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EDITORIAL

Twelve Modern Digital Technologies That Are Transforming Decision Making for Diabetes and All Areas of Health Care

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Introduction

The efforts in the area of diabetes technology are intended to make measurements, detect patterns, and develop conclusions about a patient's or population's condition so that appropriate decisions are made. These processes are equivalent to the basic tenet of information science, which describes a hierarchy of data, information, and knowledge. Modern technologies are revolutionizing the collection of data, the formulation of information and knowledge, and the development of decisions based on the knowledge derived from new types of data and information. This article describes 12 important emerging technologies that will be shaping decision making in diabetes and all other areas of medicine in this century.

Data, Information, and Knowledge

Data represent objective facts or observations that have not been analyzed in any way. Data are accepted as true and verifiable. Data can be thought of as a quantity of sensory stimulation (such as light, sound, smell, taste, and touch) perceived by our own senses or these same types of signals detected by artificial sensors. Information represents data that have been organized, analyzed, and processed to become useful for a purpose. Knowledge is actionable information that has been processed by adding the experiences, values, insights, and opinions of the user to create a framework for evaluating a set of information.[1]

The purpose of knowledge acquisition in medicine is to facilitate good decision making. The data collected about a patient's glucose values, insulin doses, caloric intake, and exercise can be organized into patterns that represent information about the patient's glycemic patterns and responses to common perturbing factors. When the information about a patient (or set of patients) is filtered through the lens of knowing the context of the patient's information, the treatment goals for that patient, and the preferences of the clinician and the patient for treatment, then a good decision can be made. A good treatment decision requires: (1) collecting adequate high-quality data; 2) processing the data into relevant, accurate information; and (3) contextualizing the information to the point of deriving knowledge of the patient's situation.

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Abbreviations: (CDSS) clinical decision support software

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Technologies for Improving Decision Making

In this century, we are witnessing the emergence of 12 innovative technologies for improving decision making in diabetes and medicine as a whole. These technologies are changing the way medicine is practiced and the ways that people are taking charge of their health, even to the point of not seeking out the medical establishment in some cases. These 12 technologies are intended to: (1) collect new types of data using new tools; (2) create new types of information based on new types and relationships of physiological data; (3) transmit data remotely for analysis and storage with new types of wireless technologies; (4) predict information by using new predictive simulation tools; (5) use information to create knowledge; and (6) create knowledge directly from facts and information. In some cases, these technologies are not intended to make better decisions. The ones that generate data or develop information from data do not necessarily lead to knowledge or the best decisions. However, if knowledge of a patient's situation can be attained, then the best decisions can be made, and some of these technologies can accommodate the inputting of contextual factors to a set of information that will lead to the best decisions.

Table 1 contains a list of the 12 modern digital technologies. The table presents what the technology does, how the technology contributes to decision making, and whether the technology by itself is intended to lead to decisions. These technologies are new. Most of them have emerged to become important only since the 1990s or later, but they are expected to create or interpret enormous amounts of data that will, in turn, create enormous amounts of new information about human physiology and disease.

Table 1.
Twelve Modern Technologies That Are Transforming Decision Making for Diabetes and All Areas of Medicine

	Technology	What does the technology do?	How does the technology contribute to decision making?	Is the technology by itself intended to lead to decisions?
1.	Nanotechnology	Collects data	What is a person's structure—nanoscale	No
2.	Gene sequencing/ personalized medicine	Collects data	What is a person's structure—microlevel data	No
3.	Omics/gene activation/ systems biology	Collects data/creates information	What is a person's function—micro level data/information	No
4.	Wireless sensors and devices	Collects data	How can information about function be collected—macrolevel information	No
5.	Imaging	Collects data	How can information about structure be collected—macrolevel information	No
6.	Global positioning system	Collects data	How does a patient interact with environment—local information	No
7.	Wireless connectivity and smart phones	Transmits data	How can a patient interact with the environment—worldwide information	No
8.	Virtual reality/three-dimensional animation	Predicts information	How can new information about structure and function be predicted	No
9.	The Internet	Creates information from data	How can a patient find objective information	Maybe
10.	Computing power	Creates information and knowledge	How can new information and knowledge be created from personal data	Yes
11.	Cloud computing	Creates information and knowledge	How can new information and knowledge from personal data be shared	Yes
12.	Social media	Creates knowledge	How can a patient find knowledge from a cloud?	Yes

Clinical Decision Support Software

Development of clinical decision support software (CDSS) is becoming an important field of medicine and diabetes for reacting to information about patterns of glycemia and other measurements. Clinical decision support software is defined as a computerized process for improving medical care by providing clinicians, patients, or other individuals with intelligently filtered information at the appropriate time to enhance health and health care. Decision support is the process of utilizing medical information and clinical guidelines to convert patient information derived from interpretation of data into appropriate decisions and recommendations.[2]

The data-generating and data-interpreting power of the 12 technologies in **Table 1** can dwarf the human brain, which makes it imperative that the correct metrics are measured and that the context of patient information is included in the decision making process. The decision is only as good as the input. Only with proper context, the information from data that is soon to be generated will comprise the appropriate knowledge that will power the decision to be made by clinical decision support software.

Eric Topol[3] described in "The Creative Destruction of Medicine: How the Digital Revolution Will Create Better Health Care" eight super-convergence elements comprising digital health: (1) wireless sensors and devices; (2) genomics; (3) social networking; (4) mobile connectivity and bandwidth; (5) imaging; (6) health information systems; (7) the Internet; and (8) computing power and the data universe. I agree with this observation, although I consider health information technology to be part of computing power. I also believe that five additional important sources of digital data for medical and diabetes decision support include: (1) nanotechnology; (2) personalized medicine; (3) global positioning systems; (4) virtual reality along with three-dimensional animation; and (5) cloud computing, which takes the power of computing to a new dimension.

The U.S. mHealth manufacturing community is currently awaiting publication of a new guidance on CDSS by the Food and Drug Administration. One of the types of products for which clarification is currently sought is mobile decision support software to harness new types of data from continuous wirelessly transmitting sensors and other novel sources and recommend specific treatment for a specific patient. An insulin bolus dosing mobile CDSS product based on self-monitored blood glucose levels is an example of this type of software. To the extent that the software provides general advice or information, like a library, article, or textbook, it is more likely that such software will be readily approved, and to the extent that the software is designed to provide a specific recommendation for a specific patient whose individual data have been entered, it is more likely that safety and effectiveness will need to be rigorously demonstrated.[4] If a CDSS product can incorporate individual factors into its output, reflecting knowledge of the patient and not merely information, then it is likely that it will be easier to demonstrate safety and effectiveness.

Digital Health Revolution

The digital health revolution is a new movement to allow patients to monitor personal digital health data generated by wearable sensors and by the clinics, hospitals, and laboratories where they receive care.[5] This term means that we are seeing a trend toward the collection, transmission, and analysis of digital data related to medical conditions. Digital health encompasses multiple technologies that are listed in **Table 2**.[6] Of the list of 12 transforming technologies in **Table 1**, all but one generate digital data and are compatible with automatic computerized decision support software. The one type of nondigital data, social media, is transmitted through digital technologies. Ten of the 11 types of digital data are binary, with outputs of 0 or 1, but genetics is based

Table 2.
Forms of Digital Health

1. Telehealth systems
2. Therapeutic and diagnostic medical devices
3. Remote monitoring devices
4. Mobile health applications
5. Secured wireless communication medical devices
6. Medication monitoring equipment
7. Mobile health devices
8. Medical robotics
9. Personal health records
10. Communications networks
11. Gaming for health
12. E-prescriptions

on a four-character output of A, C, G, and T, which is a type of digital output also. The only nondigital technology, social media, can generate either discrete quantifiable digital output or else purely analog output, but the decision process is usually based on nondigital input and is the only source of human output on the list.

The premise of the digital health revolution is that digital information will become increasingly important. The potential amount and types of physiological data that will be collected soon is staggering. It has been estimated that personal sensor data will balloon from 10% of all stored information to 90% within the next decade.[7] Will analog information be replaced? Context for digitally derived information can be obtained through direct patient contact, a physical examination, conversation, and nonverbal communication. These nondigital interactions have value; however, their relative importance compared with the impending torrent of digital information that is becoming available from the transforming technologies in **Table 1** is unclear at this point. Are clinicians about to be replaced by computers basing decisions on digital data? The human element of medicine cannot be replaced by a computer for obtaining nondigital information and possibly for setting goals, accounting for patient preferences, and factoring in patient experiences that cannot be easily quantified. Most of these transforming digital technologies were not appreciated 20 or even 10 years ago. I expect that the practice of medicine will change greatly in the next 10 or 20 years as increasing amounts of digital data are collected, analyzed, and used to make treatment decisions.

Personalized Digital Medicine

Some patients might perceive that future data-driven digital health decision making systems will deliver less "personal" attention than the current ones. There are potentially negative perceptions of such high-tech systems, which have less of a "high-touch" interface between the health care professional and the patient. Digital health will lead to health care professionals spending less time talking with and listening to patients and more time verifying digital data, soliciting databases, and working with computerized decision support systems. The health care professional will no longer be the source of information but will become the interpreter of medical information.[8] At this time, medical decisions are based on a personally performed analog history and physical. In the future, I expect that most medical decisions will be made through computerized sorting, structuring, and analysis of massive amounts of digital data. Much of these data will be delivered by way of real-time streaming from diverse sources filtered through a the prism of personal filters of individual goals and preferences and based on decision support software that is constantly updated with best practices guidelines. The 12 transforming digital technologies described in this article, when applied to medical decision making, will often lead to better outcomes than can be attained through current analog decision making, which lacks massive streams of data. It is critical to separate clinical situations where high-tech digital medicine can be an improvement over current practices from situations where the human touch is still critical to effective medical outcomes. Future digital medicine will be more personal than it is now but in a different way than we are used to.

Conclusions

Journal of Diabetes Science and Technology has been closely covering the 12 transforming technologies for medicine and diabetes. In the next decade, we expect to publish many articles on new types of measurements for managing and predicting diabetes and other diseases as well as new tools for collecting and interpreting data. Future decision support software systems based on new types of data and information obtained through new digital measurement technologies will make intelligent decisions for patients. These systems, embodying new dimensions of knowledge, will need to stand up to scrutiny by the clinical, regulatory, and payer communities.

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