Using Location-Based Smartphone Alerts within a System of Care Coordination

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1. STRUCTURED ABSTRACT

Purpose: To design and implement a health information technology-enabled system to improve care coordination following an inpatient admission or emergency department (ED) visit.
Scope: Primary care teams frequently do not know when their patients visit the hospital, precluding their ability to coordinate care in a timely fashion. These circumstances may disproportionately harm vulnerable populations, who are likely to: 1) frequently visit the ED, and; 2) have comorbid medical and social needs that put them at risk for poor outcomes. In this context, smartphones may be effective for facilitating information transfer and care coordination in vulnerable populations.
Methods: Working with a high-risk, low-income patient population, we developed a smartphone app that would: 1) use real-time smartphone location data to identify hospital encounters throughout a metropolitan area; 2) send push notifications (i.e. alerts) to users' phones, asking them to confirm hospital arrival/discharge; 3) send automated messages to primary care teams about confirmed hospital encounters.
Results: In a small beta test of an initial version of the app, the app demonstrated moderate sensitivity and high positive predictive value for identifying hospital encounters. Although the app's push notifications and care coordination workflows were acceptable to participants, we identified several barriers to implementation that were addressed in subsequent revisions to the app. In a feasibility study of the revised app, the FQHC received timely notification about nearly 80% of encounters, and completed timely follow-up for roughly 70% of encounters.

Key Words: Care coordination, primary care, safety-net providers, medical informatics, smartphone

2. PURPOSE

Aim 1: Develop a care coordination system in which a novel smartphone app facilitates information transfer and care coordination following inpatient admissions and ED visits
Aim 2: Conduct a feasibility study examining the system's preliminary impacts and implementation in a care management program for high-risk patients

3. SCOPE

Background: Despite widespread adoption of health information technology (HIT),[1,2] U.S. providers face persistent barriers to coordination of care across settings. Although use of electronic health records (EHRs) can improve care through advances in patient safety[3] and delivery of recommended care processes,[4] EHRs frequently fail to facilitate care coordination between health care settings due to factors such as a lack of interoperable information systems and insufficient inter-provider communication.[5,6]

In practice, these barriers to coordination can make it challenging for primary care providers to know when their patients have ED visits or inpatient stays.[7] Although regional health information exchange (HIE) can improve care coordination in ways that lead to increased information transfer and reductions in unnecessary health care use,[8,9] HIE is subject to financial barriers such as the costs of creating and sustaining HIE infrastructure,[10] as well as other barriers like the need for long-term partnerships between local competitors.[11] HIEs are only in use among a minority of American hospitals,[2] with particularly low use of data from providers in external organizations for patient care.[12] These barriers to care coordination generate unnecessary health care costs while limiting providers' ability to prevent adverse patient outcomes.[13-16]

The risks associated with poorly coordinated care are especially acute for traditionally underserved American populations. Uninsured patients and those with Medicaid coverage visit the ED at higher rates than privately insured patients,[17] and low-income populations have high prevalence of medical and behavioral comorbidities, housing instability, and financial stressors, putting them at high risk for suboptimal coordination and poor outcomes.[18] Sustainable methods for improving care coordination in these populations are urgently needed.

Context: Smartphones may be effective for facilitating information transfer and care coordination in vulnerable populations. Whereas EHR-based tools such as online patient portals are used less by racial/ethnic minorities[19] and require high health literacy for effective usage,[20] low-income patients report interest in smartphone-based tools that allow for more immediate access to, and communication with, health care providers.[21] In addition, smartphone location tracking has previously been used to identify hospital encounters for research data collection[22] and advertising[23] purposes.

Prior to the current project, our study team conducted qualitative research exploring the acceptability of a smartphone app for regional care coordination.[24] In focus groups, high-risk Medicaid enrollees expressed a willingness to have their location tracked by an app that sent real-time notifications about hospital encounters to their primary care team. Potential barriers to acceptability included inconveniences such as excessive numbers of prompts to confirm hospital encounters (e.g. “false alarms” when walking or driving by a hospital) and smartphone battery drainage. Consistent with national data on low-income consumers,[25] patient focus group participants reported substantially higher ownership of Android smartphones (versus iPhones). Both clinicians and care managers expressed interest in receiving notifications from the app when patients arrived at the hospital and at discharge.[24]

In this context, we developed and tested a smartphone app to improve care coordination for patients at a federally qualified health center (FQHC) who receive care from hospitals across a large urban region.

Setting: This study was conducted at Erie Family Health Centers (Erie), an FQHC that serves a largely low-income, racial/ethnic minority patient population. Erie operates seven adult clinics in and around the U.S. city of Chicago, Illinois, and serves over 60,000 patients annually, more than two thirds of whom are Hispanic. The organization has a care management program serving high-risk patients in a local Medicaid plan; patients can screen into the program through multiple criteria such as repeated ED visits, repeated inpatient admissions, or the prevalence of multiple social and clinical risk factors. Care managers conduct timely coordination of care transitions for ED visits and inpatient admissions, including a phone call to the patient before or immediately after hospital discharge and, when appropriate, scheduling an in-person visit at an Erie clinic within seven days of discharge. At the time of this study, approximately 450 patients were under active care management.

Despite the FQHC’s pursuit of multiple approaches to stay informed about health care received in other settings or organizations—e.g. an online portal documents real-time admission/discharge data at several hospitals for patients in one local Medicaid plan, but not for uninsured patients or those with other forms of insurance—Erie care teams cannot comprehensively identify their patients’ visits to local hospitals in real time.

Participants: Patients were eligible for inclusion if they were an adult (age ≥18) who received care management services at the FQHC where the study was conducted (program eligibility criteria restricted care management services to high-risk Medicaid enrollees), spoke English or

Spanish as their preferred language, owned an Android smartphone, and were willing to enable smartphone location tracking.

4. METHODS

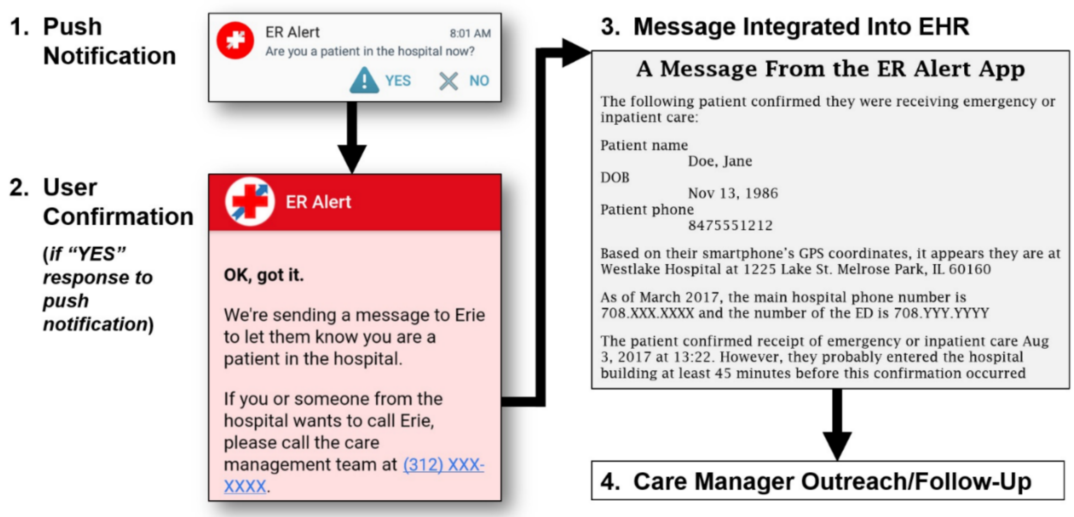
4.1: Aim 1: Intervention development and beta test

4.1.1: Study design: Single group observational study involving initial design of the *ER Alert* smartphone app and related care coordination workflows, results of an intervention beta test, and subsequent app modifications based on findings of a formative mixed methods evaluation.

4.1.2: Intervention: We worked to develop an app that would: 1) use real-time smartphone location data to identify hospital encounters throughout the Chicago metropolitan area; 2) send push notifications (i.e. alerts) to users' phones, asking them to confirm hospital arrival and discharge; 3) send automated messages to Erie care teams about confirmed hospital encounters.

In December 2016, we held the first of two retreats to design the app and related intervention protocols. The retreat was attended by Northwestern University researchers, leaders of Erie's care management program, and two Erie patients (both owned smartphones and received care management services). Attendees designed workflows for the period immediately following hospital arrival, presented below in Figure 1. Once a user confirmed receipt of hospital-based care, an automated, secure eFax was sent to Erie including: user name and date of birth (these data points are collected at app installation); hospital where receiving care, and; estimated arrival time. Indexing software at Erie then automatically integrated message contents into the EHR (based on user name and date of birth), which triggered an EHR-based alert to a care manager, who then conducted follow-up according to program protocols. Similar workflows occurred following hospital discharge.

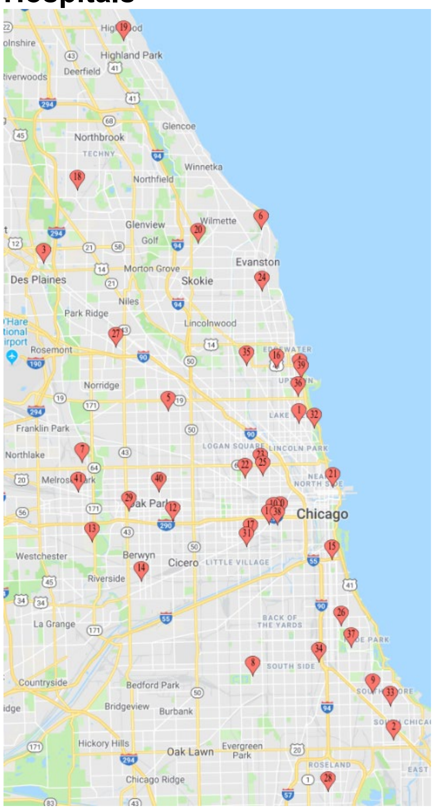
Figure 1: Beta test intervention workflows



Development of an English-language *ER Alert* app for Android phones began in January 2017. To track location, the app used geofencing methods—in which virtual geographic boundaries define the perimeter of real-world geographic areas—to identify 41 Chicago-area hospitals (Figure 2). The app collected time-stamped location data when users' phones entered or exited a defined geofence, based on latitude and longitude of the main building at each hospital campus. Following initial app development, our research team conducted internal alpha testing and solicited feedback from two Erie patient consultants on the app's design and notifications. Data collected by the app was available to study researchers on a secure, password-protected online dashboard.

Following the intervention beta test, a second design retreat was held in October 2017. At this second retreat, attendees reviewed beta test findings and collectively decided on modifications to improve the app's user interface, stability, and performance.

Figure 2: Geofence Locations Tracked by *ER Alert* App to Identify 41 Chicago-Area Hospitals



4.1.3: Measures & data collection: Quantitative measures examined the performance of the app's location detection algorithm, focusing on instances when push notifications should have fired in the app (i.e. when a smartphone was within an individual hospital geofence for 45 minutes or more). Dates of participant-reported ED visits and inpatient stays were validated against time-stamped location data from the online dashboard, retrospective chart review in Erie's EHR, and—if not confirmed by app data or chart review—discharge summary data from individual hospitals. Other participant-reported events, such as visits with hospitalized loved ones or outpatient visits, were validated against secure dashboard data.

We evaluated two quantitative outcomes: (1) sensitivity, i.e. the proportion of validated study events when notifications fired in the app, and; (2) positive predictive value (PPV), i.e. the proportion of times when notifications fired that were validated study events.

Our qualitative evaluation utilized data from participants' semi-structured interviews during beta test follow-up. Two study team members independently listened to each audio-recorded interview to identify barriers experienced by app users, key takeaways, and opportunities for improvement. Additional barriers to app implementation were identified by triangulating online dashboard data with participant-reported study events.

4.1.4: Limitations: Limitations include the beta test's small sample size and observational design. Also, it is unclear whether results observed here are generalizable to other patient populations or primary care settings. Going forward, it will be important to develop and test an *ER Alert* app for the iOS operating system, and to explore ways to consolidate this app with other patient-facing health IT such as EHR portal apps.

4.2: Aim 2: Feasibility study

4.2.1: Study design & intervention: Single-group feasibility study of the revised *ER Alert* app, which had been modified in accordance with Aim 1 findings (Table 1). After providing informed consent, participants downloaded an Android app they could use to notify their FQHC care team about hospital encounters throughout metropolitan Chicago. After a participant used the app to confirm a hospital encounter, an electronic fax was sent and indexed into the FQHC's EHR. Study follow-up lasted four months.

4.2.2: Measures & data collection: After relevant administrative data became available, we collected retrospective data from multiple sources in 2019. Hospital encounters during follow-up were identified using retrospective Medicaid plan claims. We abstracted FQHC EHR data on participants' demographic characteristics, chronic illnesses at baseline, and care team follow-up after hospital encounters.

To identify how care teams were notified about hospital encounters, we used EHR-based documentation of data from four information sources: 1) a cloud-based portal listing in-progress encounters and recent discharges for Medicaid plan enrollees at selected local hospitals[26]; 2) communication with hospital care teams or receipt of discharge documents; 3) electronic faxes from the smartphone app described above, or; 4) patient self-report to their FQHC care team. Our primary outcome was a binary measure of whether FQHC care teams conducted timely follow-up. We defined timely follow-up based on organizational protocols to either: 1) contact the patient within three business days of discharge, or; 2) have the patient complete an in-person visit within one week of inpatient discharge.

4.2.3: Limitations: Our results are not generalizable to other geographic regions, or integrated delivery systems, with the capability to comprehensively identify hospital encounters in real time. Nevertheless, observed rates of notification likely exceed those of some primary care practices, since the FQHC under study utilized multiple information sources to identify hospital encounters. Also, organizations that heavily rely on fee-for-service reimbursement are generally unable to sustain non-visit-based care,[27] potentially impeding their ability to conduct follow-up at the rates observed here.

5. RESULTS

5.1. Aim 1: Intervention development and beta test

5.1.1. Principal findings: There were 12 beta test participants who met all inclusion criteria and provided valid follow-up data. They all had Medicaid insurance, as dictated by inclusion criteria. Participants had a mean age of 38 years, and 75% were female. Eleven participants (92%)

were racial/ethnic minorities, and 10 (83%) had less than a four-year college degree. There were high rates of chronic illnesses such as diabetes (42%), asthma (50%), and hypertension (42%).

During follow-up, participants received care at many hospitals across metropolitan Chicago. Participants had 12 validated study events (i.e. instances when push notifications should have fired in the app, asking participants to confirm a hospital encounter) at a total of 9 hospitals across the region, including Chicago’s downtown, South Side, West Side, northern suburbs, and western suburbs. Five of 12 events were confirmed ED visits or inpatient stays, which occurred at 4 different hospitals. Seven of 12 validated study events involved other occasions such as visiting hospitalized loved ones (at 5 hospitals). Among the 9 participants with any study events, there was a median of 1 event per participant (range, 1-2 events per participant). In quantitative analysis, the app demonstrated moderate sensitivity and high positive predictive value for identifying hospital encounters. Push notifications fired for 9 of 12 events (75% sensitivity). Push notifications fired in the app 10 times; 9 of these instances were validated events (90% PPV).

In qualitative analysis, 10 of 12 participants completed the audio-recorded three-month phone interview. Although the app’s push notifications and subsequent care coordination workflows were acceptable to participants, we identified several barriers to implementation. Participants reported some confusion regarding how to respond to notifications about being “a patient in the hospital” when receiving care in the ED. Participants also reported slow loading of app pages, and some expressed concerns about limited phone storage that could motivate them to delete the app. It was sometimes challenging to pinpoint smartphones’ location inside hospital buildings, as limited cellular service decreased location tracking accuracy (via Global Positioning System [GPS] and Wi-Fi). Also, the app sometimes had difficulty distinguishing between hospitals in close proximity to one another (e.g. across the street).

Following the beta test, we held our second design retreat. Along with an Erie patient who had been a beta test participant, study team members from Northwestern and Erie reviewed initial quantitative and qualitative findings and jointly agreed on several app modifications (Table 1).

Table 1: Changes made to *ER Alert* app following beta test due to observed implementation barriers

Aspect of Intervention	Observed Barrier	Change Made to App Following Beta Test
User interface	During ED visits, some participants unsure how to respond to notifications asking about being a patient “in the hospital”	Refined notification text to ask about being “in the ER/hospital,” i.e. explicitly inquire about both ED visits and inpatient stays
User experience and app stability	App written in hybrid source code (for use across Android and iPhone mobile platforms) had slow page loading speed and background app processing/refresh functions	Native version of app, developed specifically for Android mobile platform, led to increased app loading/data processing speeds
User concerns	Participants expressed concerns about needing to delete apps to free up phone storage	Added FAQ page/tab to address common user concerns, specifying the relatively small app file size
Performance of location tracking algorithm	Limited cellular service inside hospitals can affect location data accuracy, causing app to erroneously identify departures from a hospital geofence	Defined separate small (inner) and large (outer) geofences for each hospital. After phone entered an inner geofence, firing of notifications was conditioned on length of stay inside outer geofence
	Adjacent/overlapping hospital geofences limit app’s ability to pinpoint individual hospital locations	Reduced geofence size and/or combined neighboring geofences of selected hospitals in close proximity to one another

5.1.2. Discussion & Conclusions: In this small developmental study, we used participatory design methods to design, implement, and evaluate the *ER Alert* app, with patients from a traditionally underserved population included as partners in nearly all aspects of intervention design. Over a three-month follow-up period, beta test participants obtained emergency or inpatient care at four different hospitals, and visited a total of nine regional hospitals for any reason. The app had moderate (75%) sensitivity and high (90%) positive predictive value for identifying when participants went to hospitals. Additionally, we identified several barriers to implementation related to factors such as the app’s user interface and performance. These findings then informed a subsequent round of intervention development.

Perhaps the most noteworthy aspect of this intervention was our approach to developing it for, and with, a low-income FQHC patient population. Before designing and implementing this intervention, we obtained critical data on its acceptability in the target patient population,[24] who we then engaged throughout the iterative design and testing phases. In addition, the smartphone app developed for use in this safety net setting represents an important innovation in how regional health care utilization data are collected and transferred. This app used widely available mobile technology to engage users and transfer information on patients’ hospital encounters to an FQHC, where it was ultimately integrated into the care team’s EHR.

In conclusion, we partnered with low-income patients in a U.S. safety net setting to develop and implement a smartphone app that uses location tracking to facilitate care coordination following hospital encounters. The app demonstrated moderate sensitivity and high positive predictive value for identifying when patients went to hospitals. Observed barriers to implementation related to factors such as the app’s user interface and performance.

5.2: Aim 2: Feasibility study

5.2.1. Principal findings: Sixty two participants consented, enrolled and completed study follow-up; however, five lost Medicaid plan coverage during follow-up and were excluded due to lack of available claims data. The final sample of 57 participants had a mean age of 45.0 years (SD 13.4), was largely female (73.7%), and predominantly racial/ethnic minorities (8.8% non-Hispanic Whites). Twenty four (42.1%) participants had a high school education or less, and 18 (31.6%) had limited health literacy. There were high rates of chronic illness, especially hypertension (40.4%), depression (40.4%), and diabetes (26.3%).

During follow-up, 17 (29.8%) participants had any claims-validated hospital encounters; three participants had multiple encounters (range, 2-5). In total, participants had 23 encounters at 12 hospitals. The FQHC received timely notification about 18 of 23 hospital encounters (78.3%). There was substantial heterogeneity in how care teams identified individual hospital encounters, with each of the four information sources identifying at least six, but no greater than 10, of 23 total hospital encounters (Table 1). Among the 18 encounters where the FQHC received timely notification, a mean of 1.6 information sources were used to identify each encounter (range, 1-3).

The primary outcome—timely follow-up—was achieved for 16 of 23 hospital encounters (69.6%) (Table 2). In the 16 instances when timely follow-up occurred, there were 14 hospital encounters where FQHC care teams received timely notification and deliberately completed follow-up; there were also two encounters where care teams did not receive timely notification, but follow-up was completed when recurring nurse calls inadvertently occurred soon after hospital discharge. In the seven instances where timely follow-up did not occur, there were four encounters where care teams received timely notification but did not complete follow-up, and three encounters where care teams did not receive timely notification.

Table 2: Information sources used to identify observed hospital encounters, stratified by completion of timely follow-up

Participant ID	Hospital encounter type	Information source			
Hospital encounters where FQHC care teams complete timely follow-up (n=16)					
		Online portal[a]	Hospital[b]	Smartphone app[c]	Patient self-report
1	Observation stay		✓	✓	✓
2	ED visit		✓	✓	✓
3	ED visit		✓		✓
4	ED visit		✓		
5	ED visit	✓			
6	ED visit	✓		✓	
7	ED visit	✓	✓		✓
8	ED visit		✓		✓
9	ED visit	✓		✓	
10	ED visit			✓	
11[d]	ED visit				
11	Inpatient admission	✓			
12[d]	ED visit				
13	ED visit	✓			
14	Inpatient admission			✓	
15	Inpatient admission		✓		✓
Hospital encounters where FQHC care teams did not complete timely follow-up (n=7)					
Participant ID	Hospital encounter type	Information source			
		Online portal[a]	Hospital[b]	Smartphone app[c]	Patient self-report
16	ED visit				
5	ED visit	✓		✓	
17	ED visit				
13	ED visit	✓			
13	ED visit	✓			
13	ED visit	✓			
13	ED visit				

[a] FQHC care teams had access to a cloud-based portal listing in-progress encounters and recent discharges at selected local hospitals. All study participants were enrolled in the local Medicaid plan that utilized this portal

[b] FQHC care team communicated with hospital care team or received relevant discharge documents

[c] Participants installed a smartphone app they could use to identify hospital encounters. For app-confirmed encounters, an electronic fax was sent and indexed into the FQHC electronic health record

[d] Care teams did not receive timely notification about these hospital encounters, but timely follow-up completed when recurring nurse calls inadvertently occurred soon after discharge

Abbreviations: FQHC, federally qualified health center; ED, emergency department

5.2.2. Discussion & Conclusions: Over one fourth of participants had any hospital encounters, with 23 total observed encounters at 12 different hospitals. Although FQHC care teams utilized multiple information sources, none of these information sources comprehensively identified hospital encounters across the fragmented Chicago-area health care market. The FQHC ultimately received timely notification about nearly 80% of encounters, and completed timely follow-up for roughly 70% of encounters.

Our results vividly demonstrate the challenges of care coordination in the presence of fragmented health care structures and information transfer processes. Ideally, care teams could access a single, comprehensive source of real-time data about patients' hospital encounters, without forcing high-risk patients—who are disproportionately likely to visit the hospital—to bear the burden of tracking their own data.[28] In practice, however, organizations often rely on a patchwork of fragmented data sources,[7,29] resulting in overlapping and incomplete information transfer processes.

In summary, high-risk Medicaid enrollees obtained care from many different regional hospitals. Despite utilizing multiple information sources, FQHC care teams did not receive timely notification about roughly one fifth of observed hospital encounters. Results demonstrate the extent to which even highly motivated organizations rely on fragmented, sometimes redundant information transfer processes that are insufficient for population-based care coordination.

6. LIST OF PUBLICATIONS AND PRODUCTS

<u>Manuscripts published or accepted for publication</u>

- Liss DT, Serrano E, Wakeman J, Nowicki C, Buchanan DR, Cesan A, Brown T. "The Doctor Needs to Know": Acceptability of Smartphone Location Tracking for Care Coordination. JMIR mHealth and uHealth: 2018 May 4; 6(5): e112. [PMID 29728349]
- Liss DT, Brown T, Wakeman J, Dunn S, Cesan A, Guzman A, Desai A, Buchanan D. Development of a Smartphone App for Regional Care Coordination Among High-Risk, Low-Income Patients. *Telemedicine and e-Health*: In press.

<u>Manuscripts in preparation</u>

- Guzman A, Brown T, Liss DT. Patient perspectives of an app for care coordination after hospital encounters.
- Liss DT, Guzman A, Dunn S, Desai A, Nightengale G, Brown T. Information Transfer and Primary Care Follow-Up After High-Risk Patients Visit the Hospital.

<u>Invited lectures</u>

- "A Smartphone App that Uses Location-Based Alerts to Coordinate Care." Panel on engaging community partners, NU-PATIENT K12 Faculty Scholars Training Program. Chicago, IL; October 3, 2017. Presenter: David T. Liss, PhD
- "Using Location-Based Smartphone Alerts Within a System of Care Coordination." AHRQ National Web Conference on the Role of Health IT to Improve Care Transitions. Webinar presentation; September 26, 2019. Presenter: David T. Liss, PhD

<u>Conference posters and presentations</u>

- "A Smartphone App that Uses Location-Based Alerts to Coordinate Care: Design, Development and Implementation." Plenary oral presentation, SGIM Midwest Regional Meeting. Chicago, IL; September 14, 2017. Lead presenter: David T. Liss, PhD
- "Development and Initial Implementation of a Smartphone App That Uses Location-Based Alerts to Coordinate Care." Poster presentation, Northwestern University Feinberg School of Medicine Annual Lewis Landsberg Research Day. Chicago, IL; April, 2018. Lead presenter: Adriana Guzman, BA

- “Development and Initial Implementation of a Smartphone App That Uses Location-Based Alerts to Coordinate Care.” Poster presentation, AcademyHealth Annual Research Meeting. Seattle, WA; June 25, 2018. Lead presenter: David T. Liss, PhD
- “A Smartphone App that Uses Location-Based Alerts to Promote Care Coordination: Development and Initial Results.” Podium presentation, SGIM Midwest Regional Meeting. Chicago, IL; September, 2018. Lead presenter: Adriana Guzman, BA
- “Information Transfer and Follow-Up by Primary Care Teams During Care Transitions for High-Risk Patients.” Poster presentation, National Association of Community Health Centers Community Health Institute & EXPO. Chicago, IL; August, 2019. Lead presenter: Adriana Guzman, BA
- “Patient perspectives of an app for care coordination after hospital encounters.” Podium presentation, SGIM Midwest Regional Meeting. Minneapolis, MN; September, 2019. Lead presenter: Adriana Guzman, BA

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