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## Improving cirrhosis care: The potential for telemedicine and mobile health technologies

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### Abstract

Decompensated cirrhosis is a condition associated with significant morbidity and mortality. While there have been significant efforts to develop quality metrics that ensure high-value care of these patients, wide variations in clinical practice exist. In this opinion review, we discuss the quality gap in the care of patients with cirrhosis, including low levels of compliance with recommended cancer screening and other clinical outcome and patient-reported outcome measures. We posit that innovations in telemedicine and mobile health (mHealth) should play a key role in closing the quality gaps in liver disease management. We highlight interventions that have been performed to date in liver disease and heart failure—from successful teleconsultation interventions in the care of veterans with cirrhosis to the use of telemonitoring to reduce hospital readmissions and decrease mortality rates in heart failure. Telemedicine and mHealth can effectively address unmet needs in the care of patients with cirrhosis by increasing preventative care, expanding outreach to rural communities, and increasing high-value care. We aim to highlight the benefits of investing in innovative solutions in telemedicine and mHealth to improve care for patients with cirrhosis and create downstream cost savings.

**Key words:** Cirrhosis; Liver disease; Quality improvement; Telemedicine; Telemonitoring; Mobile health

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**Core tip:** Telehealth and mobile health technologies have been used in other disease states with great success to reduce morbidity, mortality and cost while employing

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innovative design. Providers caring for patients with cirrhosis have not widely adopted these technologies but could benefit greatly from doing so. More resources need to be devoted to using innovative telemedicine strategies to improve the care of patients with liver disease. In turn, policy change will be necessary to allow all centers to implement these solutions in a cost-effective manner.

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## INTRODUCTION

Patients with cirrhosis are at risk for a variety of complications including ascites, hepatic encephalopathy, esophageal or gastric varices, and hepatocellular carcinoma (HCC). The development of ascites, encephalopathy, or bleeding varices defines the transition from compensated to decompensated cirrhosis, a change that is associated with a marked decrease in survival, from 12 years to approximately 2 years after initial diagnosis<sup>[1]</sup>. A pressing need exists to develop strategies to prevent or slow the transition to decompensated cirrhosis, improve management of complications including HCC, and ensure patients are referred for liver transplantation when appropriate.

Recently, the Practice Metrics Committee of the American Association for the Study of Liver Disease (AASLD) developed quality measures in the care of patients with cirrhosis, identifying process and outcome measures for the management of ascites, gastric and esophageal varices, hepatic encephalopathy, HCC screening, and evaluation for liver transplantation<sup>[2]</sup>. The final 46 metrics were intended to drive quality improvement and allow providers to deliver high-value care to patients with cirrhosis. Based on this assessment, there is considerable room for physicians to improve on the metrics laid out by the AASLD.

Prior studies have also supported the need for improvement. While several published cost-effectiveness models have reported that performing screening for HCC is cost effective, the screening rate for HCC in the United States is under 20%, and substantial disparities exist in screening for those followed by primary care physicians compared to hepatology/gastroenterology subspecialists (16.9% *vs* 51.7%)<sup>[3-5]</sup>. This screening rate is likely lower in developing regions of the world, where many countries do not have national screening programs for the early detection of HCC and cost effectiveness has not been evaluated in these populations<sup>[6]</sup>. Retrospective studies in Veterans Health Administration cohorts show that less than one third of patients receive all recommended care in the management of cirrhosis-related ascites and even fewer receive all recommended care related to the screening and management of varices<sup>[7,8]</sup>. Readmission rates among patients with cirrhosis are approximately 30% at thirty days and 50% at ninety days from hospital discharge<sup>[9,10]</sup>.

There are many potential reasons for these shortcomings. The limited supply of hepatologists, particularly in rural and underserved locations in the United States and worldwide, can make it difficult for patients with cirrhosis to access specialized care. Patients with cirrhosis require multidisciplinary, coordinated care for titration of their medications, frequent laboratory monitoring and vaccinations, and scheduling screening endoscopies and imaging. Yet, the shortage of hepatologists and limited appointment availability of primary care providers and gastroenterologists leaves many patients and their families with much of the burden of managing their disease.

There are significant challenges to the implementation of successful and wide-reaching quality improvement initiatives for patients with cirrhosis. While much of the care of individuals with cirrhosis in the United States is done through the care of hepatologists at academic medical centers, there are fewer than 600 board certified hepatologists in the United States, roughly one for every 550000 persons<sup>[11]</sup>. Although certified hepatologists may be best suited to implement change, their scarcity means that the majority of the burden of medical care for patients without access to hepatologists likely falls on primary care providers and gastroenterologists. As noted above, outcomes may be improved for patients with cirrhosis who have access to care under the guidance of hepatologists or gastroenterologists. These challenges are similar in other countries with many more patients with liver disease than specialized

physicians available to provide such care. Innovative health care solutions will be critical to improve the care of patients with cirrhosis. Specifically, telemedicine (a broad term for medicine practiced at a distance) and mobile health (mHealth, the use of interactive and mobile devices such as mobile phones and tablets to improve health) could play a key role in closing the quality gap in the care of patients with liver disease by expanding the ability of hepatologists to provide care.

## TELEMEDICINE IN THE CARE OF CHRONIC DISEASES AND LIVER DISEASE

Telemedicine is defined by the World Health Organization as the delivery of health care services from a distance by the use of telecommunications and virtual technology to provide health care outside of traditional health-care facilities. Three promising types of telemedicine for patients with cirrhosis are teleconsultation, televisits and telemonitoring, each of which have been used in the care of patients with liver disease<sup>[12]</sup>.

Teleconsultation, in which a practitioner in one location presents a case to an expert in another location, has been used in some settings with encouraging results. One of the most well-known telemedicine interventions is through the Veterans Health Administration (VA) system, which implemented the Specialty Access Network-Extension for Community Healthcare Outcomes (SCAN-ECHO) model to provide specialty consultation to practitioners in underserved areas regarding new treatment options for hepatitis C in case-based formats<sup>[13]</sup>. Developed at the University of New Mexico, the ECHO model has been successfully implemented in other locations, including Argentina<sup>[14]</sup>. It has also been used in the VA system for managing patients with chronic liver disease, with promising results suggesting increased screening rates for liver cancer and varices and a lower mortality in those that received the intervention<sup>[15]</sup>. Teleconsultation has also proved useful in determining which patients may be candidates for liver transplantation and who should proceed to formal evaluation<sup>[16]</sup>.

Televisits, in which the patient has direct contact with a provider in another location, have been shown to be a feasible model in the treatment of hepatitis C (Table 1), although they have not been well described in caring for patients with liver disease in other settings. Face-to-face telemedicine encounters for the treatment of hepatitis C have been successfully implemented in rural populations in California and Canada, and for helping patients with opioid use disorder during their attendance at an opioid substitution program<sup>[17-19]</sup>.

A hybrid between a teleconsultation and televisit model is that of a provider to provider consultation, with the patient physically present with the less specialized provider. The consultant can advise the general gastroenterologist or primary care provider to elicit a particular history, to perform certain physical exam maneuvers, or advise on a treatment plan. The physician physically present with the patient is responsible for the visit. While these hybrid consultations may be beneficial, this model has potential for difficulties with payment models and provider reimbursement.

Through telemonitoring, patients are monitored remotely for signs and symptoms of disease progression as well as objective data that may inform management. This approach has been described using smart tablets in patients in the perioperative period after liver transplantation and as a modality to monitor weight, vital signs, and laboratory values for pediatric liver transplant patients<sup>[20,21]</sup> (Table 1). A smartphone-based Stroop test has been validated for the diagnosis of covert hepatic encephalopathy<sup>[22]</sup>. Similarly, a "Patient Buddy App" that monitors symptoms such as weight gain along with medication adherence and daily sodium intake has shown potential to prevent hospital readmissions secondary to hepatic encephalopathy<sup>[23]</sup>. Additionally, an innovative program utilizing a telehealth platform with 4-G tablets, wireless blood pressure monitors, pulse oximeters and scales demonstrated efficacy in remotely monitoring patients for signs and symptoms of decompensation including hepatic encephalopathy, fluid overload, bleeding, and infections. Preventable readmissions were reduced from 33.8% in the standard of care arm to 0% at 30 and 90 days in the intervention arm. This intervention showed the ability for telemonitoring to reduce 30-d and 90-d readmissions while promoting patient-centered care<sup>[24]</sup> (Table 1).

Studies performed in cirrhosis and liver transplant populations highlight the potentials of telemedicine and mHealth in liver disease, and yet, relative to other specialties and disease states, there is a paucity of literature implementing these innovative technologies with patients. Comparatively, the role of telemedicine in



**Table 1 Interventions targeting hepatitis C treatment, cirrhosis care and readmissions, and liver transplant recipients**

Study	Population	Modality	Findings
<b>Interventions targeting hepatitis C treatment</b>			
Arora <i>et al</i> <sup>[40]</sup> , 2011	Patients with hepatitis C in rural areas and prisons in New Mexico ( <i>n</i> = 261), compared to in-person visits at a University clinic ( <i>n</i> = 146)	Videoconferences at ECHO site between community physicians and specialists, compared to in person visits at a University clinic	Comparable rates of SVR were seen between ECHO model and those seen in person at the University HCV clinic (58.2% <i>vs</i> 57.5%, <i>P</i> = 0.89)
Marciano <i>et al</i> <sup>[14]</sup> , 2017	Providers treating hepatitis C in the Patagonia Region in South America ( <i>n</i> = 14)	Videoconferences at ECHO sites between community physicians and those at a University Hospital in Argentina	Survey data focused on skills and competence in hepatitis C before and after 6 months of participating in the project, ultimately showing significant improvement in provider confidence regarding their ability to stage fibrosis, determine appropriate candidates for treatment, and select appropriate HCV treatment
Rossaro <i>et al</i> <sup>[17]</sup> , 2008	Patients with hepatitis C in rural California ( <i>n</i> = 103)	Videoconference between patients and specialists	23% of patients were candidates for therapy, 15 patients were evaluated for liver transplant
Talal <i>et al</i> <sup>[19]</sup> , 2018	Patients with hepatitis C undergoing an opioid substitution therapy program ( <i>n</i> = 62)	Biweekly telemedicine sessions between the patient and a specialty provider during the treatment course	Of 45 treated patients, 42 (93.3%) achieved SVR
Cooper <i>et al</i> <sup>[18]</sup> , 2017	Patients with hepatitis C in Canada receiving care from the Ottawa Hospital Viral Hepatitis Outpatient Clinic, comparing telemedicine ( <i>n</i> = 157) and non-telemedicine ( <i>n</i> = 1130)	Videoconference between patients and specialists	Significantly fewer telemedicine patients initiated antiviral therapy compared to non-telemedicine patients (27.4% <i>vs</i> 53.8%, <i>P</i> < 0.001). Among those treated with DAA they noted similar SVR rates (94.7% <i>vs</i> 94.8%, <i>P</i> = 0.99)
<b>Interventions targeting cirrhosis care and readmissions</b>			
Su <i>et al</i> <sup>[15]</sup> , 2018	Patients with liver disease in the Veterans Health Administration (VA) system receiving ECHO visits ( <i>n</i> = 513) compared to all patients in the VHA with liver disease ( <i>n</i> = 62237)	Virtual Consultations (through the VA SCAN-ECHO Project) compared to usual care	Propensity-adjusted mortality rates showed improved survival in the SCAN-ECHO cohort (HR of 0.54, 95% CI 0.36-0.81)
Khungar <i>et al</i> <sup>[24]</sup> , 2017	Patients with cirrhosis received 4G tablets with wireless devices to monitor blood pressure, heart rate, weight, symptoms, and medication administration. Telehealth nurses in conjunction with primary hepatology team intervened to prevent readmissions. ( <i>n</i> = 19 intervention, 143 control)	Remote monitoring with telehealth based early intervention	The remote monitoring/ telehealth arm had 0% of readmissions due to potentially preventable causes (fluid overload or hepatic encephalopathy) due to early outpatient interventions whereas 31% of readmissions were due to these causes in the control arm
Konjeti <i>et al</i> <sup>[16]</sup> , 2019	Potential Liver Transplant Candidates in the VA system ( <i>n</i> = 19091 through SCAN-ECHO and 99 seen in-person)	Virtual Consultations (through the VA SCAN-ECHO Project) compared to in-person visits	The telehealth-based triage reduced futile transplant evaluations by approximately 60%
Ganapathy <i>et al</i> <sup>[23]</sup> , 2017	Cirrhotic patients with caregivers after hospital discharge ( <i>n</i> = 40)	Home monitoring using an iPad with the Patient Buddy App (monitoring medication adherence, sodium intake and weights, and cognition)	17 of 40 patients were readmitted within 30 d. 8 potential readmissions related to hepatic encephalopathy were prevented via early outpatient interventions
<b>Interventions targeting liver transplant recipients</b>			
Ertel <i>et al</i> <sup>[20]</sup> , 2016	Post Liver Transplantation Patients ( <i>n</i> = 20)	Telehealth home monitoring (vital sign tracking) and an educational video program	19 of the 20 patients responded to a survey, with 95% watching all videos and 100% finding them effective. 90-d readmission rate of 30% (42% lower than historical controls)
Song <i>et al</i> <sup>[21]</sup> , 2013	Pediatric Post Liver Transplant Patients, International ( <i>n</i> = 4)	Home monitoring and decision support using a tablet PC and a specially developed software	Four international patients/families transferred 38 records of blood tests, demonstrating that this software is technically feasible
Le <i>et al</i> <sup>[37]</sup> , 2018	Post Liver Transplant Patients	Televisits ( <i>n</i> = 21) versus in clinic visits ( <i>n</i> = 21)	Similar patient satisfaction. Less commute and waiting times in the televisit group

SCAN-ECHO: Specialty Access Network-Extension for Community Healthcare Outcomes; CI: Confidence interval; HR: Hazard ratio; HCV: Hepatitis C virus; VA: Veterans Health Administration.



monitoring and facilitating treatment of patients with heart failure has been widely studied. Similar to patients with cirrhosis, patients with heart failure frequently require emergency hospitalizations and can have prolonged hospital admissions and frequent readmissions. Many of these hospitalizations could be avoided if patients received more education and had access to remote interactions with their medical teams, thereby empowering them to participate in the management of their own disease including modifications to their sodium intake or titration of medications.

The heart failure literature is robust with randomized control trials, systematic reviews, and meta-analyses showing associations with reductions in mortality and hospitalizations for heart failure<sup>[25]</sup>. In addition, telemedicine in congestive heart failure can be economically beneficial; studies show savings that ranged from \$5000 to over \$50000 per year per patient<sup>[26]</sup>. Examples of innovative technologies that facilitate remote monitoring and treatment of patients with heart failure include telemonitoring devices that track hemodynamics, video-based nursing visits after hospital discharge, and a mobile application to set physical activity goals and provide feedback to individuals undergoing cardiac rehabilitation<sup>[27-29]</sup>.

By contrast, the use of telemedicine in liver disease is limited to a handful of individual interventions and limited publications. Overall, the medical field has been slow in adapting telemedicine to interact with patients. According to data from the American Medical Association's 2016 Patient Practice Benchmark Survey, only 15.4% of physicians use telemedicine to interact with patients. Of all specialties, gastroenterologists were lowest-only 7.9% use telemedicine to interact with patients<sup>[30]</sup>.

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## THE POTENTIAL UNMET NEEDS

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Effectively managing cirrhosis requires titrating medications, closely monitoring symptoms including changes in weight and cognitive abilities (as a surrogate for hepatic encephalopathy), and establishing regular reminders to schedule imaging, labs, and procedures. As such, cirrhosis is a medical condition ripe for telemedicine and mHealth interventions, with a myriad of potential targets for improvement.

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## IMPROVING SCREENING AND PREVENTATIVE CARE

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Some of the most innovative uses of telemedicine and mHealth have been in dermatology and skin cancer screening, including use of smartphone applications for skin monitoring and melanoma detection<sup>[31]</sup>. Text message interventions have shown increases in screening rates for other cancers, including breast, cervical, and colorectal cancers<sup>[32]</sup>. Likewise, newly-developed smartphone applications aim to improve patient and provider education regarding screening for cancers, including colorectal and prostate cancer<sup>[33,34]</sup>. For the care of patients with liver disease, the implementation of the SCAN-ECHO program for chronic liver disease by the Ann Arbor Veterans Affairs Healthcare System found marked improvement in the frequency of HCC screening (42% *vs* 25%) and variceal surveillance (25% *vs* 15%) in patients whose providers consulted virtually with a liver specialist, compared to those who had no consultation at all<sup>[15]</sup>. Relatively simple, low cost interventions like text messaging, smartphone applications and teleconsultations could improve the rates of HCC screening and variceal screening-two interventions that have been shown to be cost-effective in the care of patients with advanced liver disease-and ultimately improve outcomes for patients<sup>[4,5,35]</sup>.

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## IMPROVING ACCESS TO SPECIALTY CARE IN DISADVANTAGED POPULATIONS

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Certain populations have difficulties engaging with specialized care for liver disease, including those who suffer from substance abuse and those living in rural locations. In a retrospective cohort study of over 16000 persons with chronic liver disease, those who live more than 150 miles from a liver transplant center were shown to have a higher mortality and transplant-free mortality, highlighting significant geographic disparities that could be addressed by telemedicine<sup>[36]</sup>. Prior studies examining the use of teleconsultation in the treatment of hepatitis C and patients with opioid use disorder on methadone show the efficacy of these interventions in reaching groups that lack access or do not seek out medical care<sup>[19]</sup>. Strategies such as video conferencing with patients, primary care providers, and general gastroenterologists

could play a significant role in increasing the reach of liver specialists to improve outcomes in patients with cirrhosis.

## PROVIDING VALUE BASED HEALTHCARE

Approximately 30% of patients with cirrhosis are readmitted within 30 d of discharge, posing a significant cost burden to the United States healthcare system<sup>[9]</sup>. Given the promising cost-savings shown from using telemedicine among persons with heart failure, similar models should target patients with cirrhosis to reduce costs in the healthcare system, allow monitoring of patients in between visits, and facilitate communication for patients and providers between hospital discharge and clinic follow up. In one study in the care of patients after liver transplantation, general patient satisfaction of those who had telemedicine visits via video connection was similar to that of patients who had in-person visits. Moreover, telemedicine patients reported significantly less commute and waiting times compared to patients seen in-person<sup>[37]</sup>. Above all, the improved survival rates, as seen in the VA system with virtual consultations, indicate strong potential benefits to investing in telemedicine.

## MONITORING INDIVIDUALS IN THEIR NATURAL ENVIRONMENTS

Patients suffering from chronic disease spend only a few hours with providers each year. This means that much of the burden of their disease management falls on the individual patients and their families during the remaining 5000 waking hours each year-including decisions on taking medications, following dietary restrictions, and making other choices that can significantly affect their health<sup>[38]</sup>. When patients with cirrhosis are seen in clinic, they often feel the need to hold their lactulose or diuretics to facilitate travel without frequent bathroom breaks. This disruption in medication dosing can lead to mild encephalopathy during their clinical assessment, and they may not be aware of everything conveyed to them during a visit. The use of televisits and telemonitoring strategies can give providers the opportunity to obtain assessments of patients in their home environment and gather more useful information than what they would otherwise obtain in a clinic visit.

## BARRIERS TO OVERCOME

While telemedicine is a promising field, there are several barriers that will need to be overcome before its use can become widespread. Reimbursement remains an ongoing challenge, as payment varies for private payers and according to state laws, and Medicare currently reimburses for video consultation only for individuals in designated Health Professional Shortage Areas<sup>[12]</sup>. In addition, concerns regarding the quality of healthcare have been raised in telehealth, particularly with the limitations of the remote physical exam, the difficulty in establishing patient-physician trust remotely, and the fragmentation of care among multiple providers<sup>[39]</sup>. Consideration will also need to be given to ensuring adherence to state and national regulations and to establishing the appropriate infrastructure for patients with limited access or ability to use telecommunication technologies.

Additionally, the majority of interventions described to date are single arm interventions without control groups, making it difficult to estimate the true benefit of any intervention or to have a clear understanding of cost effectiveness. To understand downstream cost savings of such interventions, considerations will need to be given to defining clinical outcomes, clearly stating costs, and carefully defining control groups to better assess the potential benefits of an intervention.

## CONCLUSION

The available literature suggests we are falling short of meeting a variety of quality metrics in the care of patients with cirrhosis-including preventative strategies such as cancer screening and treatment strategies such as the management of variceal bleeding and ascites. Interventions using telemedicine and mHealth provide logical solutions to improve screening rates, to reach disadvantaged rural populations, and to provide value-based care. Telemedicine may prove to be the guiding force in the

coordination of care between episodes for patients with cirrhosis. There is a need for more resources to evaluate telemedicine interventions and to develop infrastructure to care for patients with cirrhosis. If executed effectively, telemedicine and mHealth technologies can provide cost savings and improve outcomes for patients with cirrhosis.

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