Abstract: 152

Text: 3,608

References: 57

Figures: 4

Improving Psychiatric Care through Integrated Digital Technologies

J. Christopher Fowler, PhD[a,b,c]
Alok Madan, PhD, MPH[a,b,c]
Courtenay R. Bruce, JD, MA[a]
B. Christopher Frueh, PhD[b,d]
Bita Kash, PhD. MBA[a,e]
Stephen L. Jones, MD, MSHI[a]
Farzan Sasangohar, PhD[a,e]

[a]Houston Methodist Institute for Academic Medicine, Houston, TX 77035

[b] Univ. of Texas McGovern School of Medicine, 1941 East Rd, Houston, TX 77054

[c] Baylor College of Medicine, One Baylor Plaza, Houston TX 77030

[d]University of Hawaii, 200 West Kawili St., Hilo, HI 96720

[e] Texas A&M University, College Station, TX 77843

Correspondence concerning this article should be addressed to J. Christopher Fowler, PhD at

jcfowler@houstonmethodist.org

Abstract

This manuscript provides an overview of our efforts to implement an integrated electronic monitoring and feedback platform to increase patient engagement, improve care delivery and outcome of treatment, and alert care teams to deterioration in functioning. *Patients First* utilizes CareSense, a digital care navigation and data collection systems, to integrate traditional patient-reported outcomes (PROs) monitoring with novel biological monitoring between visits to provide patients and caregivers real-time feedback on changes in symptoms such as stress, anxiety, and depression. The next stage of the project development incorporates digital therapeutics (computerized therapeutic interventions) for patients, and video resources for primary care physicians and nurse practitioners who serve as the de facto front-line for psychiatric care. Integration of the PROs monitoring with continuous biological monitoring, and digital supports is a novel application of existing technologies. Video resources pushed to care providers whose patients trigger a symptom severity alert is, to our knowledge, an industry first.

Philosophically, healthcare providers and policy makers understand that services must be driven by objective and standardized measures of clinical outcomes and an evidence-based practice approach; however, few psychiatric settings in the United States systematically assess patient reported outcomes (PROs). When psychiatric outcomes are assessed in clinical practice it has predominantly been measured from the perspective of the treatment provider, a practice that often over-estimates progress and dramatically under-estimates worsening symptoms.[1] Policy makers in the United States and abroad have called for efforts to obtain the patient's unique perspective in assessing efficacy of healthcare.

Major inroads are being made in large healthcare systems utilizing PROs to assess outcomes in medical specialties including radiology[2], oncology[3], and orthopedics.[4] Despite the calls for increased utilization of the patient's perspective, and the positive impact of PROs in improving outcomes[5-8] integration of outcomes assessment in psychiatric practice in the United States is challenging and tends to be the exception rather than standard of care.[9] Recent efforts to demonstrate the effectiveness of smartphone applications to augment alcohol recovery[10] and more ambitious efforts to advance a platform for digital psychiatry[11,12] holds significant promise for individuals with psychiatric symptoms, most of whom cannot access adequate psychiatric care due to shortages of providers, geographical barriers, and stigma.[13]

In January 2018 Houston Methodist launched "*Patients First",* an integrated patient-reported outcomes (PROs) platform with the broad aims to increase patient engagement, improve delivery and outcome of treatments, alert care teams to deterioration in functioning,

and facilitate research into psychiatric illness and treatment response.[14] Clinical researchers partnered with colleagues specializing in medical ethics, patient-centered decision making, telepsychiatry, and bioinformatics to create a novel integrated monitoring and treatment augmentation system. Our team partnered with an industry leader in digital care navigation and data collection systems (CareSense), because surgical departments in the hospital system found the platform to be user-friendly, customizable, and capable of integrating with the electronic health record. This collaboration with a proven partner allowed for rapid expansion of psychiatric monitoring in outpatient, inpatient psychiatry (1,000 admission per year), and high-volume consult liaison service (over 3,300 evaluations per year).

Expanding evaluation of psychiatric symptoms to large numbers of medical patients, many of whom will not have a psychiatric care specialist brings with it the ethical responsibility to connect individuals in psychiatric distress with timely and effective resources. Anticipating this future demand, the team created a project timeline for adding digital therapeutics, and expert consultation to care providers (many of whom are primary care physicians and nurse practitioners) via video archive and telepsychiatry consult from a group of psychiatrists and allied health professionals. Herein we describe the team's efforts in the development, implementation, and iterative modification of a robust electronic platform for PROs integration, feedback, and clinical support. Patients First creates a novel integration of tradition PROs, between-visit biometric monitoring and feedback, patient-facing digital therapeutics that are pushed to patients when symptoms worsen, and physician-facing alert systems with a digital resource center for physicians.

The need to improve clinical outcomes and reduce economic burden of ill health (particularly in mental illness, diabetes, and vascular disease) was identified as the greatest impetus to the deployment of technological innovation in medicine.[15] Information technology (IT) solutions should support shared medical decision-making, self-management, and more efficient healthcare.[16] From our vantage, IT solutions can best be used to measure, monitor, support patients between sessions, and aid in communicating with healthcare providers. Yet, challenges abound in harnessing information technology to serve healthcare consumers and providers.[17] Among the greatest is to ensure that we do it in a manner that is clearly evidence-based, fits into new and developing information technologies, and engages consumers to address their needs. This means that patients, providers, and stakeholders must be engaged at each stage of development and implementation, ensure that they are feasible and acceptable to patients, do not burden healthcare professionals with more documentation tasks, and that they are effective in providing needed information to treat the symptoms and disorders to which they are applied. To meet these aims, digital platforms need to be structured to have the best possible balance of increasing access, minimizing costs, and maximizing clinical outcomes. This is neither simple nor obvious because the technological landscape is rapidly evolving, bringing with it myriad of potential ways to use, combine, and synthesize the array of options.

Our solution to the above challenge was to stage the development and implementation allowing the team to survey the needs of the target user groups (patients, healthcare providers, researchers, and IT), troubleshoot and reassess the value of adding new components, and modify the facets in an iterative fashion. Thus far the team has identified four stages of development: 1. Electronic PROs monitoring and feedback platform integration, 2. Merge

biometric data from commercial-off-the-shelf (COTS) devices monitoring heart rate, heart rate variability (HRV), sleep, and movement, as well as a periodically scheduled voice and facial recognition assessment, 3. Implement a series of digital therapeutics made available to patients when levels of symptoms or stress are elevated as an augmentation to treatment as usual, and 4. Create a library of brief video consultations for physicians and nurse practitioners who are working with patients whose psychiatric symptomatology is outside of the scope of their normal practice.

Stage 1 was created based on the authors' experience building and testing various survey suites for use in psychiatric and medical-surgical hospitals. The selection of measures ensures a rapid, yet broad screening and monitoring platform, but with the obvious limitations of a self-report system. Stage 2 was selected to address limitations of self-report functioning, as well as gaps in current psychiatric PROs platforms that monitor self-report functioning at set intervals of weeks duration. Stage 3 was selected to address the anticipated need for resources for patients seen by a consult-liaison team in the hospital system who may not have a psychiatric care team available in their community. Stage 4 was envisioned as an industry-first resource for primary care providers who serve as the de-facto front line for psychiatric care, but who do not have the training to treat more complex cases that may be refractory to treatment-as-usual.

Stage 1: Patient Reported Outcomes of Psychiatric Symptom Monitoring and Feedback

The foundation for all future phases is based on a highly flexible PROs platform allowing for real-time feedback to patients and healthcare teams via a graphic dashboard of baseline

and follow-up symptom and functional metrics (i.e., evidence-based, app-delivered assessments for depression, anxiety, insomnia, and drug/alcohol abuse, functional disability, and well-being). CareSense™ is the digital solution that Houston Methodist uses for several purposes: 1. Deliver education to patients and caregivers; 2. Provide timely reminders for various patient tasks (e.g. pre-operative evaluation appointments and labs); 3. Monitor health and recovery; and (4) Collect patient-reported outcome data and transmit trending data over time to providers and patients. The digital platform is integrated into EPIC, the electronic health record utilized by the entire hospital system. This integration creates a single touchpoint for all current and future monitoring and feedback actions while reducing provider burden of navigating multiple platforms.

Messages are transmitted via text or email, depending on the purpose of the message. Time-sensitive, short messages are transmitted via text message, and longer educational messages, especially those with embedded multimedia content, are sent via email. For unidirectional messages, information is sent with no expectation of a response, and we provide no means of responding to us through the messages. Instead, for unidirectional messages, we encourage patients to call the office if they have questions or concerns. Examples of unidirectional messages include: Directions on where to park; frequently-asked questions and answers; reminders on when to start and stop medications; who to call for urgent issues and under what circumstances; and other educational or informational aspects of care.

Conversely, we send bidirectional messages for two different purposes: (1) monitor patients' current health status by soliciting patient responses to our monitoring questions; and (2) collect patient-reported outcomes data for making adjustments to the treatment plan.

Monitoring questions are used to actively assess the patient's status in real-time. If the patient responds in a concerning way, an automatic alert is generated and routed to the appropriate healthcare professionals. For example, one bidirectional message is: "In the past two weeks, have you wished you were dead or wished you could go to sleep and not wake up?" If the patient responds with "yes," the decision logic is written such that an alert is automatically routed to the healthcare team via the care team's secure, HIPAA-compliant emails or text, letting them know that a patient responded to a monitoring question in a concerning way. The "team" receiving the alert includes medical assistants, nurses, and physicians who care for the patient. One team member can [reply all] in a secure manner, letting the other team members know they will call the patient to ensure timely follow-up. By including multiple team members on the alert, the chance of communication break-down between team members is minimized thus providing a robust safety-net for the patient. After receiving an email alert, the care team calls the patient and then, following that phone call, dismisses the alert on the dashboard within the enterprise electronic health record (EHR) to show how the issue is resolved.

Bi-directional messages are also used to collect patient-reported outcomes. For example, patients are asked to complete the Patient Health Questionnaire for Depression (PHQ-9)[18] and the Generalized Anxiety Disorder Scale (GAD-7).[19] The first time the PHQ-9 is administered, a baseline graph is created showing a total score, using the sum of items to generate a visual graph. The measures are re-administered at fixed intervals during the treatment course and up to 1-year post-treatment, and new visual graphs are created and pushed to the patient and their respective teams showing trend lines and benchmarks for the severity levels for each measures. Graphs are stored in an electronic, password-protected, two-

factor authentication, secure electronic database that is accessible to patients and authorized healthcare professionals.

Uptake and satisfaction metrics are excellent for the CareSense platform among a large sample surgical patients. [20] Those patients whose surgeons actively used the platform received and read 83% of and 84% of emails. Perhaps most critically, 30, 60 and 90-day inpatient re-admission rates for non-participating post-surgery patients were statistically higher than those adopting the platform.[20] We do not have sufficient data to determine the impact on inpatient re-admission rates for psychiatric patients, and it appears that early adoption among psychiatric patients is slightly lower.

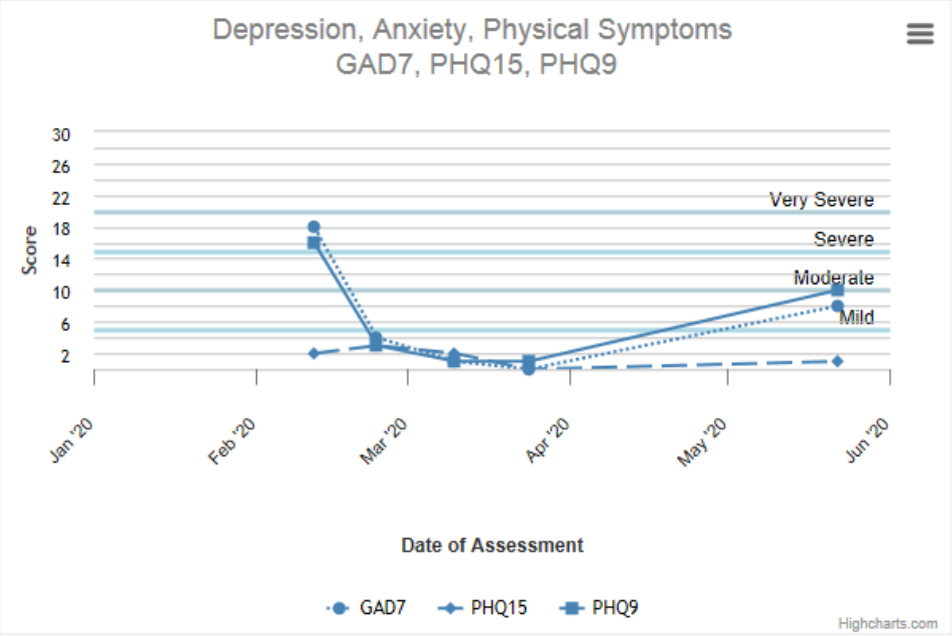
Real-Time Feedback: A Case Vignette

Q was a 25-year old man seeking treatment for depression, anxiety, cyclical alcohol abuse. Intake assessment completed via smartphone prior to the first appointment indicated depression and anxiety in the severe range. An automated suicide alert (sent to his new therapist) was triggered by endorsement of suicidal ideation on item 9 the PHQ, and Columbia Suicide Severity Rating Scale (C-SSRS). In-person suicide assessment confirmed passive suicidal ideation with no plan or intent. Q elaborated on his sense of hope and forward momentum in seeking help. He added that the instructions queried the last two weeks, thus he responded based on his state of mind his after the last binge drinking episode the previous weekend.

A treatment plan was agreed upon to include psychotherapy, medication, and involvement in alcohol recovery program to lower the frequency of suicidal ideation, reduce depression, anxiety, and binge drinking. As seen in Figure 1, symptoms reduced during the first

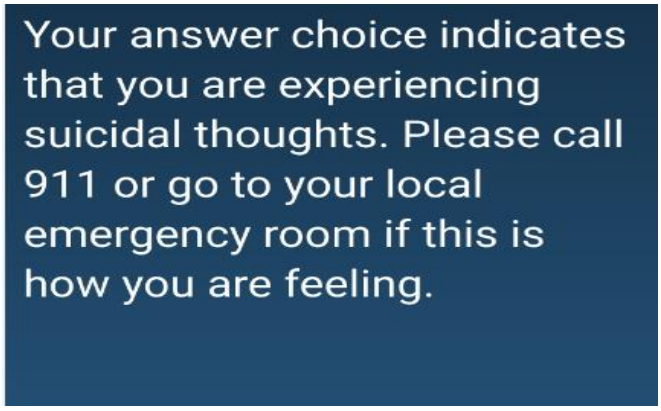
two weeks of treatment and remained in the healthy range several months with no reported recurrence of suicidal ideation. The treatment preceded in a maintenance phase; however, Q experienced a rupture in a romantic relationship and relapsed on alcohol. In therapy session later in the week, his mood was stable and he reported being alcohol free for 72 hours with no discernible withdrawal symptoms. CareSense survey the day after his session revealed a more alarming state.

Figure 1: Q's Trending data from CareSense



His responses to the PHQ-9 and C-SRSS indicated heightened suicidal risk. Q received an alert encouraging him to seek medical attention (Figure 2).

Figure 2. Patient-facing Suicide Risk Alert

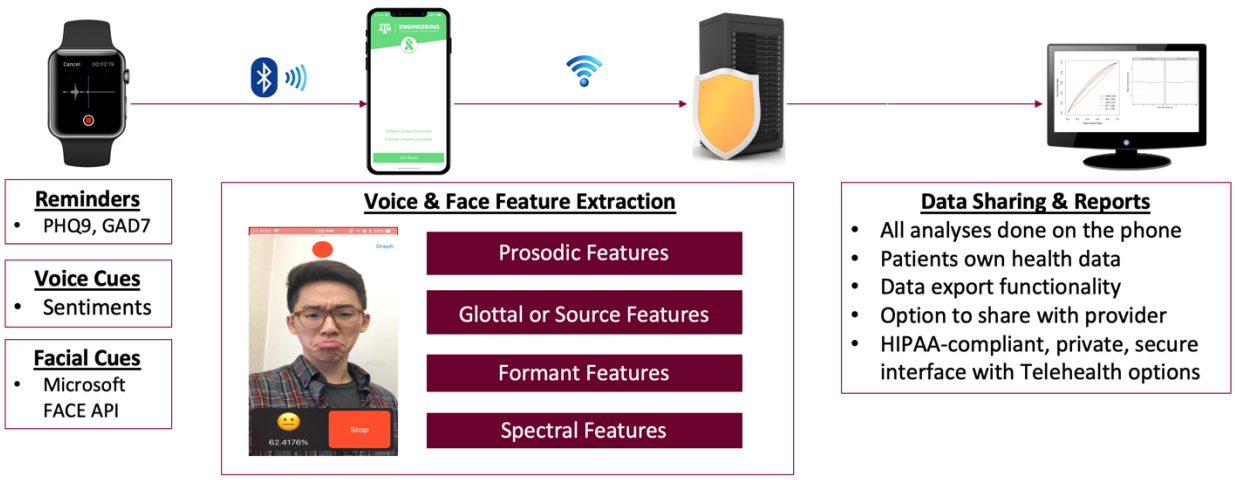


Simultaneously his therapist received an alert concerning Q's suicide risk. The therapist called to learn that he was crestfallen and angry after an unsuccessfully attempted to reconnect with his girlfriend. Therapist and Q discussed ways to remain safe and seek additional supports including the possibility of presenting to the emergency department. He asked to see the therapist later that afternoon, thus an intermediate plan was agreed upon to include reaching out to his sponsor immediately after the call. Q arrived for a session later in the afternoon in better spirits. He had a good meeting with his sponsor during which he gained a clearer understanding of the emotional triggers for his alcohol use. Review of the graphic data during the therapy session helped Q recognize that his attempts to use alcohol to soothe emotions had the opposite impact. The close call with hospitalization and the distress he felt after drinking made him realize that drinking fueled the pain that was a main driver of suicidal ideation. Q and his therapist agreed to more frequent check-ins to help support his sobriety and to monitor his safety.

Stage 2: Between-Session Biometric Monitoring

The second stage integrates continuous monitoring of several relevant biomarkers including heart rate and HRV using COTS such as smart watches. COTS are used since they are affordable, accessible, come with an array of physiological sensors, and most importantly are discreet; an important factor contributing to acceptance among mental health patients. Recent work by the co-author (FS) and colleagues[21] developed a predictive machine learning algorithm that used heart rate sensor data from smart watches to detect mental health anomalies such as high anxiety and hyper-arousal in veterans. This patent-pending technology will form the basis for the continuous *momentary assessment* and monotiling of the patients' mental health status.

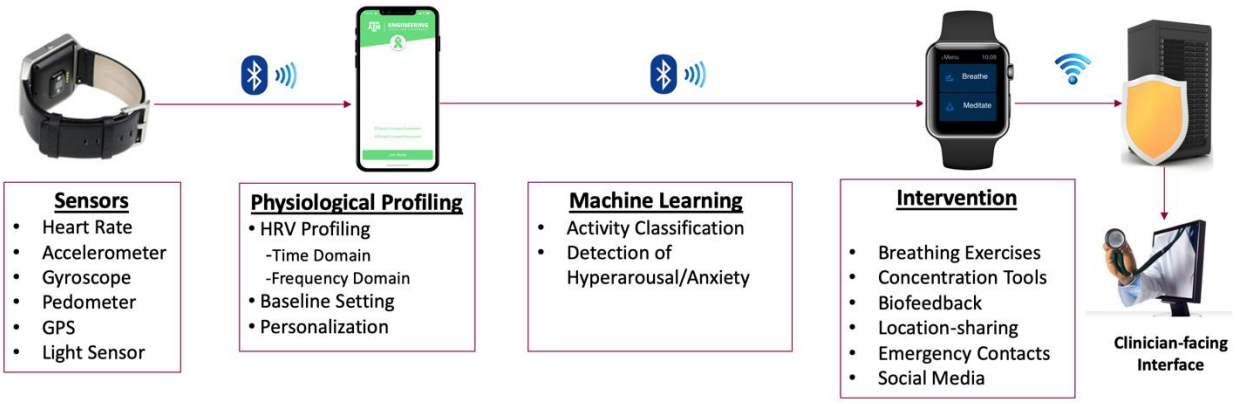
Figure 3. Overview of periodic assessment



Periodic assessment and intervention will facilitate self-assessment of mental health discussed in stage 1 in conjunction with facial emotion and voice analysis. The effects of mental distress on voice features have been documented. For example, patients with depression tend to speak slower, and their tone is monotonous, uniform, and expressionless.[22,23] The team will utilize an open-source real-time voice feature analysis engine (OpenVokaturi) in addition to

Microsoft's face and emotion recognition software (Face API) to identify facial and auditory cues for distress. Participants receive persuasive and planned reminders to complete weekly anxiety screening questionnaires (i.e., PHQ-9 and GAD-7). As part of this weekly self-assessment, participants will be asked to read a sentence to serve as baseline before completing the questionnaire. The PHQ-9 and GAD-7 scores, in conjunction with speech and facial emotion recognition tools, will contribute to a holistic assessment and a combined score which will trigger notifications to suggest actions, such as follow-up appointments with therapists, telehealth counseling, or digital therapeutics. The tool also enables the user to share this data with their therapist or licensed counselor. Persuasive design features and notifications will be implemented to effect attitudinal shifts and sustained engagement.

Figure 4. Overview of activating digital therapeutics



Smart phones and watches are particularly promising as a convenient platform for delivering mobile health (mHealth) interventions enabling self-management of symptoms between visits. For example, upon detection of an abnormal biomarker, patients can be engaged in evidence-based therapeutic interventions such as cognitive behavioral interventions for sleep, depression,

and anxiety. Other functionality available on the smartphone or smart watch app include customized messages to select contacts (e.g., friends, family, counselors), location sharing, real-time connection to local mental health crisis helpline, and counseling service appointment booking. Patients will have access to personalized reports and an export functionality to share the report with their therapist, or primary care physician.

Stage 3: Digital Therapeutics and Virtual Psychiatric Consultation

Digital assessment of PROs, combined with wearable and smart-home monitoring technologies will create rapid screening of common psychiatric symptoms, and send alerts to care providers when concerning values are detected. Providers will then be sent short informational videos and screening resources from experts in assessment and treatment for the specific symptoms and disorders. Simultaneously, symptom-specific digital therapeutics will be sent to the affected patients to begin augmented treatment. Digital therapeutics (via smartphone applications) are already available in the marketspace and are adapted from evidence-based therapies such as cognitive behavioral therapy for depression.[24] For individuals who cannot access traditional psychiatric care via in-person encounters, digital therapeutics fills a much-needed gap. Effectiveness and efficacy studies of the new digital therapeutics will be necessary but as of yet have not been conducted. Multi-modal monitoring of symptom severity over time will allow care-givers and patients to track progress, alter treatment plans to address inadequate or non-response, and know when to suspect remission.

Stage Four: Testing Feasibility and Uptake in Primary Care

Primary care is the touch-point for the recognition, diagnosis, treatment, and specialist referral for psychiatric disturbance[25]. The fact that at least 25% of the population suffers from a mental disorder during the past year[26-28] means that primary care physicians are encountering many individuals with psychiatric symptoms. The prevalence of undetected mental illness in primary care is profound: by one estimate, 5.4% of all primary care patients present for a psychiatric reason, yet a systematic survey indicated that threshold/sub-threshold psychiatric disorder was detected in 42.5% of all patients.[29] This places an extraordinary burden on primary care providers, one that they cannot adequately address given time constraints and the expertise needed to provide specialty assessment, care, and referral.[30,31] This burden and its downstream impact on patient care is borne out by survey data indicating that performance is best described by the rule of diminishing halves: half the patients with a threshold disorder are recognized; half of those recognized are treated; and half of those treated receive effective intervention.[32,33]

A significant barrier to providing the needed treatment is the time, expense, and staffing required to deliver the interventions within a tight window of brief contacts with primary care providers (PCPs)-this is particularly true for PCPs given their large panels and broadband care for their patients. Digital assessment will create rapid diagnostic evaluation of psychiatric symptom severity and send alerts to PCPs. Providers will then be sent short video resources from experts in assessment and treatment. Simultaneously, digital therapeutics will be sent to the affected patients during visits and after the patient returns home.

Conclusions

Building on lessons learned from a decade of modifying and improving digital PROs platforms[14] has alerted the team to several ongoing challenges: 1. As alluring as technological innovations are, the focus must continually be brought back to the value of human contact and interaction in delivering quality care,[34] 2. The user interface (for patients and caregivers) must be simple and intuitive, 3. Building and maintaining viable partnerships with institutional leadership, department chairs, and front-line clinicians is crucial particularly in the planning stage, and 4. Given the high cost and resource demands of such projects, targeting tangible return-on-investment (Eg., reductions in emergency department admissions) is essential for long-term viability.

At its base, symptom reduction and improvement in functional capacity are cornerstones of good psychiatric care; however, few mental health providers systematically monitor symptom changes, and between-visit functioning goes undetected by virtually all mental health care providers. As a result, clinicians opportunities to intervene and alleviate suffering is stymied by the lack of between-session monitoring. Furthermore, symptoms such as sleep disturbance may be difficult for some individuals to detect yet sleep-tracking devices can alert patients and caregivers to worsening sleep—a bellwether for depression.[35] This information vacuum also impairs our ability to understand which interventions are most effective in reducing relapse and readmissions. Remarkably, monitoring PROs in real-time is an effective augmentation strategy to state-of-the-art treatments. Dramatic examples from oncology demonstrates substantial improvement in symptom improvement, quality of life, and decreased rates of ED admissions when PROs are utilized in daily practice.[3,36] In psychiatry, PROs are emerging as a clear catalyst for improvement. A recent meta-analysis found that

psychotherapy augmented with PROs was superior to treatment-as-usual in two-thirds of the studies evaluated.[37]

Electronic application of PROs has also led to the development of unique algorithms to detect adverse outcomes such as suicidal risk[38] and prediction of treatment-resistant depression.[39-43] This novel approach is now possible due to the uptake of smart phones in the US populace, advances in digital care navigation technology, and dramatic advances in computational technologies and capabilities leveraging artificial intelligence and machine learning.[44-55] It is also imperative that we better integrate these approaches with primary medical care, so that undetected psychiatric symptoms can be identified and addressed.

Leveraging information technology to improve access to mental healthcare is only just beginning to touch on its real potential. Going forward, we must discover how to best integrate telemedicine with in-person care and other forms of communications technology[56], including the Internet, mobile technology and its apps, social media, virtual reality, smart homes, and wearable monitoring devices that are synchronized together – and incorporate algorithms to keep patients and providers aware of critical information.

As appealing as these technologies are, there is still a great deal of work to be done. First, approaches such as Patients First must demonstrate the feasibility and cost of implementing integrated digital platforms to augment treatment as usual, and to serve as the primary intervention for those unable to access traditional psychiatric care. Second, studies are needed to assess the effectiveness of digital therapeutics and digital resources for primary care providers. While both interventions are based on evidence-based practices, it is yet to be demonstrated if such modifications are effective in reducing symptom severity in common

psychiatric disorders encountered by primary care providers who serve as the front-line providers of mental health services in the United States.

References

1. Walfish S, McAlister B, O'Donnell P, Lambert MJ. An investigation of self-assessment bias in mental health providers. Psychological Reports. 2012 Apr;110(2):639-44.
2. Rotenstein LS, Agarwal A, O'Neil K, Kelly A, Keaty M, Whitehouse C, Kalinowski B, Orio III PF, Wagle N, Martin NE. Implementing patient-reported outcome surveys as part of routine care: lessons from an academic radiation oncology department. Journal of the American Medical Informatics Association. 2017 Mar 2;24(5):964-8.
3. Basch E, Deal AM, Kris MG, Scher HI, Hudis CA, Sabbatini P, Rogak L, Bennett AV, Dueck AC, Atkinson TM, Chou JF. Symptom monitoring with patient-reported outcomes during routine cancer treatment: a randomized controlled trial. Journal of Clinical Oncology. 2016 Feb 20;34(6):557.
4. Franklin PD, Allison JJ, Ayers DC. Beyond joint implant registries: a patient-centered research consortium for comparative effectiveness in total joint replacement. Jama. 2012 Sep 26;308(12):1217-8.
5. Basch E. Patient-reported outcomes—harnessing patients' voices to improve clinical care. New England Journal of Medicine. 2017 Jan 12;376(2):105-8.
6. Calvert M, Kyte D, Price G, Valderas JM, Hjollund NH. Maximising the impact of patient reported outcome assessment for patients and society. BMJ. 2019 Jan 24;364:k5267.
7. Rotenstein LS, Huckman RS, Wagle NW. Making patients and doctors happier—the potential of patient-reported outcomes. New England Journal of Medicine. 2017 Oct 5;377(14):1309-12.

8. Baumhauer JF. Patient-reported outcomes—are they living up to their potential. N Engl J Med. 2017 Jul 6;377(1):6-9.
9. Snyder CF, Aaronson NK, Choucair AK, Elliott TE, Greenhalgh J, Halyard MY, Hess R, Miller DM, Reeve BB, Santana M. Implementing patient-reported outcomes assessment in clinical practice: a review of the options and considerations. Quality of Life Research. 2012 Oct 1;21(8):1305-14.
10. Gustafson DH, McTavish FM, Chih MY, Atwood AK, Johnson RA, Boyle MG, Levy MS, Driscoll H, Chisholm SM, Dillenburg L, Isham A. A smartphone application to support recovery from alcoholism: a randomized clinical trial. JAMA psychiatry. 2014 May 1;71(5):566-72.
11. Torous J. Digital psychiatry. IEEE Spectrum. 2017 Jun 22;54(7):45-50.
12. Torous J, Kiang MV, Lorme J, Onnela JP. New tools for new research in psychiatry: a scalable and customizable platform to empower data driven smartphone research. JMIR mental health. 2016;3(2):e16.
13. Kullgren JT, McLaughlin CG, Mitra N, Armstrong K. Nonfinancial barriers and access to care for US adults. Health services research. 2012 Feb;47(1pt2):462-85.
14. Fowler JC, Madan A, Frueh BC, Bradshaw M, Flack J, Weinstein B. Lessons learned while integrating patient-reported outcomes in a psychiatric hospital. Psychotherapy. 2019 Mar;56(1):91.
15. Jiwa, M., McManus, A., Dadich, A., White, J., Rieck, A., & Razmi, S. (2013). Harnessing information technology to innovate in primary care. *Quality in primary care*, *21*(1), 43-49.

16. Kuo, A. M. S., Thavalathil, B., Elwyn, G., Nemeth, Z., & Dang, S. (2018). The Promise of Electronic Health Records to Promote Shared Decision Making: A Narrative Review and a Look Ahead. *Medical Decision Making*, *38*(8), 1040-1045.

17. Darwish A, Hassanien AE, Elhoseny M, Sangaiah AK, Muhammad K. The impact of the hybrid platform of internet of things and cloud computing on healthcare systems: Opportunities, challenges, and open problems. Journal of Ambient Intelligence and Humanized Computing. 2019 Oct 1;10(10):4151-66.

18. Kroenke K, Spitzer RL, Williams JB. The PHQ-9: validity of a brief depression severity measure. Journal of general internal medicine. 2001 Sep;16(9):606-13.

19. Spitzer RL, Kroenke K, Williams JB, Löwe B. A brief measure for assessing generalized anxiety disorder: the GAD-7. Archives of internal medicine. 2006 May 22;166(10):1092-7.

20. *Bruce CR, Harrison P, Nisar T, et al. Assessing the Impact of Patient-Facing Digital Technology on Patient Outcomes: A Retrospective Observational Cohort Study. *Journal of Medical Internet Research (mHealth).* 2020. (provisional acceptance)

21. McDonald AD, Sasangohar F, Jatav A, Rao AH. Continuous Monitoring and Detection of Post-Traumatic Stress Disorder (PTSD) Triggers Among Veterans: A Supervised Machine Learning Approach. IISE Transactions on Healthcare Systems Engineering. 2019 Mar 7(just-accepted):1-5.

22. Cummins N, Scherer S, Krajewski J, Schnieder S, Epps J, Quatieri TF. A review of depression and suicide risk assessment using speech analysis. Speech Communication. 2015 Jul 1;71:10-49.

23. Hashim NW, Wilkes M, Salomon R, Meggs J, France DJ. Evaluation of voice acoustics as predictors of clinical depression scores. Journal of Voice. 2017 Mar 1;31(2):256-e1.

24. Cho CH, Lee HJ. Could digital therapeutics be a game changer in psychiatry?. Psychiatry investigation. 2019 Feb;16(2):97.

25. Wittchen HU, Mühlig S, Beesdo K. Mental disorders in primary care. Dialogues in clinical neuroscience. 2003 Jun;5(2):115.

26. Kessler RC, McGonagle KA, Zhao S, et al. Lifetime and 12-month prevalence of DSM-III-R psychiatric disorders in the United States: results from the National Comorbidity Survey. Arch Gen Psychiatry. 1994;51:8-19.

27. Andrade L, Caraveo-Anduaga JJ, Berglund P, et al. Cross-national comparisons of the prevalences and correlates of mental disorders. Bull World Health Organ. 2000;78:413-426.

28. Wittchen HU, Nelson CB, Lachner G. Prevalence of mental disorders and psychosocial impairments in adolescents and young adults. Psychol Med. 1998;28:109-126.

29. Ansseau M, Dierick M, Buntinkx F, Cnockaert P, De Smedt J, Van Den Haute M, Vander Mijnsbrugge D. High prevalence of mental disorders in primary care. Journal of affective disorders. 2004 Jan 1;78(1):49-55.

30. Jacobi F, Wittchen HU, Hölting C, Höfler M, Pfister H, Müller N, Lieb R. Prevalence, co-morbidity and correlates of mental disorders in the general population: results from the German Health Interview and Examination Survey (GHS). Psychological medicine. 2004 May;34(4):597-611.

31. Bijl RV, de Graaf R, Hiripi E, et al. The prevalence of treated and untreated mental disorders in five countries. Health Affairs. 2003;22:122-133.

32. Wittchen HU, Pittrow D. Prevalence, recognition and management of depression in primary case in Germany: the Depression 2000 Study. Hum Psychopharmacol Clin Exp. 2002;17(suppl 1):S1-S11.

33. Kroenke K, Spitzer RL, Williams JB, Monahan PO, Löwe B. Anxiety disorders in primary care: prevalence, impairment, comorbidity, and detection. Annals of internal medicine. 2007 Mar 6;146(5):317-25.

34. Frueh BC, Oldham JM, Fonagy P. Programmatic research at a specialty psychiatric inpatient clinic: Opportunities, challenges, and future directions. Bulletin of the Menninger Clinic. 2009 Dec;73(4):251-8.

35. Gregory AM, Rijsdijk FV, Lau JY, Dahl RE, Eley TC. The direction of longitudinal associations between sleep problems and depression symptoms: a study of twins aged 8 and 10 years. Sleep. 2009 Feb 1;32(2):189-99.

36. Nipp RD, El-Jawahri A, Moran SM, D'arpino SM, Johnson PC, Lage DE, Wong RL, Pirl WF, Traeger L, Lennes IT, Cashavelly BJ. The relationship between physical and psychological symptoms and health care utilization in hospitalized patients with advanced cancer. Cancer. 2017 Dec 1;123(23):4720-7.

37. Lambert MJ, Whipple JL, Kleinstäuber M. Collecting and delivering progress feedback: A meta-analysis of routine outcome monitoring. Psychotherapy. 2018 Dec;55(4):520.

38. Madan A, Mahoney J, Allen JG, Ellis T, Hardesty S, Oldham JM, Fowler JC. Utility of an integrated electronic suicide alert system in a psychiatric hospital. Quality management in health care. 2015 Apr 1;24(2):79-83.

39. Fowler JC, Patriquin M, Madan A, Allen JG, Frueh BC, Oldham JM. Early identification of treatment non-response utilizing the Patient Health Questionnaire (PHQ-9). Journal of psychiatric research. 2015 Sep 1;68:114-9.

40. Ellsworth JR, Lambert MJ, Johnson J. A comparison of the Outcome Questionnaire-45 and Outcome Questionnaire-30 in classification and prediction of treatment outcome. Clinical Psychology & Psychotherapy: An International Journal of Theory & Practice. 2006 Nov;13(6):380-91.

41. Hannan C, Lambert MJ, Harmon C, Nielsen SL, Smart DW, Shimokawa K, Sutton SW. A lab test and algorithms for identifying clients at risk for treatment failure. Journal of clinical psychology. 2005 Feb;61(2):155-63.

42. Lambert MJ, Whipple JL, Bishop MJ, Vermeersch DA, Gray GV, Finch AE. Comparison of empirically-derived and rationally-derived methods for identifying patients at risk for treatment failure. Clinical Psychology & Psychotherapy: An International Journal of Theory & Practice. 2002 May;9(3):149-64.

43. Lutz W, Lambert MJ, Harmon SC, Tschitsaz A, Schürch E, Stulz N. The probability of treatment success, failure and duration—what can be learned from empirical data to support decision making in clinical practice?. Clinical Psychology & Psychotherapy: An International Journal of Theory & Practice. 2006 Jul;13(4):223-32.

44. Madan A, Fowler JC, Patriquin MA, Salas R, Baldwin PR, Velasquez KM, Viswanath H, Molfese DL, Sharp C, Allen JG, Hardesty S. A novel approach to identifying a neuroimaging biomarker for patients with serious mental illness. The Journal of neuropsychiatry and clinical neurosciences. 2017 Feb 27;29(3):275-83.

45. Birnbaum ML, Ernala SK, Rizvi AF, De Choudhury M, Kane JM. A Collaborative Approach to Identifying Social Media Markers of Schizophrenia by Employing Machine Learning and Clinical Appraisals. J Med Internet Res. 2017;19(8):e289. doi:10.2196/jmir.7956

46. D'Alfonso S, Santesteban-Echarri O, Rice S, et al. Artificial Intelligence-Assisted Online Social Therapy for Youth Mental Health. Front Psychol. 2017;8:796. doi:10.3389/fpsyg.2017.007960

47. Ricard BJ, Marsch LA, Crosier B, Hassanpour S. Exploring the Utility of Community-Generated Social Media Content for Detecting Depression: An Analytical Study on Instagram. J Med Internet Res. 2018;20(12):e11817. doi:10.2196/11817

48. Du J, Zhang Y, Luo J, et al. Extracting psychiatric stressors for suicide from social media using deep learning. BMC Med Inform Decis Mak. 2018;18(Suppl 2):43. doi:10.1186/s12911-018-0632-8

49. Mohr DC, Zhang M, Schueller SM. Personal Sensing: Understanding Mental Health Using Ubiquitous Sensors and Machine Learning. Annu Rev Clin Psychol. 2017;13:23-47. doi:10.1146/annurev-clinpsy-032816-044949

50. Ioannidis K, Treder MS, Chamberlain SR, et al. Problematic internet use as an age-related multifaceted problem: Evidence from a two-site survey. Addict Behav. 2018;81:157-166. doi:10.1016/j.addbeh.2018.02.017

51. Conway M, Hu M, Chapman WW. Recent Advances in Using Natural Language Processing to Address Public Health Research Questions Using Social Media and ConsumerGenerated Data. Yearb Med Inform. 2019;28(1):208-217. doi:10.1055/s-0039-1677918

52. Wongkoblap A, Vadillo MA, Curcin V. Researching Mental Health Disorders in the Era of Social Media: Systematic Review. J Med Internet Res. 2017;19(6):e228. doi:10.2196/jmir.7215

53. Hariman K, Ventriglio A, Bhugra D. The Future of Digital Psychiatry. Curr Psychiatry Rep. 2019;21(9):88. doi:10.1007/s11920-019-1074-4

54. Mowery D, Smith H, Cheney T, et al. Understanding Depressive Symptoms and Psychosocial Stressors on Twitter: A Corpus-Based Study. J Med Internet Res. 2017;19(2):e48. doi:10.2196/jmir.6895

55. Ambalavan AK, Moulahi B, Azé J, Bringay S. Unveiling Online Suicide Behavior: What Can We Learn About Mental Health from Suicide Survivors of Reddit? Stud Health Technol Inform. 2019;264:50-54. doi:10.3233/SHTI190181

56. Venkatesh S, Christensen H. Using life's digital detritus to feed discovery. Lancet Psychiatry. 2017;4(3):181-183. doi:10.1016/S2215-0366(16)30351-0

57. Frueh BC. Solving mental healthcare access problems in the twenty-first century. Australian Psychologist. 2015 Aug;50(4):304-6.