Health and societal implications of medical and technological advances

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Scientific and technological breakthroughs are transforming the future of medicine and health, but they inevitably carry risks and have societal implications that need to be addressed proactively.

In the history of medicine, we have witnessed advances that have rewritten the script for preventing and treating disease. Consider the reduction in common infectious diseases owing to public health measures, vaccines, and antibiotics, or the decline in cardiovascular disease morbidity and mortality due to advances in prevention and therapy. Today, we are witnessing an even more accelerated trajectory with the convergence of basic science, data science, and technology. We have seen substantial progress in many fields—biomedicine, biotechnology, engineering, nanotechnology, digital technology, robotics, artificial intelligence (AI)—all with the potential for improving health (Fig. 1).

This impact will be apparent for diseases with the highest burden such as cardiovascular disease and cancer. For example, a new class of drugs, known as PCSK9 inhibitors, are fully humanized monoclonal antibodies that inactivate PCSK9 and lower LDL (low-density lipoprotein) cholesterol when combined with a statin, reducing the risks of heart attack, stroke, or heart failure (1, 2). Impressively, a recent RNA interference (RNAi) study reported sustained inhibition of LDL cholesterol in human patients (over 180 days) after a single dose of inclisiran, a long-acting RNAi therapeutic (3).

Cancer immunotherapies harness the body’s own immune system to fight tumors by either stimulating the activities of specific components of the immune system (such as chimeric antigen receptor T cell therapy) or counteracting signals produced by cancer cells that suppress immune responses (such as checkpoint inhibitors). Likewise, scientific and technological developments may lead to improvements in prevention and early detection of tumors using biomarkers, genomics, and other “omics.” Diagnosing tumors at an early stage through a simple blood test aimed at detecting and analyzing “circulating tumor DNA” released from dead cancer cells is becoming a possibility. Indeed, scientists have reported initial successes in the development of these so-called liquid biopsies for cancer detection (4).

Advances, such as genome editing using CRISPR-Cas, may offer a cure for some diseases. Germline editing could cure diseases with permanent interregenerational changes (e.g., cystic fibrosis). Somatic genome editing could treat, control, and possibly cure acquired diseases. Envisage, for example, deletion of the PCSK9 gene in the adult liver by genome editing, the major site of cholesterol biosynthesis, with the potential for lifelong suppression of hypercholesterolemia.

Advances in precision medicine, particularly the development of new diagnostics, may help to guide health care decisions toward the most effective treatment for a given patient or subset of patients, thus improving quality care while reducing ineffective diagnostic testing or treatments. Applying precision medicine to public health could result in identification of at-risk individuals and populations, resulting in more appropriate population health strategies including screening tests and preventive measures.

Some of the most important advances are in the areas of digital technology and big data. Vast amounts of health data are being generated and captured in real time, which will play a critical role in the development of a learning health system. The ability to integrate these data from disparate sources and analyze them will enable us to better understand patterns of disease and drivers of health, especially the social determinants of health. AI may improve health care by helping clinicians to make better diagnoses and treatment decisions and by transforming the way that patients make personal and health care decisions. In the future, AI-based personal health assistants could support patients in achieving better health, e.g., by reminding them when to take their medications. Advances in digital and AI technologies are likely to change the way health care is delivered, when care is delivered, whom care is delivered by, and where care is delivered. The overall result will be a shift away from the clinic, with care delivered in new settings, such as the home, and a greater focus on prevention.

Health care will be increasingly democratized with better access to health information, and new technologies will give patients greater freedom to make choices about their own health care.

IMPLICATIONS AND RISKS FOR SOCIETY

Rapid technological advances will increase the pace of change, potentially aggravating divisions between winners and losers and widening social inequity.

Affordability and access

It is important to ensure that emerging technologies are available to everyone, not just a select portion of society. There are concerns that new technologies will increase health care costs. The rising cost of health care and the unaffordability of treatments are a global challenge. Global health spending is expected to increase from $7.83 trillion in 2013 to $18.28 trillion in 2040 (5). Already, the United States spends 19% of its gross domestic product (GDP) or nearly $3 trillion on health care. The primary reason for the rise in U.S. health care costs between 2000 and 2011 was an increase in the price of drugs, medical devices, and hospital care (6). Many innovations, however, may incur high upfront costs only to be cost saving in the long term. As a result, we must consider the cost-effectiveness as well as long-term outcomes and savings of new innovations as they enter the market. Such approaches, coupled with reimbursement policies, can help to rein in rising health care spending by only covering innovations with demonstrated cost effectiveness.
Workforce

Successfully implementing and adopting these advances requires an effective workforce, with the right skills and composition of professions to support a new vision of health and health care. New technologies have important implications for the nature of the existing workforce; some jobs will disappear and others will be transformed. For example, technological advances will yield robots capable of performing manual tasks, displacing certain professions. Even some intellectually intensive professions will need to evolve. For instance, interpreting radiological image and tissue pathology could be performed more efficiently and accurately by AI. Health professionals will need to learn and adapt to computerized decision support systems.

Policy-makers and other stakeholders, such as professional societies, must think about the implications for education and training, for how education will need to evolve for those entering the workforce as well as how to retrain the existing workforce. We need to understand where and how jobs are created or displaced by new technologies. The question here is not only what will be done by people and what will be done by machines but also what will be the man/machine combinations. What are the talent requirements for these new jobs? What are the combinations of knowledge, skills, and disposition necessary to thrive in specific jobs and in the future workforce?

It will be important to consider the impact of new digital and AI-based approaches on the practice of medicine, especially on provider workload. In the United States, we do not need to look very far back to see the effects of indiscriminate deployment of technology. The emergence of electronic health records has inadvertently contributed to physician burnout and, in some ways, disrupted the doctor-patient relationship.

Governance and regulation

It will be important to ensure that patients are not harmed by emerging technologies, especially those that enter the market before there is robust evidence of efficacy. Science and technology advances often raise challenges for existing regulatory systems, so there will be a need to examine our existing regulatory frameworks to ensure that they are suitable for emerging technologies. New technologies and therapies will necessitate a shift in the way evidence is collected and evaluated. Randomized, controlled clinical trials continue to be the gold standard for evidence generation. However, an emerging approach is for health care organizations to collect data as part of ongoing clinical care to generate real-world evidence of continued safety and efficacy.

Ethics, equity, and society

Advances in science and technology often raise social and ethical considerations for society. For instance, societies must consider how to control the use and speed of adoption of emerging technologies as well as how to ensure that the distribution of risks and benefits is fair and equitable. Currently, “evidence-based” medicine often relies on research results based on data that might be lacking diversity of gender, race, and age. AI alone cannot overcome these biases. The algorithms underlying AI approaches are dependent on the quality and quantity of datasets, which might not be free of biases. Trained and empathic health professionals, researchers, and technologists must supplement efforts to deploy and analyze new AI-based technologies to offset any bias.

Additionally, some emerging technologies will require societies to consider the effects on societal structures (e.g., families), belief systems (e.g., religion), and cultural norms (e.g., attitudes about sexuality, race, and disability). Consider attitudes toward disability: Because medical and technological breakthroughs enable the treatment or even cure of disease and disability, it will be important to ensure that those individuals living with disabilities can continue as full participants in society, even if they choose to forgo new genetic therapies. Such scenarios can have tangible implications for society and public policy. For example, reducing the frequency of birth defects may lead to weaker public support for accommodating the needs of people with disabilities. Likewise, the potential to use genome editing technology for enhancement raises concerns about exacerbating existing social inequities or creating pressure for individuals to use technologies they would not otherwise choose.

Norms, standards, and responsible conduct

Although most societies will have legal rules/regulations that govern behavior, there will be a need for ethical norms and standards that tend to be broader and more informal than laws. Indeed, regulations/legal governance systems will often not be able to keep up with the pace of change. This is where the scientific community has an important role to play by establishing norms and standards that distinguish between acceptable and unacceptable behavior. Furthermore, the views of different stakeholders, especially public and social, ethical, and religious groups, must be taken into account. Different societies will need to consider the application of new technologies (such as genome editing) in the context of their diverse historical, cultural, and social characteristics. Thus, specific regulations/legal frameworks will differ among countries.
Data ownership, privacy, and sharing
Many advances rest on the free exchange of data and information. However, questions about data ownership, privacy, and sharing remain. Patient data are central to many of these advances, and patients have a right to own their data and control how they are used. There is a need for national regulatory systems and other protocols to protect patients’ rights to their personal data. Moreover, protections must be in place to ensure that patients feel comfortable sharing their personal health information. Importantly, the exchange of health data knows no borders. At present, there are different national policies governing the exchange of personal and health data. For instance, countries such as China, Russia, and Brazil have put in place comprehensive plans governing data exchange, including requirements that companies must locate data centers inside their borders to do business in the country. The European Union (EU) General Data Protection Regulation (GDPR) took effect in May 2018. The GDPR builds on earlier EU privacy measures but sets a higher bar for obtaining personal data, requiring companies to obtain explicit and informed consent from an individual before obtaining personal data. Importantly, the GDPR applies to any organization that collects, processes, manages, or stores the data of European citizens, essentially setting a new global standard for data protection.

In contrast, the United States lacks a comprehensive federal law that regulates the collection and use of personal information. It remains to be seen how companies will adapt to new regulations, such as the GDPR, and how countries will enforce such measures. Clearly, there is a need to consider the development of an international framework or international norms to govern the cross-national exchange of health data.

Cybersecurity concerns
As the field of data and analytics advances and the collection and exchange of personal data becomes even more ubiquitous, it will be crucial to ensure that personal information is protected and secure. Patient data are particularly valuable and vulnerable to cyberattacks. Health care is consistently among the most targeted industries when it comes to cyberattacks, and this threat is only likely to increase.

Hospitals and health systems are vulnerable to cyberattacks that could put patients in danger. These issues range from malware that compromises the integrity of systems and privacy of patients to denial of service attacks that disrupt the ability to provide patient care. Furthermore, attacks to broader infrastructure, such as the electric grid, could stop hospitals from functioning. Notably, any medical device connected to a network is potentially at risk of being exploited by hackers, from magnetic resonance imaging machines to electric wheelchairs. Health systems and individuals will need to become more aware of their vulnerability to cyberattacks and take measures to protect themselves.

Finally, many new technologies and scientific advances raise national security concerns. In February 2016, James Clapper, former U.S. Director of National Intelligence, noted that new technology could open the door to “potentially harmful biological agents or products,” with “far-reaching economic and national security implications” (7). There is a need for an international governance mechanism that engages public, private, research, regulation, and security sectors.

CONCLUSIONS
In the next decade, transformative changes will take place in health and medicine resulting from rapid advances in science and technology in the Fourth Industrial Revolution. Medical and technological breakthroughs will provide new tools and approaches that will transform health and health care, rendering them more connected, precise, democratized, and people-centered with better outcomes and improved population health. However, emerging technologies inevitably have risks. The challenges will be significant in the extent and speed of adoption, as well as the ability to control cost of care and to prevent aggravating inequity. The extent to which the benefits are maximized and the risks mitigated depends on the quality of governance—the policies, norms, standards, and incentives that shape the development and deployment of these emerging technologies. We must proactively assess technologies on the horizon and their societal implications and take intentional measures to mitigate their risks.

REFERENCES

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