed a platform, Xealth, that integrates data from digital content vendors into a single, accessible platform. Xealth allows clinicians to both prescribe digital tools and track patient-generated data from the tool directly through a “digital health” tab in the electronic health record. It recommends applications to physicians based on a patient’s diagnosis. Once a clinician prescribes the digital tool, the patient receives an email with instructions regarding its use and submission of digital content. The platform has been well received by Providence’s patients, with almost half of patients completing digital programs.

Integrating patient-generated data into clinical workflows is critical for providers to use that data for clinical decisions. Data integration also allows health systems to analyze large amounts of patient-generated data at scale. For example, Providence is using Xealth to monitor over 20,000 patients with sleep apnea via CPAP devices, which would have been extremely difficult and labor intensive without EHR integration.

Case in Brief: Xealth

- Technology start-up based in Seattle, WA; created through Providence St. Joseph Health Ventures
- Digital content tab embedded into EMR; platform is compatible with all digital content vendors
- Platform enables clinicians to “prescribe” digital content to patients, as well as view and act on data

80%
Open rate for average patient email sent through Xealth platform

40%
Percentage of digital programs that are completed by the patient

>20K
Patients monitored via CPAP device integrations at Providence St. Joseph Health

Implications of Real-Time Patient Data from the “Internet of Things” for Hospitals and Health Systems

1. Despite a noisy, consumer-oriented, over-hyped market, it’s increasingly clear that **analysis of real-time patient data can have demonstrable clinical utility**. Collection of patient-generated data is likely to be expected by consumers in the future. However, data should not be collected merely for the sake of doing so. Providers must establish actionable alert systems and follow-up guidelines for a limited number of conditions initially, or else risk overwhelming the care team or the data going unused.

2. Digital health connectivity will apply best to a subset of service lines, types of devices, and patient profiles; for example, consumers who are engaged in their health, new or expecting parents, caregivers, or patients with a life-threatening condition that can be managed. **Providers should focus their efforts on specific clinical areas where there is patient need, market demand, potential to create longitudinal relationships with patients, or opportunities to intervene in life-threatening situations.**

3. Realizing both business and clinical benefit remains challenging. **Patient-generated data must be embedded into clinicians’ workflows and some types of data should be automatically processed in real time.** Incorporating non-physician staff into the team model may be a feasible solution to managing patient-generated data and following up efficiently on alerts.

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Source: Health Care Advisory Board interviews and analysis.
3. AI-Guided Decision Support Platforms

Case Study: AI Product Streamlines Low-Acuity Care

What is it?
AI has a wide range of potential applications in health care, including (but not limited to) using computer systems to derive insight and/or relieve staff from time-intensive tasks so they can practice top-of-license care and make more informed clinical decisions.

Why is it important?
AI can extend and amplify human capabilities in a wide range of ways. To take one major health care example, advancements in detecting new indicators of disease, both in diagnostics and real-time monitoring of patient data, have added information to an already data-overloaded diagnostic process. Humans will not be able to fully read and analyze data from future technologies in any reasonable time frame without assistance. AI can help providers analyze clinical information to systematize ‘right care’ for every patient at the right time, ideally decreasing the growing data burden on clinicians.

Key Facts
- 5% of hospitals report using AI today, but 50% of hospitals are forecasted to use such technologies within the next 5 years
- 40% compound annual growth rate is expected for AI technologies from 2014 to 2021
- $6.6B market size for AI technologies expected by 2021 (from $600M in 2014)

Evolution of Computer Technology

| Personal computer | Internet and web | Mobile first | Artificial intelligence |

Case in Brief: Bright.md
- Virtual care vendor based in Portland, OR
- SmartExam software uses AI to dynamically “interview” patients and generate a preliminary diagnosis for one of 300+ low-acuity conditions
- On average, it takes clinicians two minutes to review case and treatment; cost is $20-$25 for patients out-of-pocket

Bright.md’s virtual visit platform uses artificial intelligence to diagnose over 300 low-acuity conditions. When patients initiate a virtual visit, they are prompted to answer a series of questions to explain their symptoms. The AI platform adapts questions based on a patient’s responses and then develops a preliminary diagnosis and treatment plan for a clinician to review.

In the 10% of cases that the platform cannot generate a diagnosis, clinicians can prompt the patient to go to their primary care physician for in-person care.

The platform increases a provider’s ability to practice top-of-license care and is also appealing to consumers. Patients receive quick resolutions for low-acuity health conditions at a low out-of-pocket cost.

Typical Virtual Visit Platform
- 15 minutes per case
- 30 patients per day

Bright.md SmartExam Platform
- 2 minutes per case
- 150-200 patients per day

Case Studies: Providers Harnessing AI for Diagnostic Insight

Five-Year Melanoma Survival Rates, by Stage of Detection

<table>
<thead>
<tr>
<th>Stage</th>
<th>Survival Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1; small and localized</td>
<td>99%</td>
</tr>
<tr>
<td>4; spread to lymph nodes</td>
<td>14%</td>
</tr>
</tbody>
</table>

While AI can raise provider efficiency in low-acuity cases, it can also improve a health system’s approach to high-acuity cases—for example, in diagnostics, where early detection has a measurable impact on patient outcomes.

For example, timely diagnosis and treatment of malignant melanoma can mean the difference between life and death. Patients diagnosed in stage 1 are more than seven times more likely to survive than those diagnosed in stage 4.

Stanford has developed an AI platform that can recognize over 2,000 types of skin diseases, including malignant melanoma. In an early study, the platform was able to recognize malignancies with accuracy equal to that of dermatologists.

Given that wait times for dermatology appointments exceed 30 days in many parts of the US today, this technology’s potential to improve outcomes is impressive. Imagine the access, time-to-treatment, and population-level outcome improvement if a technology like this were incorporated into telemedicine—potentially even accessed by patient smartphone.

Using Neural Networks to Diagnose Skin Cancer from Images

1. 129,450 clinical images of skin abnormalities uploaded to AI platform for analysis; 2,032 different diseases recognized
2. Program recognized melanoma with accuracy on par with the average accuracy across a control group of 21 board-certified dermatologists
3. Future: Platform could be integrated onto consumer-facing smartphone application to provide digital access

AI offers tantalizing possibilities for advancing predictive analytics—with the caveat that providers must retain enough control over the analysis to understand the reasons behind any conclusions that AI can provide.

For example: Mount Sinai created a pilot platform, Deep Patient, which read thousands of patient records to predict the onset of certain diseases. The program also made connections and became smarter, without human programming, over time. The catch? Deep Patient succeeded in predicting diseases with surprising accuracy. However, it could not explain the basis for its predictions, making it impossible for clinicians to fully trust.

Again, AI offers tremendous potential benefits on some of health systems’ top priorities—efficiency, access, patient outcomes—but humans will need to understand and trust the reliability of any guidance AI provides.

Deep Patient Program at Mount Sinai

Deep-learning model trained using data from >700K patients’ medical records

Using AI platform, computer learns to predict onset of certain diseases when tested on new records without expert instruction—including schizophrenia and liver cancer


Case in Brief: Stanford Health Care

• Academic health system based in Stanford, CA
• Created deep convolutional neural network (CNN)—a type of AI platform—which is able to read skin lesions and identify over 2,000 different types of skin diseases
• AI-based system identified melanoma on sample images with equal accuracy than the average performance of a control group of 21 board-certified dermatologists

Case in Brief: Mount Sinai Health System

• 7-hospital health system based in New York, NY
• Applied deep learning to database of patient records in program called Deep Patient
• Model identified hidden patterns in medical records and predicted disease with surprising accuracy—but researchers were sometimes unable to understand basis of predictions

Five-Year Melanoma Survival Rates, by Stage of Detection

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<tr>
<td>4; spread to lymph nodes</td>
<td>14%</td>
</tr>
</tbody>
</table>
4. Next-Generation Natural Language Processing

Case Study: One Group Uses NLP to Synthesize Findings, Update Guidelines

What is it?

Natural language processing (NLP) applications use computer systems to process text, streamlining reading and writing tasks such as reviews of clinical literature, dictation of notes, and clinical documentation.

Why is it important?

Providers dedicate significant time to reviewing and producing qualitative information—and NLP can ease the time and effort required.

For example, clinicians invest valuable time tracking clinical research to stay current with evidence-based standards, or reading through patient charts to find qualitative information pertinent to the case at hand. NLP can help by synthesizing qualitative information, streamlining the time and effort of clinician review, and freeing clinicians to use their time in a more top-of-license way.

Key Facts

- 40% of the total revenue in the cognitive computing market is currently attributed to NLP applications
- 15 seconds is all it takes for IBM Watson to process 40M documents

The Cochrane Project aims to produce a “living review” of evidence-based guidelines for clinicians with their initiative, Project Transform. Using NLP technology, researchers can conduct near instantaneous reviews of clinical literature so they can review and validate new guidelines for a given condition, procedure, or patient profile as guidelines evolve. Cochrane has analyzed over 34,000 clinical trials and synthesized corresponding recommended guidelines into their platform to date.

Cochrane’s “Living Reviews”

1. Researchers initiate monthly searches of evidence in clinical literature
2. Computer processes clinical trial text
3. Contributors approve and integrate new evidence identified
4. Provider embeds best practice into EMR

Case Study: An NLP Solution That Helps Cut to the Chase in ED Visits

**Case in Brief: MedStar Health**

- 10-hospital health system based in Columbia, MD
- Developed an algorithm that instantly scans the entire patient history and provides recommendations on what facts are most important, based on the patient’s presenting symptoms

In addition to keeping evidence-based standards up to date, NLP can also increase the efficiency of patient visits. At MedStar, NLP is used in the ED to streamline the patient chart review process.

MedStar’s Institute for Innovation worked with data scientists at Booz Allen Hamilton to develop an NLP solution called Dictation Lens. When patients present to the emergency department, the platform analyzes keywords from the patient’s subjective report and compares it to information from the patient’s medical history. The platform predicts the most relevant information related to the patient’s presenting symptoms for the treating clinician to review. Automation of this process can provide a tremendous efficiency boost for clinicians tasked with reviewing sometimes prohibitively long patient histories. Additionally, the speed at which information is synthesized can provide immeasurable clinical benefits when the insight informs clinical interventions in time-sensitive circumstances.

**Problem: Infeasible for Clinicians to Efficiently Analyze Patient History Comprehensively in the ED**

<table>
<thead>
<tr>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine learning system scans patient history, identifying important information based on patient symptoms</td>
</tr>
<tr>
<td>Machine generates an executive summary, flagging facts most likely to be pertinent</td>
</tr>
<tr>
<td>Physician’s time freed for top-of-license practice; evaluates recommendations and makes best diagnosis, treatment, and care decisions</td>
</tr>
</tbody>
</table>

**Implications of AI-Guided Decision Support Platforms and Next-Generation Natural Language Processing for Hospitals and Health Systems**

1. **There are many applications for AI that enable providers to become more productive and practice at top of license.** For example, AI platforms have the ability to support providers in making accurate diagnoses more efficiently and reliably. If providers can harness this potential, they could reap gains on fronts from reduced cost per case to improved clinician engagement and quality of patient care.

2. **Natural language processing can accelerate the process of updating evidence-based guidelines.** By automating initial reviews of clinical literature, providers can more quickly adopt new standards of care with less reliance on lengthy, manual literature reviews.

3. **Machine learning techniques are entering the health care industry rapidly, but significant technological hurdles remain.** Many providers may need to seek vendor partners to develop and/or customize solutions.

4. **Physicians and regulators will play a large role in the timing and extent of AI adoption.** Regulators are currently struggling to balance oversight responsibility with the pace of innovation, and physicians have concerns about safety, accuracy, and defensibility of AI-based insights—which are legitimate. In particular, machine learning algorithms need to be better at explaining insights they generate before they can be relied upon.

Source: Sohn E. et al., “Four Lessons in the Adoption of Machine Learning in Health Care,” HealthAffairs, 2017; Health Care Advisory Board interviews and analysis.
5. Molecular and Gene-Targeted Treatments

What are they?

Molecular and gene-targeted treatments are therapies that target specific molecules or genes with much greater precision and customization than most conventional treatments today. Molecular and gene-targeted treatments include biologics, gene therapies, immunotherapies, and CAR-T therapies.

Why are they important?

The opportunity to improve the effectiveness of interventions is just as infinite as the opportunity to sharpen diagnostic capabilities. The emerging pipeline of clinical interventions is shifting toward more precise treatments for this reason. Precision can be more effective by virtue of being customized to a patient or less toxic, meaning the intervention is better targeted to the patient's pathology and does not harm healthy tissue.

The market for these types of treatments is huge, and the pipeline is full of additional applications in clinical trials. However, these drugs carry high development costs and apply to more narrow or niche markets, resulting in astronomical price tags. In fact, the majority of drug spending growth across the past five years can be attributed to specialty drug spending—including molecular and gene-targeted treatments.

Key Facts

- 550 biologics were approved from the FDA from 2000 to 2015
- 504 gene therapies for cancers, genetic disorders, and infectious diseases are currently in clinical trials
- 180+ CAR-T immunotherapies are currently in clinical trials

Share of Medicine Spending on Specialty Drugs

<table>
<thead>
<tr>
<th>Year</th>
<th>Oncology</th>
<th>Autoimmune</th>
<th>Viral Hepatitis</th>
<th>Multiple Sclerosis</th>
<th>HIV Antivirals</th>
<th>Other Specialty</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>$151B</td>
<td>$83B</td>
<td>$47B</td>
<td>$15B</td>
<td>$11B</td>
<td>$3B</td>
</tr>
<tr>
<td>2014</td>
<td>$124B</td>
<td>$71B</td>
<td>$51B</td>
<td>$14B</td>
<td>$9B</td>
<td>$4B</td>
</tr>
<tr>
<td>2013</td>
<td>$97B</td>
<td>$65B</td>
<td>$46B</td>
<td>$12B</td>
<td>$8B</td>
<td>$3B</td>
</tr>
<tr>
<td>2012</td>
<td>$88B</td>
<td>$59B</td>
<td>$43B</td>
<td>$11B</td>
<td>$8B</td>
<td>$3B</td>
</tr>
<tr>
<td>2011</td>
<td>$82B</td>
<td>$56B</td>
<td>$42B</td>
<td>$10B</td>
<td>$8B</td>
<td>$3B</td>
</tr>
</tbody>
</table>

The term “precision treatments” refers to two basic therapeutic mechanisms. The first, molecular therapies, refers to drugs that target specific malfunctioning cell pathways in the body. The second, gene therapies, correct or alter genes to remove or target errors within a cell’s DNA. This process removes the gene signal that causes a disease and promotes the creation of healthy tissue instead.

Many of the breakthroughs in clinical treatments today are immunotherapies, which are therapies that harness the body’s own healing power to more effectively fight disease. Immunotherapies can be both molecular and gene therapies, and are responsible for a large portion of drug spending growth in the market today.

**Two Ways Therapeutics Target Patients More Precisely**

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drug binds tightly to specific biomolecules or cell types</td>
<td>Influence malfunctioning cellular pathways</td>
</tr>
<tr>
<td>Genes inserted or altered to combat disease</td>
<td>Eradicates source of errant signaling mechanism</td>
</tr>
</tbody>
</table>

**Editing the Human Genome**

Source: Health Care Advisory Board interviews and analysis.
Case Study: Molecular Treatment

Case in Brief: Keytruda (Pembrolizumab)

• Checkpoint inhibitor that targets the PD-1/PD-L1 cellular pathway
• First approved drug for use against all tumors that share a common genetic mutation—microsatellite instability-high (MSI-H) or mismatch repair deficient (dMMR)—regardless of location in the body

Identifying a Shared Gene Mutation in Disparate Cancer Types

1. Clinical trial for nivolumab (nearly identical to Keytruda), resulted in a colon cancer patient’s tumor disappearing—but only this one patient responded

2. Researchers analyzed that patient’s cancer cells and found a plethora of mutated genes and abnormal proteins

3. Identified tumor mutations (MSI-H and/or dMMR) that prevent tumor from repairing DNA

4. Gathered patients with 12 different types of cancers that shared the MSI-H and/or dMMR mutation to test clinical efficacy of Keytruda; found tremendous response rates

Molecular Treatments

Across the past few decades, cancer treatments have primarily targeted tumors with surgeries, chemotherapies, and radiation. New molecular therapeutics target specific mutations, which are highly variable by patient and allow the cancer to develop in the first place.

There are several established drugs on the market that target specific cancer mutations, such as the breast cancer drug Herceptin. Keytruda is another pharmaceutical that is especially interesting because it targets a specific mutation which many types of cancers share, including breast and prostate cancer.

The discovery process of Keytruda serves as a helpful illustration of the power of precision medicine.

Researchers were conducting a study on colon cancer with a drug similar to Keytruda that failed to work on a large group of patients. However, one patient experienced a complete remission of his tumor.

Investigating why the drug could have so drastically helped a single patient while proving ineffective in all the rest, researchers discovered that the drug was stimulating his immune response in a way unlike other patients in the trial. The patient’s cancer had a specific mutation that disrupted his immune system’s ability to fix damaged DNA, so the immune system essentially could not detect the cancer. The drug helped the patient by unmasking the cancer cells and allowing his immune system to work as it should have.

Armed with this insight, the researchers were able to determine that the drug could help patients who shared that mutation—even if they were diagnosed with several different kinds of cancer.

53% Of tumors in patients in the nivolumab clinical trial with radiographic evidence exhibited tumor shrinking after taking Keytruda

21% Of patients in nivolumab clinical trial saw tumors completely eliminated after taking Keytruda

4% Of cancer patients have the genetic mutation (MSI-H and/or dMMR) that is susceptible to Keytruda (60K patients a year in the US)

$13K Per-month cost of Keytruda infusion

Case Study: Gene Therapy

Case in Brief: Kymriah

- First gene therapy approved by the FDA; therapy is approved for the 20% of pediatric B-cell acute lymphoblastic leukemia patients unresponsive to traditional treatment
- Patient’s own T cells are engineered to attack cancerous cells with the CD19 receptor

Acute Lymphoblastic Leukemia (ALL)

3,100  ≈600
Number of diagnoses each year  Fatal cases annually

Gene-Targeted Treatments

New gene therapies have the ability to activate a patient’s T cells in their immune system, programming them to detect and destroy cancer cells.

In August 2017, the FDA issued a historic ruling and approved the first gene therapy, Novartis’s Kymriah. Kymriah is cleared for only a small percentage of children with acute lymphoblastic leukemia who are unresponsive to traditional treatments. Shortly after Kymriah was approved, the FDA cleared a second CAR-T therapy for adults with non-Hodgkin’s lymphoma, Yescarta, and a third gene therapy to treat a rare form of blindness, Luxturna.

At the time of this publication, the gene therapies on the market have small markets. Because of their high toxicity and potentially serious side effects, Kymriah is approved for only about six hundred children per year.

Yescarta has a slightly larger market, because there are about 30,000 Americans diagnosed with non-Hodgkin’s lymphoma each year, although its potential for serious side effects will also limit the number of adults who receive treatment.

Close to two hundred additional CAR-T therapies are currently in clinical trials; expect to see many more gene-targeted treatments entering the market in the near future.

Promising results…

83% Remission rate following treatment with Kymriah\(^1\)

…at an exorbitant cost

$475K Cost of one-time Kymriah injection

Reprogramming Immune Cells with CAR-T Therapy

T cells extracted from patient  →  Genes manipulated in the lab

T cells trigger death of cancerous cells  ←  Engineered cells infused into patient

Wrestling with the High Cost of Gene-Targeted Treatments

The gene therapies on the market today are extremely expensive because of their very narrow markets and the high R&D costs required for their development. Kymriah costs $475K for a one injection, Yescarta costs $373K, and the most expensive of them all, Luxturna, costs a whopping $850K.

Insurance coverage of these therapies varies, but payers are increasingly demanding that a clear value proposition be established prior to providing coverage. For example, Medicaid will cover Kymriah only if the treatment is successful and the child’s cancer enters remission. Otherwise, Novartis is at risk for the cost.


1) Within three months.
Case Study: Value-Based Payment for Costly Drugs

The rising costs of specialty pharmaceuticals is energizing the movement to apply value-based payment models to the pharmaceutical industry. Pharmaceutical manufacturers recognize the need to demonstrate a value proposition to payers and are increasingly willing to cover more or all of the cost of their drugs if they do not deliver the promised results.

For example, Amgen makes an injectable cholesterol drug, Repatha, which costs about $14,000 per year. If a patient taking Repatha is hospitalized with heart disease or stroke, Amgen will refund the cost of Repatha back to payers. Novartis has implemented a similar model for its heart failure drug, Entresto. If the rate of hospitalizations for patients on Entresto exceeds a prespecified threshold, Novartis reduces the price of Entresto to payers.

There is a strong likelihood that more pharmaceutical companies will follow suit with value-based payment models to increase utilization of their extremely specialized, high-cost drugs. Providing a clear value proposition will help increase access to these treatments, however this is by no means a complete solution to the rising costs of specialty pharmaceuticals.

1. Money-Back Guarantee

Drug: Repatha

Use: Helps the liver clear low-density lipoprotein for those with high cholesterol by limiting actions of PCSK9\(^1\)

Cost: $14,000/year

Outcomes:
- 27% reduced risk of heart attack
- 21% reduced risk for stroke
- 22% reduced risk for coronary revascularization

Payment: If patient is hospitalized with heart disease or stroke, Amgen will refund the cost of Repatha to the insurance company

2. Outcomes-Based Payment

Drug: Entresto

Use: Treatment for heart failure patients with reduced ejection fraction (HFrEF) that uses sacubitril and valsartan\(^2\)

Cost: $12.50/day

Outcomes:
- 20% reduced risk of heart failure hospitalization or cardiovascular death
- 44% reduced risk of readmission for heart failure; 36% fewer patients readmitted for any cause

Payment: If heart failure hospitalizations of patients exceed a predetermined threshold, Novartis reduces price of Entresto to payers


1) Gene called “proprotein convertase subtilisin/kexin type 9, responsible for regulating the number of low-density lipoprotein receptors in the body.
2) Sacubitril is an eprilysin inhibitor, valsartan is an angiotensin receptor blocker.
CRISPR: Clustered Regularly Interspaced Short Palindromic Repeat (CRISPR) refers to short, partially palindromic-repeated DNA sequences in the genomes of bacteria and other microorganisms.

The technique enables a much faster and easier gene editing approach compared to previous methods.

CRISPR gene-editing technology has the potential to lower the cost of gene editing. CRISPR received a lot of press for its promises to cure single gene mutations. It has even been used to successfully correct hypertrophic cardiomyopathy in human embryos at Oregon Health & Science University.

Curing single-gene mutations alone would be transformative for the health care industry, but doing so at a low cost would be even more so. However, CRISPR is still a couple of years from entering the health care industry widely.

Gene Editing Could Cure Disorders Caused by Single-Gene Mutations

>10K Number of known single gene disorders

Sample Single-Gene Disorders
- Cystic fibrosis
- Sickle cell anemia
- Marfan syndrome
- Huntington’s disease
- Hemochromatosis
- Hypertrophic cardiomyopathy

First disorder to be successfully “corrected” in human embryos by CRISPR gene editing

Implications of Molecular and Gene-Targeted Treatments for Hospitals and Health Systems

1. The shift from blockbuster, broadly applicable drugs to niche therapies (e.g., for specific cancer variants) has resulted in a pipeline’s worth of interventions that are astronomically expensive. Coverage options will exist for effective drugs, but expect rigorous prior authorization requirements and significant hurdles around affordability issues among underinsured and high-deductible patients.

2. Given the high technology expense and limited market size for these therapies, not all hospitals and health systems are likely to offer all of them. Some will build centers of excellence to draw patients regionally or nationally. Others must forge partnerships and referral channels with those providers—and find ways to educate patients’ home physicians about ongoing risks and non-standard side effects that might be unfamiliar to, for example, an ED physician.

3. Providers must balance the desire to offer patients access to new treatments with a thoughtful evaluation of inherent risks. For example, the two approved applications of CAR-T to date have high toxicity and a dearth of data on their long-term efficacy. Clinicians must be prepared to communicate the full cost-benefit analysis—and the unknowns—to patients.

6. Engineered Organ Replacements

Case Study: In-Development Xenotransplantation Research

**What is it?**
Engineered organ replacements are strategies to produce a supply of healthy organs for patients that need transplants through either xenotransplants or stem cell therapies.

**Why is it important?**
Providers are currently falling short of meeting US transplant demands. It is estimated that over 80,000 people do not receive needed transplants every year. The industry has not found a way to produce a supply of healthy organs to meet patient needs while ensuring minimal toxicity after the transplant.

Xenotransplants and stem cell therapies both have the potential to increase the supply of healthy organs for transplant patients and significantly improve clinical outcomes for patients with organ failure.

**Key Facts**
- **34K** people received an organ transplant in the US in 2016
- **117K** people were on the US organ transplant waiting list in 2016

**Xenotransplantation**
Providers have used pig valves in cardiac surgery for years. Because many pig organs are similar in size to human organs, there is the potential for researchers to alter pig organs for human use. Human rejection of pig tissue is the key concern, but realistically there are several other considerations for using animals to supply human organs, including ethical concerns. Despite companies like eGenesis that aim to sell genetically altered pig organs, it is estimated that the health care industry is at least two years away from transplanting animal organs to humans.

**Benefits**
- Ability to increase supply as needed to meet demand
- Pig organs can be the right size for human transplantation
- General societal acceptance from other decades-long pig transplant applications (e.g., valve replacement)

**Barriers**
- Ethical considerations regarding animal exploitation
- Lingering safety concerns regarding transmission of viral diseases and immune rejection

Case Study: Stem Cell Therapy to Regenerate Cardiac Tissue

Stem Cell Therapies

Reengineering a patient’s own cells is a promising solution to address transplant demand. Among other benefits, it would mitigate the risk of rejection of foreign tissue that may occur with xenotransplants or transplants from foreign material.

BioCardia and the University of Wisconsin have developed a therapy, CardiAMP, that promotes the regeneration of cardiac tissue with a patient’s own stem cells.

Aside from the enormous clinical benefit, CardiAMP or other cardiac stem cell therapies also present an enormous growth opportunity for providers because there are millions of adults in the US living with heart disease. The procedure is quick, about 60 to 90 minutes, with a very short recovery time. Additionally, transplants have a mature reimbursement model. Compared to other innovations, engineered organ transplants are relatively straightforward business opportunities for hospitals and health systems.

Case in Brief: CardiAMP

- Regenerative cell therapy developed at the University of Wisconsin in partnership with BioCardia
- Currently in phase III clinical trials at 40 medical centers across the US for the treatment of heart failure after a heart attack
- If approved, would be the first approved cardiac cell therapy in the US

CardiAMP Therapy Process

1. Patient has heart attack
2. Small amount of bone marrow collected from iliac crest
3. Cells processed at point of care to trigger regeneration
4. 60-90 minute surgery conducted in cath lab using Helix™ delivery system
5. Patient discharged same day or after one-night stay
6. Treatment triggers growth of healthy heart tissue

Implications of Engineered Organ Replacements for Hospitals and Health Systems

1. Transplant and restorative treatments are in high demand and low supply. **If new treatments become available, providers will need to build avenues to access these treatments.** Large specialized centers will be the first to adopt next-generation transplant capabilities. Smaller hospitals should first work with affiliates or partners on providing access to these treatments, but should also consider offering new restorative treatments themselves as safety and efficacy data matures, and as market demand dictates.

2. Being procedural in nature, transplants and restorative treatments have a straightforward business case and fall into acute care providers’ traditional wheelhouse. While costly to perform, transplant procedures have historically been well-reimbursed by insurers.

3. There are both benefits and drawbacks to being a first mover in offering engineered organ treatments. In addition to ethical issues, **there are clinical barriers surrounding immune rejection and unclear long-term research regarding side effects and clinical utility that must be resolved.**
7. 3D Printer-Enabled Surgeries

Case Study: Provider Use of 3D Printing to Enable Complex Surgeries

What is it?
3D printing enables the manufacture of custom-designed materials for a wide range of health care purposes. Applications of 3D printing in health care include surgical models, pharmaceuticals, and skin. In the future, 3D printers are predicted to create prosthetics, implantable devices, and even whole organs.

Why is it important?
Absent 3D printing, the main rate limiter for the custom implant market today is cost. Custom orthotics, prosthetics, and implants are extremely expensive. As a result, very few patients have access to them. 3D printing, with its low production costs, makes customized products more affordable for providers and patients alike.

Health systems that use 3D printers could experience a dramatic change in system operations. Allowing surgeons to practice complex surgeries on a replica of a patient’s exact anatomy can significantly reduce surgery times—a win for both efficiency and quality, as longer surgeries tend to be riskier for patients. Health systems that print implants on site and on demand could disrupt the current supply chain and lower supply costs in the long term.

Key Facts
- $1.2B total 3D printing spending in health care expected by 2020
- 10% estimated number of people in the developed world who will be living with 3D-printed objects on or in their body by 2019

Case in Brief: Mayo Clinic
- Academic health system based in Rochester, MN
- Created on-site 3D printing lab that uses data from MRIs, CT scans, ultrasounds, and 3D pictures to create anatomical models that surgeons use to plot customized surgical approaches that were previously impossible due to complexity; created 500 3D-printed objects in 2016

How 3D Printing Saved a Patient’s Leg

Rare tumor in pelvis, spread to bones and nerves of sacrum

Surgeons cannot remove tumor because of its complexity

Physician amputates leg to remove affected areas

Tumor stops spreading

Old Approach

New Approach

Engineers create 3D model scaled to size, showing bladder, veins, blood vessels, ureters, and tumor

Physicians plot surgical approach to allow for removal of tumor without taking leg

Case Study: System Develops 3D Printing Network

With the wide scope and specialization of 3D-printed devices, health systems will likely need to centralize the design of 3D implants among hospitals in the system more broadly. The VA has already deployed this strategy to gain scale and expertise. They created an internal 3D-printing network that centralized specialized printing supplies. Because of the demand for prosthetics within the VA system, a 3D printing network has the potential to save costs in the future.

However, not all health systems have the prosthetic and implant demand to create and internal 3D printing network. These systems may develop robust partnerships with vendors or larger systems who have sophisticated technology and materials expertise.

3D Printing Network at Veterans Administration

Ultimate Goal to Advance Assistive Technology for Custom Prosthetics

Model for procedural planning and training

Robotic prosthetic hand

Implications of 3D Printer-Enabled Surgeries for Hospitals and Health Systems

1. The advent of 3D printing is likely to disrupt some parts of the supply chain as providers take on new capabilities. For some providers, vendor partners will be crucial to overcoming barriers to entry, such as technology costs and adequate device design expertise.

2. There will likely be large consumer demand for custom, 3D-printed prosthetics and implants. These types of procedures will tend to fit within existing reimbursement frameworks—with lower provider-facing costs. First movers in this space may see significant volumes from patients who are willing to travel for customized care.

3. The extent of 3D printing applications is yet to be determined. Today, 3D printing is most often used for surgical tools and planning. In the future, a more sophisticated range of applications will likely exist. Centers that specialize in certain devices, procedures, or materials will likely take shape. Partnerships, affiliations, or network-wide hub-and-spoke models will be necessary to ensure each system’s patients can access the evolving range of 3D printing applications available.

8. Bioelectronic Device Implants

Case Study: In-Development Bioelectronic Technology

What are they?
Bioelectronic devices have the potential to cure nervous system disorders, which are difficult to treat with today’s methods. Bioelectronics promise to be far superior than our traditional pharmaceutical treatments today because they can proactively mitigate and control diseases before a patient develops complications. Additionally, the fact that bioelectronics treat the nervous system rather than cellular pathways means many of the side effects that most pharmaceuticals cause today could be eliminated.

Why are they important?
Although bioelectronic implant technology requires extensive development before it is ready for the market, it opens up the possibility of new procedures to treat many common conditions, including chronic diseases, with few side effects. Beyond benefits to patients and market opportunity for providers, if diseases regulated by the nervous system were more treatable, that could dramatically impact the delivery system—for example, if demand for medical management of chronic conditions were to drop.

Key Facts
- $700M investment that Verily and GlaxoSmithKline have stated they are willing to make to develop prototype bioelectronic devices

Bioelectronics Modulate Nerve Cell Function

Think of it as a little volume control on a nerve that controls an organ like the liver, pancreas, kidneys, or spleen. By changing the volume, the signals that go into the nerve, up or down, you can control what the organ does: whether it produces less or more of a particular hormone, or affects the constriction of the airways.”

Kris Famm, President and CEO
Galvani Bioelectronics

Diseases Galvani Believes It Can Potentially Treat
- Type 2 diabetes
- Rheumatoid arthritis
- Asthma
- Unspecified autoimmune disorder
- Arthritis
- Unspecified endocrine disorder
- Hypertension

Future Applications: Treating Paralysis and Coma Patients

Bioelectronics also have the potential to treat debilitating central nervous system disorders. Electric stimulation is currently being studied to restore movement after spinal cord injuries and restore consciousness for patients who are in a coma. Just as is the case for applying bioelectronics to treat chronic conditions, practical treatments for spinal cord injury and coma patients remain several years away from entering the market. But, if these treatments are realized, they could have a profound impact on health outcomes and patterns of utilization across the health care delivery system as a whole.

Theoretical Uses of Electric Stimulation

**Paralysis**
- Paralyzed patient
- Transcutaneous stimulation (electrode on skin)
- Epidural spinal stimulation (electrode under skin)
- Spinal cord stimulation (electrode on spinal cord)

**Coma**
- Man in vegetative state for 15 years
- Pulses of electricity sent to brain via vagus nerve
- Consciousness restored

Restoration of movement in limbs of paralyzed patients

### Implications of Bioelectronic Device Implants for Hospitals and Health Systems

1. **Researchers have a long way to go before the full potential of bioelectronics can be realized.** Major barriers include mapping the peripheral nervous system to pinpoint neuronal targets, developing an ongoing power supply for implanted devices, and designing surgical techniques to access nerves that are not easy to reach today.

2. **Once developed, bioelectronic implants will enable providers to proactively treat conditions that have little or no treatment today,** including coma, paralysis, and many chronic conditions that today are merely monitored and reactively managed.

3. **The potential market size for bioelectronics is massive.** Bioelectronics could be incorporated into care for many chronic conditions and motor and nervous system disorders. Providers will need to closely monitor the technological development and strategic investments they would need to be ready to take advantage of market opportunities as they materialize.

4. **In the long term, bioelectronics have tremendous transformative potential for hospitals and health systems. If the technology comes to market and revolutionizes how providers manage chronic conditions, those changes will have significant implications for the delivery system as a whole.**

Related Advisory Board Resources

**Delivery System Innovations**

- Developing High-Impact Innovation Centers
  Market Innovation Center | White Paper
- The Consumer Relationship Platform
  Health Care Advisory Board | Research Report
- Competing on Consumer Experience
  Health Care Advisory Board | Research Report
- Virtual Visit Opportunity Audit
  Planning 2020 | Tool
- Playbook for the Consumer-Focused Health System
  Health Care Advisory Board | Executive Briefing
- Digital Strategy Blueprint
  Market Innovation Center | Tool

**Detecting New Indicators of Disease**

- Personalized Medicine Investment Playbook
  Oncology Roundtable | Research Study
- The Journey to Personalized Medicine
  Oncology Roundtable | Infographic
- Precision Medicine Volumes Calculator and Financial Pro Forma
  Oncology Roundtable | Tool
- The Precision Medicine Business Plan Template
  Oncology Roundtable | Tool
- The Internet of Things (IoT) in Health Care
  Health Care IT Advisor | Executive Briefing
- Scaling Remote Patient Monitoring Programs
  Market Innovation Center | Research Report

**Powering Evidence-Based Decisions**

- Rise of the Intelligent Machines in Health Care
  Health Care IT Advisor | Webconference
- Cheat Sheet Series: Artificial Intelligence
  Health Care IT Advisor | Primer
- Should Radiologists Embrace or Fear Machine Learning?
  Health Care IT Advisor | Expert Perspective
- A Framework for Understanding Speech Recognition
  Health Care IT Advisor | Framework
- The Business Case for Speech Recognition in Hospitals
  IT Strategy Council | Research Report

**Delivering Precise Clinical Care**

- Clinical Innovations in Oncology
  Oncology Roundtable | Research Report
- Tumor Site Centers of Excellence
  Oncology Roundtable | Research Report
- Driving Transplant Program Growth
  Service Line Strategy Advisor | Research Report
- 3D Printing in Patient Care
  Health Care IT Advisor | Research Report
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