review article

Intersection of Digital Health and Oncology

Adam P. Dicker

Heather S.L. Jim

Author affiliations and support information (if applicable) appear at the end of this article.

Corresponding author: Adam P. Dicker, MD, PhD, Sidney Kimmel Medical College, Thomas Jefferson University, 111 South 11th St, Philadelphia, PA 19107-5097; e-mail: adam.dicker@jefferson.edu.

Health care is on the brink of remarkable change, unprecedented in the rapidity of transition and in reshaping the approach to health and disease. The foundation of this change is rooted in the digital universe, from the Internet of Things to computational computing to big data and more. Hand in hand with these capabilities is the growing ability for personalization of health care and the rise in consumerism as a force in the industry. This reflects one of the missions of *JCO Clinical Cancer Informatics* (*JCO CCI*).

Health care systems are just now embracing what the explosion in technology will mean for the practice of medicine and their institutions: changes in work, structure, and patient expectations. To be successful, organizations must rethink traditional departments, expunge silos, and acknowledge that a workforce with a different set of skills and capabilities will be required. Cross training in health care, design, and technology and an understanding of agile team functioning will become the hallmarks of preparation for a new-generation workforce, in essence creating a new paradigm for education.

As oncology practices use technology platforms as a form of communication, this will change the relationship from fee-for-service health care to collaborative medicine. Successful outcomes that rely on technology platforms are even more dependent on teamwork and shared decision making among physicians, caregivers, and patients. Oncology as a specialty has unique challenges, with treatments that result in significant and often unexpected toxicities that require complex management decisions to achieve improved outcomes. Digital health technologies can streamline communication by providing interactive decision aids, mobile applications, and Web-based resources. These technologies are changing how health care providers and patients collaborate both inside and outside the clinical setting.

Recent clinical trials have demonstrated that remote monitoring can reduce symptoms and improve survival. Basch et al[1] reported on integration of patient-reported outcomes (PROs) into the routine care of patients with metastatic cancer. They found clinic-based PRO monitoring was associated with increased survival compared with usual care. A putative mechanism of action was early and improved responsiveness to patient symptoms, preventing adverse downstream consequences. Nurses responded to symptom alerts 77% of the time with discrete clinical interventions, including calls to provide symptom management counseling, supportive medications, chemotherapy dose modifications, and referrals.

Other intriguing findings on the use of technology to improve cancer outcomes come from a recent multicenter phase III trial. Patients with advanced-stage lung cancer were randomly assigned to weekly symptom monitoring with a Web-mediated follow-up algorithm to detect possible cancer progression (experimental arm) or routine follow-up with computed tomography scans scheduled every 3 to 6 months according to disease stage (control arm). The intervention improved overall survival because of early relapse detection and better performance status at relapse.[2]

The use of sensor and mobile technology for patients with head and neck cancer may enable monitoring of patient symptoms and related outcomes during critical periods of outpatient cancer treatment, according to findings by The University of Texas MD Anderson Cancer Center. The study, published by Peterson et al,[3] also demonstrated these technologies may offer benefits for patients during radiation treatment.

These findings were presented at the upcoming 2018 American Society of Clinical Oncology Annual Meeting.

This *JCO CCI* Special Collection highlights exciting new areas of digital health. Articles describe technologic advances in the fields of geriatric oncology, novel uses of text messaging, young adult survivorship, wearable sensors, telehealth, PROs, and drug development. Taken together, these articles provide a broad overview of the current state of the science regarding use of technology in cancer care as well as anticipated future directions.

A well-conceptualized review by Cox et al[4] entitled "Use of Wearable, Mobile, and Sensor Technology in Cancer Clinical Trials" focuses on the use of technology in the context of clinical research. The authors highlight the potential benefits of technology in ensuring more accurate and complete data at a lower cost. Issues of high relevance to the clinical trial setting are also addressed, including data accuracy, provenance, and regulatory concerns. The review concludes with exciting potential uses of technology to enhance data analysis and inference with the goal of rapidly advancing efficacious treatments.

Health disparities are the focus of the article by Gonzalez[5] entitled "Promise of Mobile Health (mHealth) Technology to Reduce Disparities in Patients With Cancer and Survivors." The article notes that health disparities can result from poor access and communication between patients and providers, which can be ameliorated by technology. For example, patients who live in rural areas and those with transportation issues may benefit from telemedicine. Patients with low health literacy and those who are not fluent in English may benefit from targeted educational materials in their preferred languages. Overall, this thoughtful review envisions new approaches to mitigating longstanding inequities in cancer outcomes.

Garg et al[6] offer an insightful overview of clinical implementation of technology in their article entitled "Clinical Integration of Digital Solutions in Health Care: An Overview of the Current Landscape of Digital Technologies in Cancer Care." They describe innovative oncology applications, such as connected devices via the Internet of Things, wearable sensors such as activity monitors, Web-based data collection, and telemedicine. The next generation of technology, including chatbots, is also considered in the context of oncology care. The review provides a wealth of ideas for readers interested in developing, implementing, and evaluating cutting-edge health care solutions.

In a narrative review entitled "Text Messaging in Oncology: A Review of the Landscape," Mougalian et al[7] delve into the potential of texting to transform health behaviors. They describe multiple uses for texting, including increasing physical activity, quitting smoking, losing weight, engaging in sun protection, engaging in cancer screening, and adhering to oral medication. An additional use in the context of cancer is symptom monitoring. The review concludes with a discussion of clinical implementation of this versatile technology.

A crucial challenge in the design and delivery of optimal cancer care for the older patient population is the heterogeneity in overall health among this population. In the context of cancer care, functional age (the combination of chronologic, physiologic, and mental health) is more important to ensure both adherence to treatment and survival than chronologic age alone. Fallahzadeh et al[8] provide an overview of symptoms that could be potentially monitored using digital health technologies and describe some of the digital health technologies currently being developed that have the potential to improve the assessment and care of older adults with cancer in the future. Although the recent development of digital health solutions has been shown to be reliable and effective in many health-related applications, there is an unmet need for development of systems and clinical trials particularly designed for remote cancer management of older adults with cancer, such as advanced remote technologies for cancer-related symptom assessment, psychological behavior monitoring at home, and outcome-oriented clinical protocols for accurate evaluation.

The use of digital health is particularly relevant for adolescents and young adults (AYAs), who are pervasive users of technology. AYA cancer survivors are a growing group of survivors age 15 to 39 years who were diagnosed with cancer during childhood, adolescence, or young adulthood. There are more than 379,000 childhood cancer survivors in the United States, and approximately one in every 530 young adults age 20 to 39 years is a cancer survivor. Devine et al[9] examine the evidence for digital health interventions targeting AYA survivors. They highlight primary results from select studies that have

used the Internet, mHealth, social media, telehealth, and other emerging digital modalities to illustrate the state of the research targeting this unique patient population. This timely review demonstrates that this is an emerging area of research, primarily composed of feasibility studies with methodologic weaknesses, such as lack of control groups and small sample sizes, and emphasizes the opportunities in this growing patient population.

Do all oncology services need to be administered in a clinical setting? Clearly not. Telehealth has been used in a variety of both primary care and specialty settings as a means of connecting patients, providers, and family members. Examples of clinical uses include many forms of synchronous and asynchronous care, such as the provision of remote specialist consults, provider-to-provider training, services to rural communities, direct patient-provider communication through asynchronous platforms (text messaging or e-mail communications) or direct face-to-face video connections, and monitoring of patients at home. Primary benefits that have been identified in the use of telehealth within the oncology specialty include increased timeliness of diagnosis and treatment of malignancies, improved access to care as a result of remote monitoring, and increased patient convenience because of reduced commutes and avoidance of fees such as parking. Rising et al[10] examine reviewed telehealth-related measures applied to oncology care reported in systematic reviews and identified National Quality Forum–endorsed quality measures related to oncology care potentially amenable to telehealth. They organize identified measures by the National Quality Forum domains to inform suggestions for advancing the care of patients with cancer through telehealth.

How does one combine PROs and activity tracker data? Wright et al[11] describe the development, refinement, and pilot testing of a mobile health intervention entitled "The HOPE Pilot Study: Harnessing Patient-Reported Outcomes and Biometric Data to Enhance Cancer Care" in patients with gynecologic cancers receiving palliative chemotherapy. The HOPE study was designed to assess patient symptoms using the PRO version of the Common Terminology for Adverse Events, risk stratify responses, provide tailored feedback to patients with low-risk symptoms, and notify both patients and clinicians of high-risk symptoms. They used the Beiwe research platform, a digital phenotyping platform that monitors patients' behavior passively using their own smartphone sensors and can remotely deploy smartphone-based surveys, by adding a function to provide tailored responses to patients' survey responses and paired this platform with two accelerometers (the Fitbit Zip and Fitbit Charge 2) to monitor patients' activity levels as a proxy for performance status. Wright et al detail how a mobile health intervention that collects PROs and activity data as measures of health status is feasible and acceptable and was perceived to be effective in improving symptom management in patients with advanced gynecologic cancers. This is a cutting-edge study that creates a roadmap for the future of oncology care.

Can digital health be used to aid cancer drug development? Can technology manage the toxicity of cancer therapy? In their article "Technology Applications: Use of Digital Health Technology to Enable Drug Development," Liu et al[12] describe a mobile application for adverse effect monitoring and reporting in women with recurrent ovarian cancer. This is the first description of how an outward-facing application and an inward-facing platform can actively manage the toxicities of cancer treatment. The eCO application was designed to assist in managing acute treatment-related events most often associated with treatment discontinuation and the need for drug holidays or dose interruptions. Hypertension and diarrhea events reported via eCO allowed rapid provider response and a positive overall patient experience. Patients indicated eCO use made them feel more involved in their care and better connected to their health care team. This study highlights opportunities for cancer toxicity management that could reduce the need for frequent telephone calls leading to time-intensive telephone tag among providers, patients, and caregivers. Digital health approaches could potentially reduce the inefficiency of cancer care by using resources more efficiently, reducing time spent by providers on toxicity management, and directing providers to patients requiring more intensive toxicity management.

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Adam P. Dicker
Leadership: Department of Defense Prostate Cancer Research Program, NRG Oncology, American Society for Radiation Oncology
Consulting or Advisory Role: EMD Serono, Ferring Pharmaceuticals, Janssen, RedHill Biopharma, Self Care Catalyst, Celldex, Johnson & Johnson, CVS
Research Funding: Prostate Cancer Foundation
Travel, Accommodations, Expenses: Merck KGaA, Ferring Pharmaceuticals, Self Care Catalyst

Heather S.L. Jim
Consulting or Advisory Role: Janssen, RedHill BioPharma

Affiliations

Adam P. Dicker, Sidney Kimmel Cancer Center, Sidney Kimmel Medical College, Thomas Jefferson University, Philadelphia, PA; and **Heather S.L. Jim**, Moffit Cancer Center, Tampa, FL.

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REFERENCES

1. Basch E, Deal AM, Dueck AC, et al: Overall survival results of a trial assessing patient-reported outcomes for symptom monitoring during routine cancer treatment. JAMA 318:197-198, 2017
2. Denis F, Lethrosne C, Pourel N, et al: Randomized trial comparing a Web-mediated follow-up with routine surveillance in lung cancer patients. J Natl Cancer Inst, 2017 https://doi.org/10.1093/jnci/djx029
3. Peterson SK, Garden AS, Shinn EH, et al: Using mobile and sensor technology to identify early dehydration risk in head and neck cancer patients undergoing radiation treatment: Impact on symptoms. J Clin Oncol 36, 2018 (suppl; abstr 6063)
4. Cox SA, Lane A, Volchenboum SL: Use of wearable, mobile, and sensor technology in cancer clinical trials. JCO Clin Cancer Inform. 10.1200/CCI.17.00147
5. Gonzalez BD: Promise of mobile health (mHealth) technology to reduce disparities in patients with cancer and survivors. JCO Clin Cancer Inform. 10.1200/CCI.17.00141
6. Garg S, Williams NL, Ip A, et al: Clinical integration of digital solutions in health care: An overview of the current landscape of digital technologies in cancer care. JCO Clin Cancer Inform. 10.1200/CCI.17.00159
7. Mougalian SS, Gross CP, Hall EK: Text messaging in oncology: A review of the landscape. JCO Clin Cancer Inform. 10.1200/CCI.17.001628
8. Fallhazadeh R, Rokni SA, Ghasemzadeh H, et al: Digital health for geriatric oncology. JCO Clin Cancer Inform. 10.1200/CCI.17.00133
9. Devine KA, Viola AS, Coups EJ, et al: Digital health interventions for adolescent and young adult cancer survivors. JCO Clin Cancer Inform. 10.1200/CCI.17.00138
10. Rising KL, Ward MM, Goldwater JC, et al: Framework to advance oncology-related telehealth. JCO Clin Cancer Inform. 10.1200/CCI.17.00156
11. Wright AA, Raman M, Stapes P, et al: The HOPE pilot study: Harnessing patient-reported outcomes and biometric data to enhance cancer care. JCO Clin Cancer Inform. 10.1200/CCI.17.00149
12. Liu JF, Lee J-M, Strock E, et al: Technology applications: Use of digital health technology to enable drug development. JCO Clin Cancer Inform. 10.1200/CCI.17.00153