12

DISRUPTIVE
DOZEN

artificial intelligence

The culture of innovation at Brigham and Women's Hospital and Massachusetts General Hospital fosters a good deal of discussion about emerging technologies and which ones will have the biggest impact. The passion of clinicians and researchers drives a continuous dialogue on what state-of-the-art medical technologies are just over the horizon and their potential to help patients. The Disruptive Dozen is a process that results in a rank ordered list of 12 AI-enabled technologies that leading PHS faculty feel will have the greatest impact on healthcare in the next few years.

2019 Steering Committee
co-chairs

Anne Klibanski, MD
Interim President and CEO, Chief Academic
Officer, PHS; Laurie Carrol Guthart
Professor of Medicine, HMS;
2019 Forum Co-Chair

Gregg Meyer, MD
Chief Clinical Officer, PHS; Professor of
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Disruptive Dozen | 2019

The Nomination Process

The Disruptive Dozen involves a rigorous process to gather the opinions of physicians
and researchers that are assembled into a field of nominated innovative technologies.
The nominations are considered in a three-hour dinner session involving a subset of the
interview subjects. The output of the dinner is a consensus on the twelve technologies
that will have the greatest impact on AI in the next decade. More than 60 30-minute in-
person and telephone interviews will be conducted with leading faculty from Brigham
and Women's Hospital and Massachusetts General Hospital to elicit their nominations.

Selection Process

A meeting was held in November 2018 to jointly choose and rank the final 12
breakthrough innovations. To receive consideration for the final Disruptive Dozen,
nominated innovations must meet the following criteria:

CRITERIA 1

The innovation must have the strong potential for significant AI related clinical impact and
offer significant patient benefit in comparison to current practices. The innovation may
also have a significant benefit to the delivery/efficiency of AI related health care.

CRITERIA 2

Nominated AI related innovations must have a high probability of successful commercial
deployment – e.g., payers will be expected to support it.

CRITERIA 3

The innovation must be on the market by 2020.

Final Scores and Announcement at the World Medical Innovation Forum

Selection committee members jointly
ranked the innovations from 1 to 12 using
the initial scoring and further discussion.
The selection committee ranking is final
and will be announced April 10, 2019 in
a one-hour panel at the World Medical
Innovation Forum. The session will be
moderated by Jeffrey Golden, MD, and
Erica Shenoy, MD, PhD and feature 12
faculty members selected to briefly
comment on each technology.

Narrowing the Gaps in Mental Health Care

In the United States, mental illness has reached epidemic proportions. Nearly one in five adults grapples with a mental disorder. Opioid addiction and misuse claim the lives of more than 130 adults every day. And antidepressant use among individuals 12 and older is around 13%, a figure that reflects a staggering increase of 65% over 15 years. Beyond medications, depression exacts a tremendous toll, with a total economic burden estimated at over $210 billion a year — more than double what the country spends on cancer.

For the millions of patients with mental illness, access to quality, evidence-based mental health care can be life-changing. Yet significant barriers exist, ranging from social stigma to a dearth of available mental health specialists to high costs, which prevent patients from obtaining the care they need. Minimizing these obstacles is a top priority for the health care community.

Now, several research teams across the country are harnessing technology, including AI-based methods, to help narrow the gaps in mental health care. One particularly exciting area of innovation is the integration of rigorously validated mental health methods into smartphone apps. Researchers in Massachusetts are developing an app for patients with opioid, alcohol, and other forms of drug addiction, particularly those with co-occurring mental illness. The app provides patients with a virtual form of integrated group therapy (IGT), a highly effective treatment that teaches patients behaviors and skills to manage their own recovery and prevent relapse. The problem with IGT: it is both time-consuming and expensive, thereby limiting number of patients a single mental health care provider can treat.

By packaging the key elements of IGT into an app, the Massachusetts-based team hopes to significantly expand access to this important treatment. Notably, the team has designed their app with critical capabilities that can help extend the role of mental health care professionals. These include rapid, AI-powered support for patients in the moment when they are experiencing cravings. This assistance can be challenging for providers to deliver, yet it can be pivotal in helping patients maintain their recovery. The app also includes a resiliency meter to help predict periods of vulnerability, guiding patients and their care team on when to schedule face-to-face sessions. The app is now undergoing software development and will be tested later this year on a group of about 50 patients to compare its performance with conventional, in-person IGT.

Another Massachusetts-based team is developing a smartphone app that incorporates principles of cognitive behavioral therapy (CBT) for patients with body image concerns, including body dysmorphic disorder. Just like IGT, CBT is a first-line treatment that involves educating patients about their illness and teaching them skills they can use to help manage it, like modifying self-defeating thoughts. The researchers bundled the key elements of CBT for body dysmorphic disorder into an app and included a chat feature in which patients can interact directly with clinicians for a few minutes every week. They recently completed beta-testing through an open trial of 10 patients who received the smartphone-app-based treatment and a control group who received conventional, face-to-face care. After a 12-week treatment, the test group fared remarkably well, with a 90% response rate and a high level of patient engagement — not a single patient dropped out of treatment. Now, the team is enhancing the app by using machine learning to mine smartphone sensor data. Their goal is to use this information to target just-in-time interventions for patients, such as a phone call from their provider. They plan to further test the app through a larger, randomized clinical trial.

Smartphones aren't the only area of innovation in digital treatments for mental disorders. A Boston-based company is developing a therapeutic video game to help the millions of children who struggle with attention-deficit/hyperactivity disorder (ADHD). The tool was tested in a randomized, controlled study of more than 300 children ages 8 to 12. After four weeks, children who played the therapeutic video game performed better on tests of attention than they did before treatment. This form of therapy represents a promising new class of digital medicines with the potential to help millions of people — not just young children with ADHD but also those who suffer from other common conditions, including autism and depression. \\

One particularly exciting area of innovation is the integration of rigorously validated methods in mental health care into smartphone apps.

Voice-First Technology Comes to Health Care

Smart speakers now permeate homes in many parts of the world, taking on an array of routine tasks from reciting weather forecasts to reordering cat food. According to a 2018 survey, nearly a quarter of U.S. households have a smart speaker, and of those, almost half own more than one. By 2022, it is estimated that the technology will spread to more than half of the homes in the U.S. And as it spreads, experts expect that consumers will continue to embrace the role that voice assistants can play in their everyday lives.

Now, this AI-powered, voice-first technology is coming to the clinic. But its potential uses run deeper than simple consumer conveniences. Using speech recognition and natural language processing, several companies are developing tools that are designed to help clinicians deliver better care and also give them more of what matters — quality time with patients.

For example, a host of health care technology companies are working on voice assistants that can help reduce physicians' data entry burdens. These tools can listen in on doctor-patient conversations and automatically convert the salient portions of the audio into a text-based doctor's note. Importantly, this text can be modified by the clinician if something doesn't look quite right. The information can then be automatically fed into the electronic medical record, lightening the load of clinical documentation — a major burden for physicians. Indeed, it is estimated that doctors spend roughly half of their day on digital data entry and less than a third with their patients.

In terms of data retrieval, these same voice assistants have the potential to distill dizzying volumes of patient information from across disparate data sources to provide physicians with exactly the information they need — and not more — when they request it. Better still, these assistants can accept verbal orders from physicians and use machine intelligence to provide alerts and predictive decision support at exactly the right time in the clinical workflow.

Voice assistants are also under development that aim to make day-to-day clinical operations more efficient. A Boston-based company is working on a voice-powered version of the nurses' call button, functioning at the bedside to help address patients' needs in a timely manner and prioritize any issues or concerns that require hands-on help from the clinical care team.

Other efforts are underway that seek to leverage the hands-free aspect of voice-first technology to improve care, particularly in settings where maintaining sterile conditions is critical. For example, research teams in Massachusetts are working to develop voice-enabled tools that help nurses to readily access important administrative details in the intensive care unit. Instead of picking up the phone or rummaging through papers, clinicians can simply ask a voice assistant. In addition to boosting infection control measures, this approach can also help expedite information lookup when time is of the essence. Voice assistants are also in development that can help care teams streamline and complete clinical check lists, including a prototype for use in organ transplant surgery.

As exciting as these and other voice-first applications are, some significant challenges still limit the technology's wider adoption in health care. For example, the privacy and security of patient health information remains a thorny question: how to balance the convenience of AI-powered devices and the insatiable need for data to feed the machine learning process against the patient's expectation and right to privacy? How will health care technology companies develop applications that can run on consumer-grade voice technology platforms while complying with the Health Insurance Portability and Accountability Act (HIPAA)? As the industry moves toward a new era of HIPAA-compliant devices, the groundswell of enthusiasm around voice-enabled health care technologies will likely intensify even further.

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The Hidden Signs of Intimate Partner Violence

Each year, millions of people experience violence at the hands of an intimate partner. According to the National Intimate Partner and Sexual Violence Survey, 1 in 4 women and 1 in 9 men have been abused or threatened by an intimate partner. Globally, intimate partner violence (IPV) ranks as the leading cause of homicide-related death in women; in the U.S., over half of women murdered each year are killed by a current or former intimate partner.

The health care community can play a vital role in reducing the devastating impact of IPV. Studies show that women who are victims of IPV seek medical care more often than non-abused women and, importantly, that health care providers represent a trusted source for divulging abuse. Moreover, screening for IPV can be an effective tool for detecting and preventing future violence, particularly in emergency departments. However, several barriers limit the use and success of screening programs, precipitating a system-wide failure to identify an alarming fraction of abuse cases: roughly 80% of IPV cases come through the emergency department, yet only about 5 – 30% are appropriately flagged as abuse-related.

Recognizing the need for better approaches to IPV in health care settings, researchers are working to develop AI-enabled tools that can help alert clinicians if their patient's injuries likely stem from IPV. This work flows in part from an early effort published some ten years ago, which showed that a subset of information commonly held in patients' electronic medical records can help predict who is at risk of future abuse. The study mined the diagnostic histories, ICD diagnosis codes, and number of annual hospital and emergency department visits for over 500,000 patients spanning a 6-year period.

A research team in Boston recently extended this analysis in critical ways — notably, by analyzing data from patients' medical images, such as X-rays and CT scans. They conducted a pilot study that analyzed the electronic medical records and imaging exams of nearly 200 patients with a known history of IPV as well as a control set of over 550 age- and sex-matched, non-abused patients.

The researchers unearthed some remarkable patterns. First, the vast majority of IPV victims were women and had a mean age of 34.2 years. Second, those experiencing IPV underwent four times more medical imaging tests than the control group. They also had a higher incidence of injury to the upper face and extremities as well as obstetric and gynecological problems, such as bleeding, miscarriage, and delayed fetal growth.

Now, the team is working to expand this initial study to a larger group of patients. They will also use machine learning to detect evidence of IPV in patients' clinical information and medical images. Their goal is to create an integrated, AI-based system that can analyze a patient's clinical and radiological data and automatically alert radiologists and clinicians if the injuries are likely to be associated with IPV. They are also developing training tools to help clinicians and social workers engage patients in a dialogue about IPV, including resources they can turn to for help.

Through their AI-enabled system, the Boston-based team hopes to help break the silence that surrounds IPV by empowering clinicians with powerful, data-driven tools that can better recognize its physical signs. \\

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A Revolution in Acute Stroke Care

Stroke is a major cause of death and disability across the world — and a significant source of health care spending. Each year in the U.S., nearly 800,000 people suffer from a stroke, with a total cost of roughly $34 billion. The lion's share of this burden can be ascribed to the type of stroke that stems from a lack of proper blood flow within the brain — so-called ischemic strokes — as nearly 90% of strokes are ischemic.

When a patient comes to the emergency room with a suspected ischemic stroke, time is of the essence. A team of clinicians must swiftly converge to evaluate the patient's symptoms and determine the best course of treatment in order to save precious brain tissue. According to common clinical parlance: Time is brain. It has been estimated that, on average, for each minute a stroke is left untreated, nearly 2 million neurons are lost. However, there is substantial variation among individual patients in terms of when and how many neurons will be lost.

A landmark study published in 2017 revealed that a subset of stroke patients may have more time than previously thought — some 18 hours more. This represents a dramatic shift as previous studies recommend that stroke patients receive clot-busting treatment within 6 hours of the onset of symptoms. The 2017 report finds that for some patients this window can be extended for up to 24 hours, a revelation that has sparked a sea of change in the standard of stroke care and opened up new opportunities for AI-driven innovation.

When a stroke is suspected, clinicians typically order a series of brain imaging tests to pinpoint the source of trouble. The first questions they must ask are: is there bleeding (a hemorrhagic stroke) and is blood flow blocked (an ischemic stroke)? That is because the treatments for these forms of stroke are vastly different; a misstep in diagnosis can be fatal. Several research groups across the U.S. have developed AI tools to help automate key elements of this diagnostic journey. For example, a research team in Massachusetts has developed a set of AI-based algorithms that can help determine whether or not there is bleeding within the brain. The algorithms, which were trained on some 2,000 head CT images, can automatically review a patient's head CT scan to identify a cerebral hemorrhage as well as help localize its source and determine the volume of brain tissue that is affected.

Now, the Massachusetts-based team is working to expand these tools by creating additional AI-based methods that similarly automate the subsequent steps of ischemic stroke diagnosis. Here, the key clinical questions include: Which blood vessel in the brain is occluded? Is it a large vessel? What is the status of the compensatory blood vessels that might also help feed the affected area (the so-called collateral blood flow)? And finally, what portion of the brain is impacted by the stroke? Taken together, the full suite of algorithms represents a comprehensive, state-of-the-art approach to the rapid diagnosis and treatment of stroke, regardless of its underlying cause.

The societal implications of these tools are significant, in terms of both the number of patients who stand to benefit from them as well as the potential savings to the health care system. It is projected that ischemic stroke alone will cost the U.S. some $2.2 trillion between 2005 and 2050. If an ischemic stroke can be identified — and successfully treated — that could help defray a sizeable fraction of the health care costs that would otherwise be incurred as a result of an extended hospital stay, a long period of recovery and rehabilitative care, and other costs, including lost work income.

In addition, these AI-based tools could help augment the clinical capabilities of small community hospitals, particularly those in rural areas, where clinicians may not have the resources or expertise to rapidly differentiate a brain bleed from an ischemic stroke. But with the power of AI, these hospitals can perform as well as large academic medical centers in the early assessment of stroke patients. Because of the new 24-hour treatment window for ischemic stroke, those early diagnostic insights are crucial, opening the possibility of life-saving — and brain-saving — treatment for thousands of stroke patients across the U.S. \\

Reducing the Burden
of Health Care Administration

The technological reach of AI in health care is not limited solely to the clinic. In fact, some of the most significant improvements in health care efficiency could be realized — at least, in the short term — through the use of AI-enabled approaches that automate routine and highly repetitive administrative functions. Such "robotic process automation" or RPA has already propelled innovation in other industries, such as finance, retail, and telecommunications, and could also help liberate a large swath of the health care workforce from a variety of mundane and mindless tasks.

In the U.S., health care administration is ripe for AI-driven innovation. More than 25% of health care expenditures in this country are due to administrate costs — far surpassing all other developed nations. Moreover, administrative complexity has been cited as a major driver of increasing health care costs in the U.S., with the majority of administrative costs stemming from billing and insurance-related activities.

A key area where AI could have a sizeable impact is medical coding and billing. In the U.S., a complex system of numerical codes is used to document what diagnoses an individual patient has and what treatments and/or procedures have been rendered by the care team in order to coordinate payment with third-party payers, including insurance companies. Often, physicians themselves will enter these codes; other times, a team of dedicated "coders" handles the task. Either way, the administrative infrastructure for medical coding and billing in the U.S. is both complex and expensive — fueled in part by the financial risks for providers. Billing mistakes can result in lost revenue; they can also trigger expensive audits with hefty fines and, in the worst case, charges of fraud. Ultimately, the entire health care system bears the cost of this highly complex administration.

To help streamline the process of medical coding, teams across the country are harnessing AI to develop automated approaches. For example, a Boston-based start-up has created a suite of machine-learning algorithms that can analyze the doctors' notes from patients' electronic health records and automatically generate the proper diagnostic and procedure codes. So far, these tools have performed well across a range of medical specialties. The ultimate goal is to help reduce the complexity of the coding and billing process through automation, thereby reducing the number of mistakes — and, in turn, minimizing the need for such intense regulatory oversight.

Another aspect of health care administration where automation is making inroads is insurance claims management, especially prior authorizations. This is the process through which providers secure approval in advance from patients' insurance companies for treatments and procedures that are deemed medically appropriate. While the concept is simple, the day-to-day reality is not: for physicians, prior authorization requests represent a substantial administrative burden. According to a recent survey by the American Medical Association, over 80% of physicians find the prior authorization process to be overly burdensome, with an average of roughly two business days a week spent on paperwork and other prior-authorization-related tasks.

To help minimize these challenges, researchers in Massachusetts have applied machine learning approaches that can automate key elements of the prior authorization process, particularly on the provider side. Their work has been focused mainly in radiology and surgery and has included pilots involving third-party payers. The team hopes to expand their efforts to include other clinical specialties. A key long-term goal for the field is to devise a robust, fully automated system that spans both provider- and payer-side systems to enable a streamlined, efficient process for prior authorizations that serves the needs of all stakeholders, most of all patients. \\

A key area where AI could have a sizeable impact is medical coding and billing.

Lighting a "FHIR" Under Health Information Exchange

As the U.S. health care system has grown in complexity, the flow of clinical information has also become more complicated. Today, these challenges are on display when a patient requests copies of her own health records, and days or weeks later receives a stack of printed (or faxed) pages in return — even when those records are stored electronically.

To be sure, the exchange of health information is, by necessity, a complex, multi-step process. For example, within a single health care organization, multiple administrative systems, such as scheduling and billing, must send and receive information from various clinical systems, ranging from laboratory services to radiology. Within the vast universe of health care data, a major driver of complexity is the lack of standards for how information can be shared between disparate systems.

But now, the tides of health care information technology are turning. A new data standard, known as the Fast Healthcare Interoperability Resources or FHIR (pronounced "fire") is gaining popularity and has become the de facto standard for sharing medical and other health-related information. With its modern, web-based approach to health information exchange, FHIR promises to enable a new world of possibilities rooted in patient-centered care — and it is sparking excitement across the health care community and beyond.

For example, late last summer, six global technology giants made a joint pledge to help reduce barriers to health care data exchange and enable the "frictionless" flow of information. That includes the adoption of open standards and specifications as well as open-source tools, including FHIR.

There have been similar shifts in the government sector, too. In the U.S., the 21st Century Cures Act, which was passed in 2016, includes provisions for improving the interoperability of health care data and increasing patients' access to their own electronic health records — improvements that are now being fueled by FHIR. In addition, the Centers for Medicare and Medicaid Services has adopted FHIR as part of its Blue Button 2.0, an expanded effort to give beneficiaries ready digital access to their claims data and allow them to share it with mobile apps and other online services of their choice.

As its adoption continues to spread, FHIR and its downstream capabilities are having a noticeable impact. For example, in some health care systems, patients can already connect to their provider's online portal and have critical pieces of their medical records transferred to a special smartphone app designated for personal health information, which can then transmit relevant details to other health-related apps — like one for managing different prescription medications.

A torrent of other health-focused apps is likely to follow, which will help patients keep better track of and manage their own health care. These apps could include disease-focused tools for a host of conditions, ranging from diabetes to rheumatoid arthritis, that can enable patients — together with their doctors — to more closely monitor and improve their health.

Yet perhaps the most trailblazing aspect of FHIR is the new realm of patient-controlled data sharing it will create. With unfettered access to their own health information, patients themselves will be able to decide what they want to share — and with whom. In turn, that will give rise to new business models in which patients can forge direct connections with a range of health-focused organizations.

As this new world begins to emerge, there are important issues for patients, health care systems, and society at large to grapple with, especially when it comes to data privacy and security. As patients increasingly pull their own health information onto smartphones and tablets, that data will be exposed in ways it wasn't before and made vulnerable to theft and misuse. Moreover, certain types of health data — namely genetic and genomic information — will undoubtedly require extra-stringent protections, which will help spur additional areas of innovation and development in health information technology. \\

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AI is helping to usher in new approaches in ophthalmology that promise to improve patient care.

"A-Eye": Artificial Intelligence for Eye Health and Disease

Clinicians often monitor eye health through detailed, three-dimensional examination or imaging of the retina at the back of the eye, using photography, optical coherence tomography, and other modalities. Here the retina may indicate troubling signs of disease, like swelling, blood vessel leakage, bleeding or abnormal growth. If left untreated, these conditions can result in vision loss. Yet examination and retinal images can be difficult and time-consuming, requiring clinical expertise, expensive equipment, and skilled personnel, which make it difficult for patients to access and receive proper care. Now, just as in other imaging-based medical specialties, AI is helping to usher in new approaches in ophthalmology that promise to improve patient care.

In 2018, the Food and Drug Administration took a historic step with the approval of a new AI-based system for the detection of diabetic retinopathy — a diabetes-related eye disorder that can result in permanent blindness. The move was noteworthy for two reasons: first, it marks the first fully automated, AI-based diagnostic tool to reach the market in the U.S. — one that does not require additional expert review and is therefore suited for use in primary care and low resource settings. Second, it represents a potential advancement in care for a condition that affects a large swath of people worldwide. In the U.S. alone, over 30 million people live with diabetes and roughly 24,000 a year experience vision loss due to diabetic retinopathy. And more than half of patients with diabetes do not seek regular eye exams, highlighting the potential role that primary care providers can play in recognizing the early signs of diabetic eye disease.

Researchers based in Iowa recently examined the clinical use of this automated, AI-based diagnostic system for diabetic retinopathy through a large prospective analysis. Their study spanned 10 sites — all primary care clinics — and included more than 800 patients with no prior history of diabetic retinopathy or diabetic macular edema. The team compared the performance of the AI system to the current gold standard imaging methods for diabetic retinopathy diagnosis, and found that it achieved 87.2% sensitivity, 90.7% specificity, and an imageability rate of 96.1%. The findings help underscore the capacity of AI-enabled technologies to enhance primary care with specialty-level diagnostics — making it possible to more rapidly identify patients in urgent need of specialized care, especially in low resource settings where access to expert ophthalmologic care is limited.

Meanwhile, research teams in the U.K. have been working to design AI-based tools that are more generalizable — that is, not geared to a single eye disease but able to detect within a single imaging modality features used in the diagnosis of over 50 common eye conditions, including age-related macular degeneration and diabetic retinopathy. They developed a unique, two-stage, deep-learning framework, which they then trained on just under 15,000 retinal scans from over 7,500 patients. The team tested their framework on two independent sets of retinal images that featured a diverse array of retinal abnormalities.

The U.K. team evaluated their system's performance in prioritizing patients for follow-up specialty care according to four categories: urgent, semi-urgent, routine, and observation only. Remarkably, the system issued its recommendations with 94% accuracy, matching the capabilities of eight expert clinical reviewers (four retinal specialists and four optometrists with training in medical retina). Two key aspects of the tool's design could help pave for the way for its future clinical adoption. First, instead of operating as a "black box," the tool was designed to explicitly allow clinicians to grasp how it arrives at its decisions. Second, it can analyze images within the same modality, even if taken from instruments that are from different manufacturers than the one used during its development. However, before the team begins to embark on clinical implementation, they must undertake further tests of their AI-based system through a randomized clinical trial. \\

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A Window on the Brain: Toward Real-Time Monitoring and Analysis of Brain Health

Today, doctors can stand at a patient's bedside and watch the electrical activity of the brain in real-time. But the complexity and sheer volume of these measurements (known as electroencephalograms or EEGs) mean there is often a gap between when measurements are made and when diagnoses are rendered. But now, deep learning tools are making it possible to automate the analysis of EEGs and other high-frequency wave forms, so clinicians can rapidly detect electrical abnormalities that signal trouble. And that power is enabling a new world of real-time monitoring of the brain that promises to dramatically improve patient care.

One area where these new tools are gaining traction is seizure detection in critically ill patients. These seizures are often devoid of any outward signs, such as convulsions, making EEG the only reliable means of discovery — so patients often receive continuous EEG monitoring. Clinical experts examine the EEG recordings manually through a painstaking analysis, searching for telltale signs of a seizure. Yet because of its resource-intensive nature, this review happens intermittently and typically only during the day. That means if a critically ill patient has a seizure overnight, it may go unnoticed until the next morning.

Over the last decade, a team of researchers in Boston has annotated some 30 terabytes of EEG data from thousands of patients. They have mined these data to create deep learning algorithms that can automatically detect seizures in the critically ill — regardless of the underlying cause of illness. These tools are now under development and will be deployed in the coming year at a large hospital in the region, making real-time analysis of EEG a clinical reality.

Another significant problem in hospitalized patients, particularly older adults, is delirium — an acute mental condition characterized by confusion and inattention. It is extremely common, particularly after major surgery, and studies increasingly suggest that delirium can predispose patients to downstream health complications, including longer hospital stays, injuries due to falls, subsequent cognitive decline, and even death. If recognized early, the condition and its sequelae can be effectively managed. In an effort to minimize the impact of delirium, researchers are harnessing AI-based technologies with the goal of creating an early warning system — one that can flag patients who are at greatest risk of delirium.

For example, a Massachusetts-based team is analyzing EEG recordings using machine learning in order to devise a continuous, automated method for monitoring elderly patients following surgery. Just as clinicians reflexively monitor vital signs like breathing, blood pressure, and heart rate, these researchers envision a future where measurements of the brain and its electrical activity is also routine — and can rapidly provide actionable clinical insights.

Researchers are also combining machine learning with EEG analyses to understand another critical area of neuroscience and medicine: general anesthesia. This is the process through which doctors administer drugs that render a patient unconscious, immobile, and unable to sense pain or form memories to allow for surgery. While these drugs have been in use for well over 150 years, their activities within the brain remain poorly understood.

A team of researchers in Cambridge, Mass. has devoted several years of rigorous study to help clarify how these drugs work in part by systematically monitoring their effects on the brain's electrical activity. Their research reveals that anesthetics exhibit unique signatures when viewed through the lens of EEG recordings, and that these EEG-based signatures can enable in-the-moment readouts of a patient's brain under anesthesia. Such data-driven methods lay the foundation for a new approach to anesthesia, one that harnesses real-time, continuous EEG monitoring to guide the proper dosages of anesthesia drugs. In turn, this can help ensure that patients receive ample, but not excessive, quantities of anesthesia, which can require a longer recovery period post-surgery and may also increase the risk of complications, such as delirium and cognitive difficulties. \\

> These tools are now under development and will be deployed in the coming year at a large hospital in the region, making real-time analysis of EEG a clinical reality.

Automated Malaria Detection

For roughly half of the world's population, the threat of malaria infection is ever-present. According to the World Health Organization, there were roughly 219 million cases of malaria in 2017. Nearly half a million people succumbed to the disease, with children under five making up the vast majority. Worldwide, total spending on malaria tops some $3 billion. There have been some significant strides in recent years toward improving global malaria control and prevention — worldwide mortality rates have dropped by nearly 30 percent since 2010 — but nevertheless, key challenges remain.

One area of concern is diagnosis. From a clinical perspective, simply knowing that the malaria-causing parasites are present in a person's blood is not enough to properly manage the disease. That is why rapid diagnostic tests, which are available for malaria and work a bit like a home pregnancy test, are often insufficient on their own. Instead, doctors often must figure out whether a patient's parasite load is rising or falling in order to determine whether drug treatment is working, particularly in regions where drug-resistant strains have emerged.

For these reasons, microscopy is often the diagnostic tool of choice for malaria. That means a pathologist peers down the barrel of a microscope to visualize and manually count the malaria parasites that lurk within a drop of blood smeared on a slide. It is a slow, laborious, and often difficult process that requires skilled training — expertise often lacking in areas hardest-hit by malaria.

Now with the help of deep learning methods, a research group in Washington has developed a software program to help automate malaria diagnosis. Notably, their tool can detect and quantify malaria parasites with 90 percent accuracy and specificity — matching the level of performance of human experts. The team's software was trained using hundreds of slides drawn from collections across the globe, including both positive and negative samples. The researchers packaged their algorithm within an inexpensive, automated, digital microscope, which has yielded impressive results in field tests both in Thailand and Peru. The system continues to undergo further field tests and is now in commercial development.

Several other teams, including one involving researchers in the U.S., U.K., and Thailand, are working to develop a similar AI-based method for counting parasite-infected and uninfected blood cells under a microscope. Their software was trained on some 200,000 blood cell images. By loading the software onto smartphones, whose cameras can be connected to a microscope through a simple adaptor, the team has created a low-cost, field-ready solution for automated malaria detection. They are now pursuing field studies in multiple locations in southeast Asia.

These automated approaches to malaria detection and diagnosis have the potential to benefit millions of people worldwide by helping to deliver more accurate and timely diagnoses. In addition, as drug resistant forms of malaria continue to surge in some countries — including strains that can withstand front-line drugs — these methods could enable better monitoring of treatment efficacy. That in turn will help the global health community to more vigilantly safeguard the potency of the world's anti-malarial medicines. \\

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Streamlining Diagnosis

In medicine, few things are more important than a swift and accurate diagnosis that is seamlessly integrated into patient care. And yet, the path toward that assessment often includes myriad steps and involves complex diagnostic specialties — including pathology and radiology. These specialties are connected by a shared capacity to open critical windows on patients' anatomy and physiology through images of major organs and other crucial body parts as well as penetrating views of microscopic structures, such as cells and tissues — expert observations that underpin and guide clinicians' diagnoses.

In the U.S., clinical imaging has become increasingly digitized — first with radiology, now a fully digital practice, and more recently, pathology, which is beginning to embrace digital technologies. That evolution is paving the way for computer vision and other AI-based approaches that promise to improve clinical operations and decision-making. One example: clinical workflows. AI offers the prospect of prioritizing patients' images for analysis — moving them to the top of the virtual stack — based on the likelihood of an abnormal and potentially life-threatening finding.

For example, researchers in California recently developed a deep-learning-based algorithm that can distinguish normal chest X-ray images from abnormal ones. Rather than search for just one type of abnormality, the tool simultaneously scans for up to 14 different conditions, including pneumonia, pneumothorax, enlarged heart, and lung nodules. It performed as well as radiologists in diagnosing a majority of these conditions (11 out of 14) and could analyze images in a fraction of the time. Incorporating such a tool into radiologists' workflows could enable them to read patients' images more quickly and efficiently.

In addition, AI is propelling new approaches for reading and interpreting magnetic resonance imaging (MRI) studies, including those of the spine. Abnormal narrowing, or stenosis, of the spine, particularly in the lumbar region of the lower back often triggers pain and is a reason many patients seek spinal surgery. This procedure invariably involves multiple MRI scans of the spine both pre- and post-surgery — images that are not only difficult and time-consuming for radiologists to analyze, but whose interpretation often varies widely from one reader to the next. Researchers in Massachusetts have developed an AI-based method to help automate several key steps of the analysis of lumbar spine MRIs. Initial tests indicate that this tool can perform spinal stenosis grading with 89 to 99 percent accuracy, underscoring its potential to enable radiologists to work more efficiently.

Similar AI-based tools are also under development in pathology, a clinical specialty that ranges from high-volume screening tests, such as Pap smears, to large tissue resections, which involve tens to hundreds of slides that must be examined for abnormalities. Pathology also involves quantitative analyses — examining cells for the presence of certain molecular markers, for example — in order for clinicians to render accurate diagnoses. Finally, pathology has become a home for vast collections of molecular data. AI could help mine these data in order to prioritize or screen patient cases according to the presence of cancer cells or other urgent findings, clarify borderline diagnoses, and integrate morphologic findings with other clinical and laboratory data to support the diagnostic, prognostic, and treatment decisions clinicians make while caring for patients.
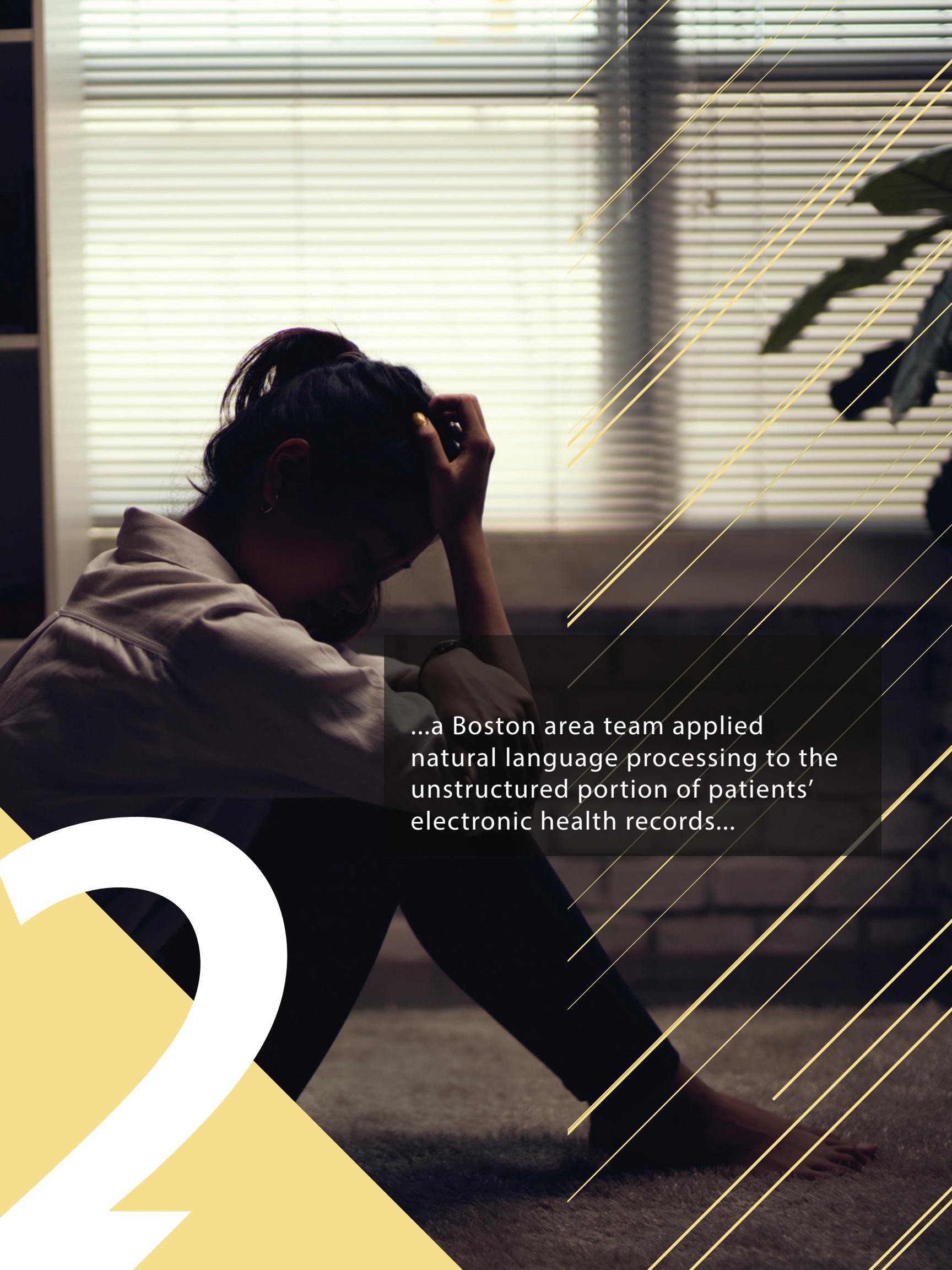
In the realm of molecular data, researchers are working to develop AI-based decision support tools that can help pathologists tame the complexity of information that flows from decoding the genetic blueprint of a tumor. Such genetic analyses are increasingly common and represent a powerful approach to identify the most effective therapies for an individual patient's tumor. Yet the oceans of data pathologists must sift through — pinpointing which of the thousands of genetic variations within a tumor represent the Achilles' heels that can be targeted with a cancer drug — is an increasing burden, and one that far exceeds the analytical limits of the human brain.

A Boston team harnessed AI to distill the clinical experience of six board-certified molecular pathologists, systematically analyzing which genetic variants they reviewed and subsequently reported over a multi-year period. The researchers then used this model to create and validate a decision support tool that, remarkably, performs as well as a human pathologist. It is now in clinical use in a large hospital in Massachusetts.

These and other innovative imaged-based tools are ushering in a new era of AI-enabled disease diagnosis — one that amplifies the collective expertise of radiologists and pathologists, empowers them to work with greater precision and efficiency, and provides better integration across the health care continuum, all with the aim of providing better care for patients. \\

AI is propelling new approaches for reading and interpreting MRI studies.

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...a Boston area team applied natural language processing to the unstructured portion of patients' electronic health records...

Better Prediction of Suicide Risk

Suicide is a vexing public health problem. In the U.S., suicides are, troublingly, on the rise: over the last two decades, suicide rates across the country have soared by nearly 30 percent. Suicide now ranks as the 10th leading cause of death in the U.S.; even more alarming, it is the 2nd leading cause of death among young people. In 2016, there were 45,000 suicide-related deaths — twice the number due to homicide.

Suicide stems from a complex mix of contributing factors, including mental and/or physical illness, economic difficulties, increased social isolation, rising gun ownership, and drug use. At the same time, effective prevention methods are exceedingly scarce. Clinical methods for flagging suicidal patients remain extremely inaccurate, leaving clinicians without a reliable means of identifying risk. And while conditions such as depression and anxiety are often precursors to suicide, more than half of the individuals who attempt suicide have no prior history of mental illness according to a recent report from the Centers for Disease Control and Prevention.
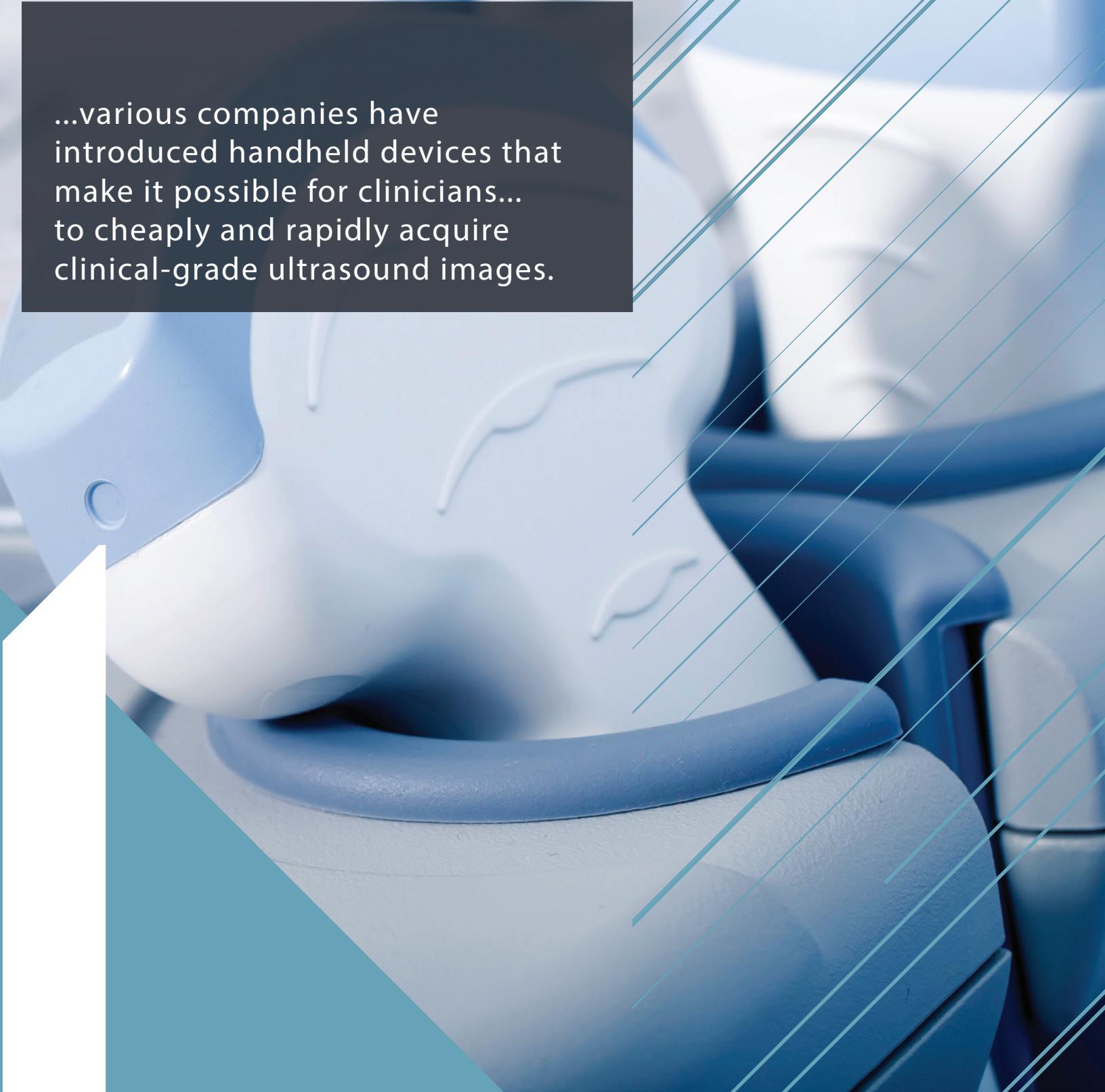
Now, researchers are leveraging AI-based approaches in various ways to help counteract this worrying trend. For example, a Boston area team applied natural language processing to the unstructured portion of patients' electronic health records (EHRs) — essentially, the narrative notes recorded by clinicians — in an effort to identify those at risk of suicide. The team retrospectively analyzed these narrative notes from the EHRs of patients at the time of discharge from two large academic hospitals spanning a nine-year period. They discovered that notes capturing positive expressions — words such as lovely, delightful, pleasant — were associated with a 30 percent lower risk of death by suicide.

Another Boston-based team also turned to EHRs to develop a risk prediction tool for suicidal behavior. They used machine-learning algorithms to mine some 1.7 million patient records from two large hospitals over a 15-year period. With their model, the researchers predicted nearly half of all suicides and suicidal behaviors with remarkable specificity and, importantly, well in advance of patients' self-harm — three to four years, on average. While the results of these EHR-based approaches are highly encouraging, they are only first steps. The studies must be replicated using additional patient data sets, especially those from other health care systems, in order to determine the tools' broader applicability.

Meanwhile, various teams across the country, both in academia and in industry, are focusing their attention on perhaps the most tragic problem of all: teen suicide. Instead of analyzing clinical notes, researchers are examining social media content — text messages and posts on social networking platforms such as Facebook and Twitter. For many people, particularly youth, their interactions with social media are much more frequent and more sustained than their interactions with the health care system, making this area ripe for investigation.

Research teams in Washington, Virginia, and other states in the U.S., as well as teams based at major social media companies, are using natural language processing and machine learning methods to create algorithms that can analyze data and detect the early warning signs of suicide. Based on their predictive power, such tools could form the basis of an app or other technology-based system that parents, other caregivers, and/or medical providers can use to alert them when an adolescent in their care is contemplating suicide. Indeed, these efforts come with some significant ethical and privacy concerns that must be carefully weighed as the medical establishment — and society at large — grapple with how to prevent suicide. \\

If you are thinking about suicide, there are organizations you can turn to now for help. Call the National Suicide Prevention Lifeline at 1-800-273-8255 (TALK) or visit SpeakingOfSuicide.com/resources for a list of additional resources.

Reimagining Medical Imaging

Medical imaging technologies including ultrasound and X-ray have been in clinical use for decades. While these methods are widely used — X-ray forms the basis of mammography, which is used to screen millions of women each year for breast cancer — they are imperfect. Now, bolstered by AI-enabled approaches, research teams across the world are working to enhance these fundamental technologies, making them smarter, more sensitive, and more accessible.

Globally, breast cancer is a leading cause of death in women. In the U.S. alone, some 40,000 women die each year from the disease. Mammograms play an important role in early detection. However, mammograms can detect lesions that appear suspicious but are actually not cancerous, causing anxiety and leading to overtreatment and unnecessary costs.

Now, researchers are using AI-based approaches to increase the power of mammography, transforming it from a one-size-fits-all method to a more targeted tool for assessing breast cancer risk. For example, a team in Massachusetts is leveraging machine learning in multiple ways to improve breast cancer screening. The researchers developed an AI-based method, now in clinical use at a large hospital for just over a year, which can automatically determine breast density using mammograms. Dense breast tissue obscures tumors on mammography and can also independently raise a woman's risk of developing breast cancer. Moreover, radiologists' assessments of breast density are subjective and can vary widely from one reader to another.

The new AI tool was used to screen over 10,000 patients in routine clinical practice; its density assessments were accepted by experienced radiologists in 94% of cases. Based on these results, the researchers believe their system could help standardize and automate breast density measurements. Now, the team is enhancing their AI-based system, incorporating both clinical and breast imaging data, to give individualized assessments of breast cancer risk that can automatically flag patients for follow-up tests, such as ultrasound or MRI. Over the next few years, they hope to make mammograms more like Pap smears — which are now read by automated systems in many parts of the world to screen women for cervical cancer.

AI is also making a big splash in ultrasound. In the last few years, various companies have introduced handheld devices that make it possible for clinicians — and, in some cases, patients themselves — to cheaply and rapidly acquire clinical-grade ultrasound images. Those innovations are now spurring new ways of harnessing ultrasound images. For example, a Massachusetts-based team is applying AI to enable a rapid, ultrasound-based method to automatically localize large veins, like the femoral and jugular veins. These blood vessels form the primary portals for rapid infusion of fluid during emergency resuscitation — a life-saving procedure that often must be performed in stressful, sometimes chaotic circumstances. In these situations, time is of the essence with little room for errors. The team's goal is to package their AI-powered software into a handheld device that will enable first responders to readily identify large veins and guide them on proper needle placement.

Researchers are also developing ultrasound-based methods to improve the detection and diagnosis of liver disease. Nonalcoholic fatty liver disease (NAFLD) is increasingly common across the world, especially in Western countries. In the United States, it is a major cause of chronic liver disease, affecting roughly 80 to 100 million people. Unfortunately, NAFLD often goes unnoticed in its earliest stages; if not adequately diagnosed and treated, it can lead to liver cirrhosis, cancer, and even death.

As its name suggests, NAFLD stems from the abnormal accumulation of fat in the liver for reasons unrelated to alcohol consumption; it is more prevalent in people who are obese or have type 2 diabetes. The standard approach for detecting fat in the liver is a biopsy. Although noninvasive methods exist (mainly MRI), they are costly and therefore impractical for screening millions of people.

Now, with the help of machine learning, researchers in Massachusetts are developing an ultrasound-based method for NAFLD detection. With their approach, the team can enhance the outputs of ultrasound images to the point where their accuracy matches MRI. This technology represents a major step toward an inexpensive, noninvasive method for reliably diagnosing NAFLD. \\

...various companies have introduced handheld devices that make it possible for clinicians... to cheaply and rapidly acquire clinical-grade ultrasound images.

2019 Disruptive Dozen
artificial intelligence

Below is our Disruptive Dozen for 2019, which was guided through the nomination and selection ranking process by our committee, each earning scores along the way.

We present these disruptors to you in order of their rank after the final committee voting was completed.

The medical professionals listed below, experts across clinical areas, were each paired with a specific disruptive innovation.

At the Forum presentation, each expert explained its potential impact on artificial intelligence in the year ahead.

12. Narrowing the Gaps in Mental Health Care

David Ahern, PhD
Clinical Psychologist/Behavioral Scientist and Director, Digital Behavioral Health and Informatics Research Program, Department of Psychiatry, BH; Assistant Professor of Psychology, HMS

11. Voice-first Technology Comes to Health Care

David Ting, MD
Chief Medical Innovation Officer, MGPO

10. The Hidden Signs of Intimate Partner Violence

Bharti Khurana, MD
Director, Emergency Musculoskeletal Radiology, BH; Assistant Professor, HMS

9. A Revolution in Acute Stroke Care

Gilberto Gonzalez, MD, PhD
Chief of Neuroradiology, MGH; Professor, Radiology, HMS

8. Reducing the Burden of Health Care Administration

James Heffernan
SVP, Finance & Treasurer, MGPO

7. Lighting a FIHR Under Health Information Exchange

Samuel Aronson
Executive Director, IT, Personalized Medicine, PHS

6. AI for Eye Health and Disease

Joan Miller, MD
Chief, Ophthalmology, MEE, MGH; Chair, Department of Ophthalmology and David Glendenning Cogan Professor of Ophthalmology, HMS

5. A Window on the Brain

Brandon Westover, MD, PhD
Executive Director, Clinical Data Animation Center, MGH; Associate Professor, Neurology, HMS

4. Automated Detection of Malaria

Rochelle Walensky, MD
Chief, Division of Infectious Diseases, MGH; Professor, Medicine, HMS

3. Streamlining Diagnosis

Annette Kim, MD, PhD
Associate Professor, Pathology, BH, HMS

2. Better Prediction of Suicide Risk

Thomas McCoy, MD
Director of Research, Center for Quantitative Health, MGH; Assistant Professor, Psychiatry & Medicine, HMS

1. Reimagining Medical Imaging

Alexandra Golby, MD
Neurosurgeon, Director of Image-guided Neurosurgery, BH; Professor, Neurosurgery, Radiology, HMS

WORLD MEDICAL
INNOVATION
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