

# Health Informatics

This series is directed to healthcare professionals leading the transformation of healthcare by using information and knowledge. For over 20 years, Health Informatics has offered a broad range of titles: some address specific professions such as nursing, medicine, and health administration; others cover special areas of practice such as trauma and radiology; still other books in the series focus on interdisciplinary issues, such as the computer based patient record, electronic health records, and networked healthcare systems. Editors and authors, eminent experts in their fields, offer their accounts of innovations in health informatics. Increasingly, these accounts go beyond hardware and software to address the role of information in influencing the transformation of healthcare delivery systems around the world. The series also increasingly focuses on the users of the information and systems: the organizational, behavioral, and societal changes that accompany the diffusion of information technology in health services environments.

Developments in healthcare delivery are constant; in recent years, bioinformatics has emerged as a new field in health informatics to support emerging and ongoing developments in molecular biology. At the same time, further evolution of the field of health informatics is reflected in the introduction of concepts at the macro or health systems delivery level with major national initiatives related to electronic health records (EHR), data standards, and public health informatics.

These changes will continue to shape health services in the twenty-first century. By making full and creative use of the technology to tame data and to transform information, Health Informatics will foster the development and use of new knowledge in healthcare.

More information about this series at <http://www.springer.com/series/1114>

Homero Rivas • Katarzyna Wac  
Editors

# Digital Health

Scaling Healthcare to the World

 Springer

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ISSN 1431-1917

ISSN 2197-3741 (electronic)

Health Informatics

ISBN 978-3-319-61445-8

ISBN 978-3-319-61446-5 (eBook)

<https://doi.org/10.1007/978-3-319-61446-5>

Library of Congress Control Number: 2017963147

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Printed on acid-free paper

This Springer imprint is published by Springer Nature

The registered company is Springer International Publishing AG

The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

# Foreword

Prepare for a new digital era of medicine. In 2017, millions of people are collecting their vital signs, such as blood pressure and respiratory rate, on everyday devices like smartwatches and iPhones. Surgeons are leveraging advanced robotics in the operating room and live-streaming their most challenging cases via virtual reality headsets. Primary care practitioners are capturing patient data in real time without glancing once at a screen, thanks to their augmented reality “smart” glasses. And medical records, once stacked in filing cabinets at hospitals and clinics across the country, are now being stored electronically (<http://www.modernhealthcare.com/article/20160531/NEWS/16053999>).

Many of these technological advancements were subsidized into existence through the major health reforms of the past decade, which should not be overlooked—notably the Affordable Care Act and the Health Information Technology for Economic and Clinical Health (“HITECH Act”). These legislative changes inspired venture investors in Silicon Valley and other tech hubs to open their checkbooks to health technology entrepreneurs, and for the world’s most valuable companies like Apple, Amazon, and Google to begin eyeing opportunities in the \$3 trillion medical sector for the first time. Healthcare is an “enormous” opportunity, Apple chief executive Tim Cook recently told the television news network CNBC in a revealing interview. “You can have patients that really feeling like customers... and can have systems and applications that bring out the best in medical professionals.” Imagine a health system that could deliver an experience on par with one that consumers expect in every other industry from retail to financial services.

But before all this technology can deliver on its potential to transform the health experience for the better, a deeper change is required. Incentives need to shift from older financial models that reward hospitals and clinics for expensive procedures and tests, rather than on keeping their patients healthier for longer. The United States spends twice as much as any other developed country on healthcare, but this investment has not resulted in improved health outcomes (<http://www.pbs.org/newshour/bb/u-s-pays-health-care-rest-world/>). This nation surpasses the rest of the

world on cutting-edge research and basic science, but it has failed to provide a path for ordinary Americans to access these innovative therapies at an affordable price tag. Former US Vice President Joe Biden considered selling his home to pay for his son's cancer treatment. If the country's leaders can barely afford life-saving treatment, just imagine the plight faced by ordinary Americans.

Shifting these incentives will be the task of policymakers, but it also presents an opportunity for the exploding crop of health technology start-ups in Silicon Valley and beyond. The emerging category known as digital health, which broadly refers to the convergence of digital tools with health and healthy living, raised a mammoth \$4.2 billion in 2016 alone (<https://rockhealth.com/reports/2016-year-end-funding-report-a-reality-check-for-digital-health/>). Other upcoming areas include digital therapeutics, which involve computer-based interventions to replace or augment drugs, and computational biology, such as machine learning tools to parse through miles of medical images and scans.

Many of these companies make their money by propping up the status quo. But a select few are attempting to forge a new path, that is, to down health costs by providing people with digital services to manage their own care preventatively and to avoid expensive medicines and emergency room visits. Such companies are producing simple apps and messaging tools that are designed to provide pertinent health information to low-income communities that lack reliable access to care. Or the companies that are connecting people in rural areas, located many miles from a hospital, with a new way to consult with a physician via video chat. A category called "liquid biopsies" are developing tests to screen for diseases like cancer that can be treated in the early stages. Vijay Pande, appointed to run the new bio fund for the well-known technology investment fund Andreessen Horowitz, has gone as far as to describe this whole transformation as the "industrial revolution for biology" (<https://a16z.com/2015/11/18/bio-fund/>).

Amid all this excitement, these technologies will need to be evaluated in three key ways: Can they improve overall health outcomes for patients, enhance the quality of care, and reduce health costs? This framework for optimizing health system performance is known as the "triple aim."

In healthcare, many new technologies will initially add cost to the system. But the hope is that such advancements are laying the groundwork for potential cost savings. The promise of electronic medical record systems, for instance, is improved care coordination and disease management between physicians and their patients, as well as reduced errors. But before that dream can become a reality, it will need to be far easier for these electronic medical record systems to aggregate and share data.

Indeed, the next phase of medicine will require integration or interoperability of health information in support of a new style of medicine based on data and evidence. Some of the world's most valuable companies, including Apple, Amazon, and Google, have all taken on this challenge in different ways. These companies are betting on health hardware, such as wearable technologies and medical devices, machine learning and artificial intelligence as applied to medical specialties like radiology, telemedicine or virtual care, and software tools for users to view their personal medical information. However, before any of these services are truly valu-

able, it will be necessary to aggregate medical information from charts, labs, devices, health apps, and so on.

From Silicon Valley to Washington D.C. and beyond, a movement is underway backed by government officials, nonprofits, and patient advocates for patients to access their medical information in a user-friendly format. One of the most successful efforts is a nonprofit organization called OpenNotes, which advocates for patients to access their physicians' notes. Despite ongoing resistance from the medical community that patients would misinterpret this information, some 14 million people have accessed these notes electronically—with little confusion and few mishaps (<https://patientengagementhit.com/news/using-opennotes-for-positive-impact-on-patient-data-access>).

The winners that emerge in healthcare in the coming years have a choice: Do they build tools for healthcare as it is today? Or are they building for a future that is both patient-centered and evidence-based? The latter option represents a windier, longer, and more challenging path, but it's the right one.

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## References

<http://www.modernhealthcare.com/article/20160531/NEWS/16053999>.

<http://www.pbs.org/newshour/bb/u-s-pays-health-care-rest-world/>.

<https://rockhealth.com/reports/2016-year-end-funding-report-a-reality-check-for-digital-health/>.

<https://a16z.com/2015/11/18/bio-fund/>.

<https://patientengagementhit.com/news/using-opennotes-for-positive-impact-on-patient-data-access>.

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