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Brief Communication

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Bridging the integration gap between patient-generated blood glucose data and electronic health records

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ABSTRACT

Telemedicine can facilitate population health management by extending the reach of providers to efficiently care for high-risk, high-utilization populations. However, for telemedicine to be maximally useful, data collected using telemedicine technologies must be reliable and readily available to healthcare providers. To address current gaps in integration of patient-generated health data into the electronic health record (EHR), we examined 2 patient-facing platforms, Epic MyChart and Apple HealthKit, both of which facilitated the uploading of blood glucose data into the EHR as part of a diabetes telemedicine intervention. All patients were offered use of the MyChart platform; we subsequently invited a purposive sample of patients who used the MyChart platform effectively (n = 5) to also use the Apple HealthKit platform. Patients reported both platforms helped with diabetes self-management, and providers appreciated the convenience of the processes for obtaining patient data. Providers stated that the EHR data presentation format for Apple HealthKit was challenging to interpret; however, they also valued the greater perceived accuracy the Apple HealthKit data. Our findings indicate that patient-facing platforms can feasibly facilitate transmission of patient-generated health data into the EHR and support telemedicine-based care.

Key words: electronic health records, patient generated health data, telemedicine, diabetes mellitus, type 2

The transition to value-based payment models emphasizes the need for effective approaches to population health.[1–3] Telemedicine, a type of remote patient monitoring that uses technology to facilitate contact between patients and healthcare providers,[4] can expedite population health management by extending the ability of providers to meet the needs of high-risk, high-utilization populations in an efficient manner.[5] Because the majority of patient self-care occurs outside of the provider's office, telemedicine enables providers to engage patients in their home setting with greater regularity.[4,6]

Telemedicine may hold particular promise as a means to improve medical management of costly chronic illnesses like diabetes.[7–9] Under telemedicine-based approaches, patient-facing technologies can be used to collect patient-generated health data (PGHD) and enable telemonitoring (monitoring of patients with diabetes in between

provider visits). Using PGHD, telemedicine interventions that include telemonitoring, self-management support, and medication management have been shown to be more effective than episodic in-person appointments for poorly controlled diabetes.[8,10–12]

While real-time collection of PGHD can facilitate telemedicine-based disease management,[13] PGHD are seldom incorporated into electronic health records (EHRs) where providers can easily and conveniently access these data.[14,15] Our current inability to integrate PGHD into EHRs deters widespread implementation of effective telemedicine interventions.[16–18] This integration gap represents both a source of frustration for providers, who must interrupt their workflow to navigate unfamiliar consumer technologies to access PGHD, and a missed opportunity to maximize the benefits of telemedicine-based care.[16,17]

To address current barriers to telemedicine-based diabetes care, we developed and tested 2 processes for integrating PGHD collected from patient-facing technologies directly into the EHR. We discuss our processes for integrating PGHD into the EHR, patient perceptions of utilizing devices to collect and transfer health data into our health system's EHR, and provider perspectives of PGHD in the EHR.

METHODS

We conducted a 6-month pilot project, *Diabetes Management – The Next Generation (DM-TNG)*, examining the feasibility of delivering an effective telemedicine intervention to high-risk diabetes patients using novel processes for integrating PGHD into the EHR.

Sample and setting

We recruited patients with type 2 diabetes from 2 primary care clinics in a southeastern U.S. city. Inclusion criteria included glycated hemoglobin persistently $\geq$8.5% for $\geq$1 year (minimum of 2 measurements over the past year) despite engagement with clinic-based care (defined as a minimum of 2 clinic appointments over the past year). We identified patients using the EHR and provider referrals; research staff contacted eligible patients by telephone to discuss the project and enrollment process. The project was conducted under a Quality Improvement exemption from the local University Health System Institutional Review Board.

Telemedicine intervention design

The telemedicine intervention in this project is effective for patients with persistently poor diabetes control[8] and includes 3 components: telemonitoring, self-management education, and physician-guided medication management. During the 6-month intervention period, telemedicine nurses delivered the telemonitoring and self-management support intervention components over 12 biweekly telephone encounters, during which interim blood glucose data were reviewed, medications reconciled, and medication adherence discussed. During most telephone encounters, telemedicine nurses delivered educational modules salient to diabetes self-management. Following each telephone encounter, the nurse compiled a summary report in the EHR; this report was routed to the project's medication provider for the medication management component of the intervention. Patients could contact the project team with concerns about blood glucose values, blood glucose monitoring, or use of these data collection platforms. Data flow is depicted in Figure 1.

Patient-facing technology platforms

As part of delivering the telemedicine intervention, we used 2 commercially-available patient-facing information technologies, Epic MyChart (Epic Systems, Verona, WI) and Apple HealthKit (Apple Inc, Cupertino, CA), to transfer patient-generated self-monitored blood glucose data directly into our health system's Epic-based EHR. The MyChart platform is the commercial patient portal associated with Epic EHR and enables communication between patients and providers. In both processes described subsequently, the PGHD were uploaded automatically into the EHR and were then displayed via flowsheets (ie, documents in the patient's chart displaying medical data). We lacked the resources to develop custom flowsheets for the purposes of this feasibility pilot, so we utilized flowsheets for both platforms that had been developed previously, and were already available for use by providers within our healthcare system. We describe the context of use for each process in Table 1.

Process 1: Epic MyChart

All patients receiving the telemedicine intervention were offered use of the MyChart platform. Patients used their personal blood glucose monitors and manually entered their blood glucose data into the MyChart platform via home computers or smart device. Patients were encouraged to enter blood glucose data into MyChart daily. For EHR users to access blood glucose data in MyChart, project staff used a flowsheet adapted by our team that compiled relevant data from the patient's MyChart. When the flowsheet was ordered, data from the patient's MyChart were sent to the EHR. The report of PGHD in the EHR using MyChart is depicted in Figure 2.

Process 2: Apple HealthKit

In order to test the feasibility of the Apple HealthKit platform, we purposively selected patients (n = 5) who had completed the majority of the scheduled biweekly telephone encounters and consistently entered blood glucose values into MyChart during the 6-month intervention. These patients used Apple HealthKit for an additional 3 months, during which they continued to receive the telemedicine intervention.

For patients participating in the Apple HealthKit phase of the project, we provided an Apple iPod Touch equipped with Apple HealthKit and a Food and Drug Administration–approved glucose meter by iHealth. Apple HealthKit is a platform that allows individuals to organize their health monitoring data on 1 dashboard that is easily accessible by the patient. Patients using the Apple HealthKit platform did not log in to MyChart to manually enter blood glucose data; instead, the iHealth glucose meter relayed blood glucose data to the iPod Touch via Bluetooth and Apple HealthKit then automatically transmitted these data into the EHR whenever a wireless internet connection was available. The report of PGHD in the EHR using Apple HealthKit is depicted in Figure 3.

For EHR users to access blood glucose data, project staff used a flowsheet adapted by our team that compiled relevant data from Apple HealthKit users. When the flowsheet was ordered, the iPod requested patient permission for the team to access relevant data in Apple HealthKit. The patient had to accept this prompt before data were sent to the EHR. Once the patient gave permission, the EHR accessed only the requested data, and the patient could revoke EHR access to these data at any time.

Evaluation measures

We invited patients to participate in semistructured interviews about their experiences participating in the project (Table 2). A research assistant conducted all patient interviews via telephone. AAL conducted email interviews with the project's endocrinologists (NEJ,

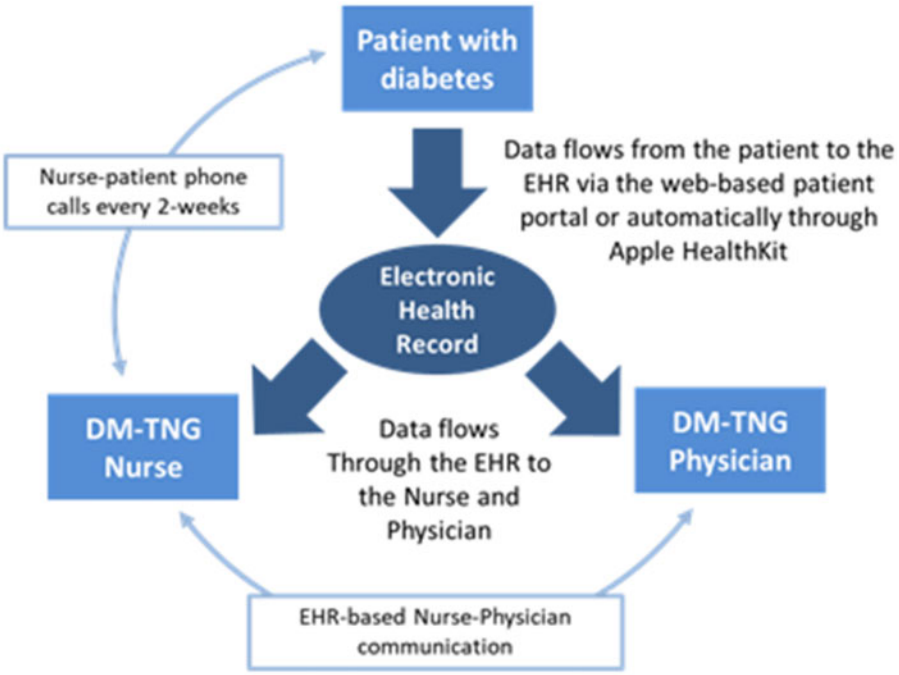

Figure 1. Overview of data flow and patient-provider interaction for Diabetes Management-The Next Generation (DM-TNG) intervention. EHR: electronic health record.

Table 1. Context of use for MyChart and Apple HealthKit

	MyChart	Apple HealthKit
Steps undertaken to transfer PGHD from personal blood glucose meter	1. Patients test blood glucose using their personal blood glucose meter 2. Patients log onto the MyChart platform via a desktop/laptop computer or smartphone 3. Patients manually enter a blood glucose value from the meter into MyChart 4. Patients repeat step #3 for each unique blood glucose value 5. Patients sign out of MyChart 6. Data are transferred into the EHR using a project-specific flowsheet 7. The telehealth nurse reviews patient blood glucose values	1. Patients test blood glucose using a project-provided iHealth glucose meter 2. The iHealth glucose meter automatically transfers blood glucose data to the project-provided Apple iPod Touch with Apple HealthKit using a Bluetooth connection 3. When the Apple iPod Touch is connected to wireless internet, patient blood glucose data automatically upload from Apple HealthKit into the EHR using a project-specific flowsheet 4. The telehealth nurse reviews patient blood glucose values
Frequency and timing of entering in data	Patients were encouraged to enter blood glucose values in MyChart daily	Patients were encouraged to connect to wireless internet daily to enable the transfer of data into the EHR
Steps taken for providers to view PGHD	1. Patients are reminded to enter blood glucose data into MyChart prior to scheduled biweekly telephone encounters 2. Provider reviews patient blood glucose data in EHR (*if available*) 3. Provider recommends medication changes as needed based on blood glucose values, and nurse implements any changes	1. Provider reviews blood glucose values in patient's EHR prior to scheduled biweekly telephone encounters 2. Provider recommends medication changes as needed based on blood glucose values, and nurse implements any changes

EHR: electronic health record; PGHD: patient-generated health data.

MJC) to obtain provider perceptions regarding use of PGHD in the EHR. We used directed content analysis[19] to compare statements about MyChart with statements about Apple HealthKit. AAL and CD independently coded and analyzed these qualitative data and then reviewed all findings with a third investigator (MJC) until consensus was reached.

RESULTS

Research staff approached 86 patients; 35 declined to participate and 16 were excluded upon further screening (ie, no access to the Internet or smartphone). The remaining 35 patients who enrolled in the project were majority female and African American (Table 3).

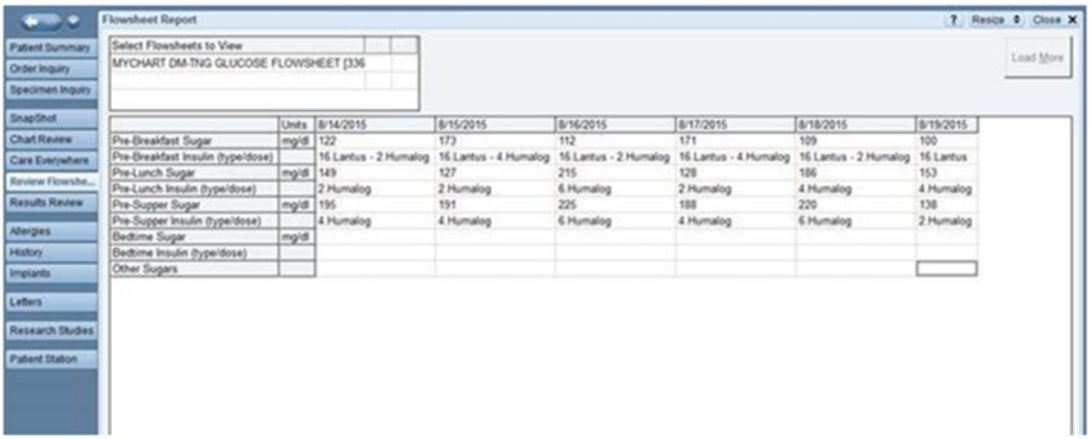

Figure 2. Flowsheet report for MyChart patients.

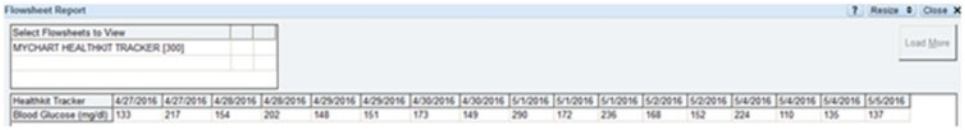

Figure 3. Flowsheet report for Apple HealthKit patients.

Table 2. Patient and provider semistructured interview questions

Patient-specific questions

Questions specific to MyChart:

- What challenges did you encounter with entering blood sugar numbers into MyChart?
- How, if at all, did entering your blood sugar values into MyChart affect your weekly routine?
- How often did you enter your blood sugar numbers into MyChart?
- How would you recommend improving the process of entering your blood sugar numbers into MyChart? Is there anything that would make it easier for you to transmit your home blood sugar readings to your care team?
- What did you think about using a computer to enter your blood sugar readings into MyChart? For you personally, what would be the best way for you to supply your blood sugar readings to your healthcare providers? (computer entry, mobile uploading, calling in readings, etc.)

Questions specific to Apple HealthKit[a]*:*

- What did you think about using the iPod (via the iHealth glucose meter and MyChart app) and wireless glucometer to have your blood sugar readings sent automatically to MyChart?
- What did you like about using the iPod/wireless glucometer instead of manually entering your readings into MyChart?
- Were there any disadvantages you found about using this method instead of what you normally do to take/record your readings?
- Did you experience any technical difficulties with either the iPod or the wireless glucometer while participating in the program?
- All things considered, what would be the preferred method for you to send your blood sugar readings to your provider in the future? Why?
- Is there anything else you would like to share about this portion of the program?

Provider questions

- What was your general impression of seeing the patient-generated health data in the EHR?
- How did having the patient-generated data in the EHR influence your medical management of, or interactions with, the patient?
- What challenges, if any, did you encounter when accessing the patient-generated health data in the EHR?
- What, if any, improvements would you suggest to seeing patient-generated health data in the EHR?
- What differences, if any, did you notice between MyChart and Apple HealthKit? (*Probe: This could be amount, type, frequency, accuracy of the patient-generated health data, or about the patients' use of these tools*)

[a]Questions only asked if patient used the Apple HealthKit technology in addition to MyChart.
EHR: electronic health record.

Research staff invited participants to complete semistructured interviews, and 10 patients agreed to participate. Of these 10, 6 used the MyChart platform and 4 used both MyChart and Apple HealthKit. The provider sample included the 2 endocrinologist medication managers for the telemedicine intervention.

Patient perspectives

Most patients (n = 7 of 10) stated that using MyChart or Apple HealthKit aided their diabetes self-management. One patient stated, "I love the charting. . .I loved looking at it daily or weekly, just seeing the trends," and another stated, "[entering blood sugar values

Table 3. Patient characteristics

	Total sample (N = 35)	Interview completers (n = 10)
Female	24 (68.6)	4 (40)
Race/ethnicity		
African American	27 (77.1)	9 (90)
White	7 (20)	1 (10)
No Answer	1 (2.9)	0 (0)
Technology platform used		
MyChart only	30 (86)	7 (70)
MyChart and Apple HealthKit	5 (14)	3 (30)
Calls completed		
<3	15 (43)	1 (10)
≥3	20 (57)	9 (90)

Values are n (%).

into MyChart] affected [me] because I knew what was going on. It helped me to remember [self-management]." However, as the patients using the MyChart platform had to manually enter data, remembering to enter in these data sometimes proved challenging. One MyChart user stated, "Just trying to remember to do it [was challenging]. . .by hand you could only enter one day at a time. It's not like it was an open spreadsheet where I could easily just put them all in without having to click 5 different times to get to another day." Patients who used Apple HealthKit found the automatic transfer of data from the glucose meter to the EHR less cumbersome. One patient stated, "[Apple HealthKit] made it easier – during the first phase [of the project] where I had to enter everything into the computer [using MyChart], it was done weekly, but [with Apple HealthKit] it was done daily and it made it easier for me." One MyChart patient who did not use Apple HealthKit commented that automatic uploading of data would have been helpful. "[I would like a] glucose monitor that actually, when you stick yourself, automatically sends that computer reading to MyChart, so [the blood glucose values] wouldn't actually have to be entered in [manually]."

Several patients experienced technological challenges using MyChart or Apple HealthKit, including logging into MyChart, manually entering data into MyChart, using the iPod, and the battery life of the iPod. Only 1 patient indicated that the technical challenges completely impeded her ability to upload blood glucose data using MyChart or Apple HealthKit.

Provider perspectives

The 2 project clinicians indicated that integration of PGHD into the EHR facilitated telemedicine-based medication management for diabetes, because data were readily available for review. The providers could easily access the EHR flowsheet without having to be familiar with multiple data-sharing platforms. One provider stated, "Compared to what I would have to do to get equivalent data otherwise, such as calling the patient and transcribing the numbers, or logging into a separate website, having these data come straight into the EHR saved multiple steps." Providers stated that automatic uploading of data with Apple HealthKit from the iHealth meter increased PGHD accuracy, because the blood sugar values were not self-reported, and were therefore less susceptible to error or falsification. However, while the PGHD entered via MyChart were systematically organized by mealtime, data entered via Apple HealthKit were displayed in a single long row. Because the MyChart display facilitated interpretation of blood glucose trends, both clinicians preferred the MyChart display over Apple HealthKit (Figure 3).

DISCUSSION

Telemedicine can facilitate improved population health management,[3,5] but depends on reliable and accurate PGHD. To address current gaps in EHR integration of patient-collected data, we examined 2 patient-facing platforms designed to facilitate the uploading of PGHD into the EHR. We found that (1) despite certain challenges, use of the platforms assisted diabetes self-management and (2) PGHD can be feasibly integrated into a health system's EHR.

Mobile health technologies that facilitate the collection of PGHD are one way to further population health management efforts for patients with complex chronic illnesses.[5] The capability to monitor health data between office visits, especially in challenging patient populations, could improve patient outcomes and reduce healthcare costs. PGHD help provide a more complete picture of the patient's self-management behaviors and allow clinicians to make patient-centered medical decisions.

While accurate PGHD are essential for informing clinical decision making, commonly available PGHD collection methods are often suboptimal. Approaches that rely on patient self-report—such as the MyChart platform used for this project or manual logging of blood glucose data in a hardcopy logbook—place substantial responsibility on patients to actively document data. Unless a patient takes the necessary steps to report their data (and in the case of hardcopy logbooks, remembers to bring data to clinic appointments), the PGHD remain unavailable to providers. Additionally, self-reported PGHD are subjective and may not accurately reflect the patient's true blood glucose values. Our findings suggest that using processes like the Apple HealthKit platform to integrate PGHD into the EHR, without relying on self-report, may have particular potential to improve patient and provider experiences.

Our findings also indicate that the presentation format for PGHD in the EHR is important to consider. Our 2 PGHD-collection platform flowsheets resulted in distinct data display formats in the EHR due to differences in the flowsheets' programming. Data from MyChart were organized in columns by mealtime, while data obtained via Apple HealthKit were presented in a single row. Our providers appreciated how each platform facilitated the availability of PGHD in the EHR, but strongly preferred the MyChart format. Overall, our results indicate that the optimal mechanism for incorporating PGHD into the EHR should include (1) passive/automatic transfer of data from the patient's monitoring device into the EHR, which assures data availability and accuracy, and (2) a user-friendly format for data presentation in the EHR, which facilitates interpreting and acting upon data. In diabetes, these changes would facilitate easy and accurate interpretation of blood glucose data in real time.

Limitations

Certain factors limit the generalizability of our findings. Because we interviewed only 10 patients and 2 providers, the reported perceptions of MyChart and Apple HealthKit may not represent the wider patient and provider populations. Additionally, due to the scope of the project, we could select only 5 patients to examine the feasibility of the Apple HealthKit platform. Finally, because the focus of this project was to explore the feasibility of EHR integration of PGHD, we did not verify the accuracy of these data transferred into the

EHR. Despite these limitations, our findings provide insight into the value and challenges of EHR integration of PGHD.

CONCLUSION

This project represents an important step toward implementing telemedicine-based care delivery models in clinical practice. Our findings indicate that EHR integration of PGHD is feasible, and may support telemedicine-based diabetes care. Future research should focus on strategies to enhance the usability of platforms for integrating PGHD into EHRs and appropriate support for providers utilizing PGHD in patient management.

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AUTHOR CONTRIBUTIONS

AAL analyzed qualitative data and wrote the manuscript. CD assisted with qualitative data analysis and manuscript editing. RJS, GLJ, and HBB assisted with data interpretation and manuscript editing. MO and SG assisted with conduct of project, collected data, and assisted with manuscript editing. NEJ served as a clinical provider during project and assisted with manuscript editing. MJC obtained project funding, led conduct of project, analyzed and interpreted data, and helped write manuscript.

CONFLICT OF INTEREST STATEMENT

HBB reports receiving research funds from Sanofi, Otsuka, Johnson and Johnson, and Improved Patient Outcomes as well as consulting funds from Sanofi, Otsuka, and Abbott. The remaining authors have no competing interests to declare.

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