Smartphone-Based Remote Health Monitoring—Implications for Healthcare Delivery in Patients with Cirrhosis

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INTRODUCTION

Cirrhosis is a leading cause of morbidity, hospitalization, and readmissions in the United States, which drive healthcare costs and increase mortality.[1, 2] Healthcare delivery for these patients is often fragmented and inadequate.[3] As patients with cirrhosis may be hospitalized with complications that have premonitory warning signs, smartphone-based remote health monitoring may allow for earlier detection of physiological abnormalities to reduce hospitalizations and to improve long-term outcomes.[4–6] Our prospective study aims to investigate the prevalence of smartphone use among patients with decompensated cirrhosis and how they relate to clinical, demographic, and social characteristics.

METHODS

We conducted a prospective multicenter study of English-speaking patients with decompensated cirrhosis aged ≥ 18 years who received inpatient or ambulatory liver care at one of three urban academic centers (two are tertiary care and one has a liver transplant program). Screening was performed over a 16-month period that ended January 2019 by weekly review of all provider lists. Patients were eligible if they had hepatic encephalopathy actively being treated, refractory ascites requiring large volume paracenteses, spontaneous bacterial peritonitis, or history of variceal bleeding within the previous 3 months. Patients were excluded if they were actively using alcohol or drugs, not fluent in English, or on hospice. Eligible patients were contacted in-person or by telephone up to three times within 1 week prior to their scheduled clinic visit regarding smartphone usership, defined as using the full functionality of a smartphone. Patients were classified as Android, iPhone, or non-smartphone users. Data was collected on age, sex, race, marital status, long-term partner relationship,

education, employment, disability, cirrhosis etiology, hepatic encephalopathy actively being treated, liver transplant listing status, patient interest in smartphone-based remote health monitoring applications, distance from study centers, and estimated household income based on household zip code using data from the United States Census Bureau and the 2017 American Community Survey 5-year estimates. We performed analyses with chi-square, *t* test, and linear regression using SAS 9.4 (SAS Institute, Cary, NC). Institutional Review Board approval was obtained.

RESULTS

Three hundred forty-one patients were identified, of whom 281 (82.4%) participated. Two hundred one (71.5%) patients had a smartphone, defined as using the full functionality of a smartphone. Of the 80 patients categorized as smartphone non-users, 68 did not possess a smartphone. One hundred eleven patients had an iPhone and 90 had an Android. Reasons for lack of participation included patient unreachability (*n* = 42), death during recruitment period (*n* = 10), study refusal (*n* = 6), and liver transplantation during recruitment period (*n* = 2).

Patients with smartphones tended to be younger, married, employed, and reside in higher income zip codes (Table 1). On multivariate analysis correcting for sex, marital status, hepatic encephalopathy, liver transplant listing, not working, disability, and interest in smartphone-based remote health monitoring, only age ≥ 55 years (OR 8.79) and alcohol etiology of cirrhosis (OR 5.21) were independently associated with not having a smartphone. Characteristics of Android and iPhone users are described in Table 2.

Patient interest in smartphone-based remote health monitoring applications did not differ between smartphone users and non-users (Table 1). When all study patients were analyzed regardless of smartphone status, there was no statistically significant difference in hepatic encephalopathy, alcohol etiology of cirrhosis, or liver transplant listing.

There was a high prevalence of hepatic encephalopathy and alcohol etiology, but there were no statistically significant

Table 1 Sociodemographic Data of Decompensated Cirrhosis Patients by Smartphone Status

	Smartphone, N = 201	Non-smartphone, N = 80	P value
Mean age ± SD	57.7 ± 9.3	62.0 ± 8.3	0.0004
Male, %	62.2	56.3	0.417
Caucasian, %	89.1	91.3	0.826
Married, %	65.7	51.3	0.029
Long term partner relationship, %	69.2	57.5	0.069
High school diploma or higher, %	96.8 (n = 90/93)	81.8 (n = 27/33)	0.010
Not working, %	65.2	86.3	0.007
Disabled, %	30.1	46.3	0.067
Alcohol etiology, %	56.2	65.0	0.183
Hepatic encephalopathy, %	76.7	81.3	0.430
Liver transplant listed, %	33.8	27.5	0.653
Mean distance from center ± SD (miles)	57.1 ± 62.8	49.8 ± 69.2	0.395
Mean household income ± SD (USD)	100,599 ± 35,899	91,776 ± 27,564	0.028
Interested in remote health app, %	70.5	77.6	0.367

associations between these and being married, having a long-term partner relationship, being on disability, not working, or having at least a high school level of education.

DISCUSSION

Our study demonstrated that smartphone-based remote monitoring may be practical for patients with decompensated cirrhosis. We found a high prevalence of smartphone use—defined as using the full functionality of a smartphone—among English-speaking patients with decompensated cirrhosis who received hepatology care at our academic centers. Smartphone users tended to be younger, married, employed, residing in zip codes of higher incomes, and to have a non-alcoholic etiology of cirrhosis. The vast majority of patients, regardless of hepatic encephalopathy or smartphone usership, were interested in smartphone-based remote health monitoring applications. Hepatic encephalopathy was common among smartphone users and half of our patients did not have a spouse or long-term partner. These clinical and sociodemographic observations may help to inform future development of remote health applications that are targeted for patients with decompensated cirrhosis with the goal of improving liver-related outcomes.

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Table 2 Sociodemographic Data of Decompensated Cirrhosis Patients by Smartphone Type

	iPhone, N = 111	Android, N = 90	P value
Mean age ± SD	57.9 ± 9.9	57.4 ± 8.5	0.731
Male, %	55.9	70.0	0.042
Caucasian, %	90.9	87.8	0.642
Married, %	72.7	57.8	0.035
Long term partner relationship, %	76.4	61.1	0.022
High school diploma or higher, %	97.9 (n = 43/45)	95.6 (n = 47/48)	0.609
Not working, %	74.2	81.3	0.356
Disabled, %	23.4	40.0	0.055
Alcohol etiology, %	52.3	61.1	0.253
Hepatic encephalopathy, %	73.0	81.1	0.185
Liver transplant listed, %	34.2	33.3	0.951
Mean distance from center ± SD (miles)	47.2 ± 49.5	69.3 ± 74.6	0.017
Mean household income ± SD (USD)	108,448 ± 36,333	90,809 ± 33,007	0.0005
Interested in remote health app, %	72.6	68.7	0.603

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