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ORIGINAL RESEARCH

Assessing Adherence to US LI-RADS Follow-up Recommendations in Vulnerable Patients Undergoing Hepatocellular Carcinoma Surveillance

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Conflicts of interest are listed at the end of this article.

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Purpose: To assess adherence to the US Liver Imaging Reporting and Data System (LI-RADS) recommendations for hepatocellular carcinoma (HCC) surveillance and associated patient-level factors in a vulnerable, diverse patient sample.

Materials and Methods: The radiology report database was queried retrospectively for patients who underwent US LI-RADS–based surveillance examinations at a single institution between June 1, 2020, and February 28, 2021. Initial US and follow-up liver imaging were included. Sociodemographic and clinical data were captured from electronic medical records. Adherence to radiologist recommendation was defined as imaging (US, CT, or MRI) follow-up in 5–7 months for US-1, imaging follow-up in 3–6 months for US-2, and CT or MRI follow-up in 2 months for US-3. Descriptive analysis and multivariable modeling that adjusted for age, sex, race, and time since COVID-19 pandemic onset were performed.

Results: Among 936 patients, the mean age was 59.1 years; 531 patients (56.7%) were male and 544 (58.1%) were Asian or Pacific Islander, 91 (9.7%) were Black, 129 (13.8%) were Hispanic, 147 (15.7%) were White, and 25 (2.7%) self-reported as other race. The overall adherence rate was 38.8% (95% CI: 35.7, 41.9). The most common liver disease etiology was hepatitis B (60.6% [657 of 936 patients]); 19.7% of patients (183 of 936) had current or past substance use disorder, and 44.8% (416 of 936) smoked. At adjusted multivariable analysis, older age (odds ratio [OR], 1.20; $P = .02$), male sex (OR, 1.62; $P = .003$), hepatology clinic attendance (OR, 3.81; $P < .001$), and recent prior US examination (OR, 2.44; $P < .001$) were associated with full adherence, while current smoking (OR, 0.39; $P < .001$) was negatively associated.

Conclusion: Adherence to HCC imaging surveillance was suboptimal, despite US LI-RADS implementation.

Supplemental material is available for this article.

Hepatocellular carcinoma (HCC) incidence and mortality continue to disproportionately affect vulnerable populations (1). Age-adjusted HCC incidence rates are higher among all minority groups, particularly in Hispanic individuals compared with non-Hispanic White populations (2). Yet, non-White populations are less likely to receive hepatology specialty care before HCC diagnosis (3). Black and Hispanic patients are more likely to be diagnosed with advanced HCC and less likely to receive curative treatment (3). Individuals with the highest poverty levels have the lowest relative survival rates at 6, 12, and 24 months, and patients at safety-net hospitals with lower education status and income status are less likely to receive curative treatment (4,5).

US is a cost-effective surveillance method for early HCC detection, leading to curative treatment and improved survival (6,7). However, only 30%–40% of eligible patients undergo HCC US surveillance per American Association for the Study of Liver Diseases guidelines (8). HCC surveillance is particularly suboptimal in socioeconomically disadvantaged groups (9,10) and those with active alcohol use disorder (11). Moreover, patients belonging to ethnic and racial minority groups, such as Hispanic and Black patients, have been reported to have lower rates of HCC surveillance in most (9,10,12,13), but not all (14), studies. These disparities underscore the need for progress toward a more equitable and standardized system for HCC surveillance.

Factors at patient, provider, and system levels affect surveillance in clinical practice (15,16). Patients who are involved in their own care and those with viral hepatitis and cirrhosis are more likely to complete surveillance (17). Access to hepatology specialty care facilitates higher surveillance rates (17). Data show that providers are more likely to consider CT or MRI for patients with higher risk of developing HCC (18). Moreover, provider belief in the

Abbreviations

HBV = hepatitis B virus, HCC = hepatocellular carcinoma, LI-RADS = Liver Imaging Reporting and Data System, OR = odds ratio

Summary

Adherence to US Liver Imaging and Reporting Data System follow-up recommendations was suboptimal and significantly associated with age, sex, smoking status, and access to hepatology specialty care in diverse and vulnerable patients undergoing imaging surveillance for hepatocellular carcinoma.

Key Points

- Overall adherence to US Liver Imaging and Reporting Data System (LI-RADS) recommendations for imaging surveillance of hepatocellular carcinoma (HCC) in vulnerable and diverse patients at risk for developing HCC was low at 38.8%.
- Hepatology clinic attendance (odds ratio [OR], 3.81; $P < .001$), having undergone a recent prior US examination (OR, 2.44; $P < .001$), male sex (OR, 1.62; $P = .003$), and older age (OR, 1.20; $P = .02$) were associated with full adherence to US LI-RADS next-step recommendations.
- Current or prior smoking was associated with suboptimal adherence (OR, 0.39; $P < .001$).

Keywords

Liver, Ultrasound, Screening, Abdomen/GI, Cirrhosis, Metabolic Disorders, Socioeconomic Issues

effectiveness of surveillance and guidelines is a critical driver for increased surveillance (19,20). Recent implementation of the 21st Century Cures Act, enabling patients' access to radiology reports with specific next-step recommendations, may also further affect HCC surveillance effectiveness (21).

In 2017, the American College of Radiology US Liver Imaging Reporting and Data System (LI-RADS) was introduced, standardizing US image reporting and interpretation, technique, and follow-up recommendations for patients undergoing HCC surveillance (22). Use of US LI-RADS–based US reports, in the era of transparent health information (23), may improve HCC surveillance rates and outcomes in vulnerable populations by clear, consistent reporting of imaging findings and next-step recommendations.

In this study, we sought to assess rates of adherence to US LI-RADS recommendations for HCC surveillance and associated patient-level factors in a diverse, vulnerable patient sample in an urban safety-net health care system to identify potential disparities in HCC surveillance rates after implementation of US LI-RADS.

Materials and Methods

This retrospective, Health Insurance Portability and Accountability Act–compliant study was approved by the institutional review board, and the need for written informed consent from patients was waived.

Study Setting and Patients

This was a single-center retrospective cohort study of adult patients at risk for developing HCC who underwent HCC surveillance US examination at least once at a safety-net hospital between June 1, 2020, and February 28, 2021, and patients were followed up until February 28, 2022. One patient who had no US category assigned at initial examination and underwent a follow-up CT examination in 58 days was excluded (Figure). The institution serves a diverse vulnerable population; 76% of patients do not identify as White, and greater than 90% of patients have public insurance (24).

US LI-RADS was implemented on June 1, 2020, after multidisciplinary (hepatology and radiology) agreements on radiology report wording and next-step recommendations (Appendix S1). Each HCC surveillance examination prompted the radiologist to assign a US category and visualization score in accordance with US LI-RADS (Table 1) (22).

US Technique

HCC surveillance US examinations were performed according to institution protocols and following American Institute of Ultrasound in Medicine practice parameters and US LI-RADS recommendations (22,25). The study institution had approximately 20 US technologists, who have scanned at least 25 abdominal US images under supervision of a more experienced sonographer before performing independent scanning. All US examinations were checked by a subspecialty-trained (abdominal imaging or US) radiologist at the time of examination.

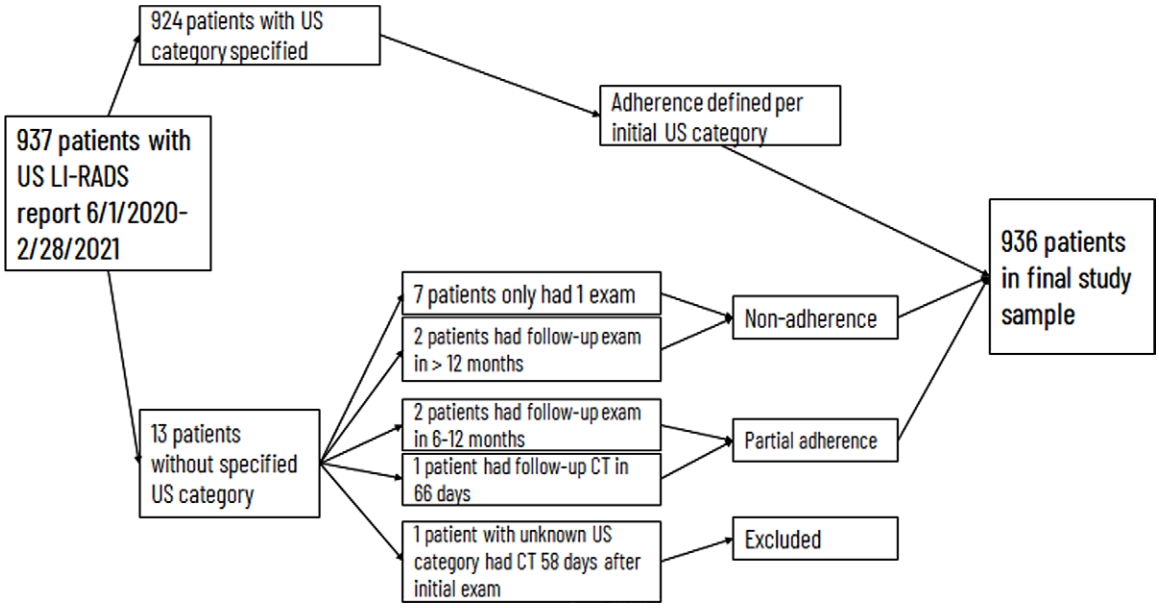
Data Collection

The institution's radiology database was queried for initial US and any subsequent follow-up HCC surveillance abdominal imaging, including US, multiphase abdominal CT, or abdominal MRI examinations until the end of study period (February 28, 2022) in the same study cohort. The examination date, US category (US-1 = negative, US-2 = subthreshold, US-3 = positive), visualization score (VIS-A = no or minimal limitations, VIS-B = moderate limitations, VIS-C = severe limitations), and reason for limited visualization were recorded for each US examination. For CT and MRI, the examination date and presence of LI-RADS 4 or 5 observations (probable HCC and definite HCC, respectively) were recorded.

Detailed patient demographic, clinical, and liver-related data were captured through electronic medical records. Race and ethnicity by self-report was categorized as Asian or Pacific Islander, Black, Hispanic, non-Hispanic White, and other. Social history (alcohol use disorder, illicit drug use, smoking, housing status) was obtained through the social history section of the electronic medical record and/or clinical notes. Etiology of liver disease (eg, hepatitis C virus, hepatitis B virus [HBV], metabolic- or alcohol-related fatty liver disease), number of comorbidities, relevant medical conditions (hypertension, hyperlipidemia, diabetes, HIV), and primary care and hepatology specialist visit attendance were captured through a combination of clinical notes and *International Statistical Classification of Diseases, Tenth Revision* codes.

Definition of Adherence to US LI-RADS Recommendations

Adherence for the first follow-up imaging examination, based on the initial US examination, was evaluated. Adherence was



Patient inclusion flow diagram. LI-RADS = Liver Imaging Reporting and Data System.

defined based on US LI-RADS and categorized as follows: *(a)* full adherence was follow-up imaging (US, CT, or MRI) in 5–7 months after a US-1 initial examination, follow-up imaging (US, CT, or MRI) in 3–6 months after a US-2 initial examination, or CT or MRI within 2 months after a US-3 examination; *(b)* partial adherence was follow-up imaging 6–12 months from a US-1 or US-2 initial examination, US follow-up after a US-3 initial examination, or follow-up imaging 3–12 months after a US-3 examination; and *(c)* nonadherence was no follow-up imaging or a follow-up examination more than 12 months from the initial examination.

Statistical Analysis

Summary statistics of demographic and baseline clinical characteristics were reported according to adherence status (non-, partial, or full) and compared using analysis of variance and χ^2 tests, as appropriate. Multivariable repeated measures logistic regression was performed to investigate factors associated with full versus suboptimal (non- or partial) adherence to US LI-RADS recommendations for each follow-up visit after initial US examination. All repeated measures logistic regression models performed were generalized estimating equation models with binomial distribution and logit link function, where an exchangeable working correlation matrix was used. Factors with $P < .10$ at univariable analysis, along with prespecified potential confounders, including age, sex, race, and time since COVID-19 pandemic onset, were included in the multivariable regression model. All potential variables considered for the model were guided by clinical knowledge, and the final model was also reviewed by domain experts who agreed that the variables included were aligned with their clinical experience. As there were minimal missing data (<1%) for each characteristic considered in the analyses, complete case analysis was used. Hypothesis tests were two-sided, and the significance threshold was set to .05. Statistical analysis was performed using SAS version 9.4 (SAS Institute).

Results

Patient Characteristics and Adherence to US LI-RADS Recommendations

The final study sample included 936 patients (Figure). Table 2 shows patient characteristics overall and categorized by adherence level. Overall, the mean age was 59.1 years ± 10.4; 531 of 936 patients (56.7%) were male, and 405 (43.3%) were female (Table 2). The majority of patients were Asian or Pacific Islander (58.1%). The etiology of liver disease was predominantly HBV (60.6%), followed by fatty liver disease (metabolic- or alcohol-related, 32.2%) and hepatitis C virus (21.0%). Approximately one-third of patients had known cirrhosis. More than half had received hepatology subspecialty care. The majority (83.8%) of patients had two or more medical comorbidities, 19.7% had a history of or current illicit drug use, 44.8% had a history of smoking or current smoking status, and 8.0% were experiencing homelessness.

Twelve patients did not have US categories or visualization scores on the original radiology report but were categorized as nonadherent or partially adherent according to our definitions and included in the study cohort (Figure). The remaining 924 initial US examinations were categorized as follows: 877 (94.9%) as US-1, 22 (2.4%) as US-2, and 25 (2.7%) as US-3; 769 (83.2%) as VIS-A, 128 (13.9%) as VIS-B, and 27 (2.9%) as VIS-C. Of the 25 patients who had US-3 examinations, 11 underwent recommended follow-up with CT or MRI within 2 months, of whom three were subsequently diagnosed with HCC. Four patients underwent imaging 2–12 months after the initial examination (mean, 198 days; range, 64–358 days). Ten patients were nonadherent: one patient

Table 1: US LI-RADS Category and Visualization Score

US Category or Visualization Score	Description	Follow-up Recommendation
US category		
US-1 (negative)	No focal observations, or observations that are definitely benign	Continue routine surveillance US in 6 months
US-2 (subthreshold)	Focal observation <1 cm that is not definitely benign	Short-interval (3–6 months) US follow-up
US-3 (positive)	Focal observation at least 1 cm in diameter that is not definitely benign, new thrombus in vein, or a geographic area of parenchymal distortion or heterogeneity	Further evaluation with multiphase liver imaging, such as contrast-enhanced CT, MRI, or contrast-enhanced US
Visualization score		
VIS-A	No or minimal limitations in visualizing the liver; unlikely to affect examination sensitivity	…
VIS-B	Moderately limited examination; small (<1 cm) observations may not be detected	…
VIS-C	Severely limited examination; significantly lowers examination sensitivity	…

Note.—LI-RADS = Liver Imaging Reporting and Data System.

Table 2: Patient Characteristics by Adherence Category

Patient Characteristic	Total Patients (n = 936)	Full Adherence (n = 363)*	Partial Adherence (n = 233)†	Nonadherence (n = 340)‡	P Value
Age (y)§	59.1 (10.4)	60.1 (9.1)	60.2 (10.2)	57.1 (11.5)	<.001
Sex					.06
Male	531 (56.7)	191 (52.6)	131 (56.2)	209 (61.5)	
Female	405 (43.3)	172 (47.4)	102 (43.8)	131 (38.5)	
Self-reported race or ethnicity					<.001
Asian or Pacific Islander	544 (58.1)	261 (71.9)	143 (61.4)	140 (41.2)	
Black	91 (9.7)	19 (5.2)	19 (8.2)	53 (15.6)	
Hispanic	129 (13.8)	37 (10.2)	38 (16.3)	54 (15.9)	
White	147 (15.7)	39 (10.7)	28 (12.0)	80 (23.5)	
Other	25 (2.7)	7 (1.9)	5 (2.1)	13 (3.8)	
Patients experiencing homelessness					<.001
Yes	74 (8.0)	13 (3.6)	16 (6.9)	45 (13.4)	
No	854 (92.0)	349 (96.4)	215 (93.1)	290 (86.6)	
Missing	8 (0.9)	1 (0.2)	2 (0.9)	5 (1.5)	
Body mass index§‖	26.2 (5.3)	25.6 (4.7)	26.8 (5.7)	26.5 (5.6)	.02
Missing	42	11	10	21	
Smoking status					<.001
Current	189 (20.4)	47 (13.0)	38 (16.5)	104 (31.0)	
Former	227 (24.5)	74 (20.4)	69 (29.9)	84 (25.1)	
Never	512 (55.2)	241 (66.6)	124 (53.7)	147 (43.9)	
Missing	8 (0.9)	1 (0.3)	2 (0.9)	5 (1.5)	
Substance use disorder					<.001
Current	68 (7.3)	11 (3.0)	11 (4.8)	46 (13.7)	
Past	115 (12.4)	25 (6.9)	30 (13.0)	60 (17.9)	
Never	745 (80.3)	326 (90.1)	190 (82.3)	229 (68.4)	
Missing	8 ([0.9)	1 (0.3)	2 (0.9)	5 (1.5)	

(Table 2 continues)

Table 2 (*continued*): Patient Characteristics by Adherence Category

Patient Characteristic	Total Patients (n = 936)	Full Adherence (n = 363)*	Partial Adherence (n = 233)†	Nonadherence (n = 340)‡	P Value
Alcohol use disorder					<.001
Current	89 (9.6)	17 (4.7)	17 (7.4)	55 (16.4)	
Past	152 (16.4)	39 (10.8)	39 (16.9)	74 (22.1)	
Never	687 (74.0)	306 (84.5)	175 (75.8)	206 (61.5)	
Missing	8 (0.9)	1 (0.3)	2 (0.9)	5 (1.5)	
Attends hepatology clinic					<.001
Yes	542 (58.2)	283 (78.0)	132 (56.9)	127 (37.7)	
No	390 (41.8)	80 (22.0)	100 (43.1)	210 (62.3)	
Missing	4 (0.4)	0	1 (0.4)	3 (0.9)	
Primary care location					.41
Within institution	324 (34.6)	117 (32.2)	85 (36.5)	122 (35.9)	
Outside institution	566 (60.5)	227 (62.5)	141 (60.5)	198 (58.2)	
No primary care	46 (4.9)	19 (5.2)	7 (3.0)	20 (5.9)	
No. of comorbidities					.03
≤2	150 (16.2)	72 (19.9)	28 (12.1)	50 (14.9)	
>2	778 (83.8)	290 (80.1)	203 (87.9)	285 (85.1)	
Missing	8 (0.9)	1 (0.3)	2 (0.2)	5 (1.5)	
Etiology of liver disease#					
HBV	567 (60.6)	271 (74.7)	139 (59.7)	157 (46.2)	<.001
HCV	197 (21.0)	49 (13.5)	43 (18.5)	105 (30.9)	<.001
Alcohol-related liver disease	122 (13.0)	33 (9.1)	30 (12.9)	59 (17.4)	.005
Metabolic-associated liver disease	180 (19.2)	86 (23.7)	49 (21.0)	45 (13.2)	.002
Other**	11 (1.2)	3 (0.8)	3 (1.3)	5 (1.5)	.72
Cirrhosis					.19
Yes	306 (32.7)	108 (29.8)	86 (36.9)	112 (32.9)	
No	630 (67.3)	255 (70.2)	147 (63.1)	228 (67.1)	
Underwent US in past 1 year					<.001
Yes	554 (59.2)	279 (76.9)	148 (63.5)	127 (37.4)	
No	382 (40.8)	84 (23.1)	85 (36.5)	213 (62.6)	
No. of days from COVID-19 pandemic onset to first US examination§	211.7 (74.1)	207.5 (71.9)	205.1 (74.8)	220.7 (75.3)	.02

Note.—Unless otherwise noted, data are reported as numbers of patients, with percentages in parentheses. HBV = hepatitis B virus, HCV = hepatitis C virus.
* Full adherence: follow-up in 6 months ± 1 with US, CT or MRI for US-1; 3- to 6-month follow-up with US, CT or MRI for US-2; and 2-month follow-up with CT or MRI for US-3.
† Partial adherence: not in either full or nonadherence categories.
‡ Nonadherence: no follow-up visit, any examination with follow-up >12 months.
§ Data are means, with SDs in parentheses.
‖ Body mass index was calculated as patient weight in kilograms divided by patient height in meters squared.
Patients could have more than one etiology of liver disease; thus, the sum exceeds the number of patients.
** Other etiologies of liver disease included primary sclerosing cholangitis, amyloidosis, Wilson disease, congestive hepatopathy, and idiopathic.

underwent CT more than 12 months after the initial examination, two underwent US more than 12 months after, and seven did not undergo any follow-up imaging.

The nonadherence group had a lower mean age (57.1 vs 60.2 vs 60.1 years; nonadherence vs partial adherence vs full adherence groups, respectively; P < .001) and a lower proportion of Asian or Pacific Islander patients (41.2% vs 61.4% vs 71.9%; nonadherence vs partial adherence vs full adherence groups, respectively; overall P < .001 for race) compared with those who had either partial or full adherence (Table 2). With respect to etiology of liver disease, a higher proportion of patients with hepatitis C virus and alcohol-related liver disease were nonadherent, whereas a higher proportion with HBV and metabolic-associated liver disease had full adherence. Nonadherence and partial

adherence groups also had higher percentages of patients experiencing homelessness compared with the full adherence group (13.4% vs 6.9% vs 3.6%, respectively; $P < .001$). Moreover, a lower proportion of patients in the nonadherence group had attended hepatology specialty clinics compared with patients in the full and partial adherence groups (Table 2).

Factors Associated with Adherence to US LI-RADS Recommendations

Total adherence rates to US LI-RADS recommendations from initial US visit to the first follow-up visit were as follows: full adherence, 38.8% (95% CI: 35.7, 41.9); partial adherence, 24.9%; and nonadherence, 36.3%. At univariable logistic regression, older age (odds ratio [OR], 1.20 [95% CI: 1.07, 1.35]; $P = .002$), Asian or Pacific Islander race (OR, 3.12 [95% CI: 2.16, 4.50]; $P < .001$), HBV infection (OR, 2.81 [95% CI: 2.16, 3.66]; $P < .001$), metabolic-associated fatty liver disease (OR, 1.58 [95% CI: 1.17, 2.12]; $P = .002$), attending hepatology specialty clinic (OR, 4.49 [95% CI: 3.41, 5.90]; $P < .001$), and having undergone a US examination within the past year (OR, 3.55 [95% CI: 2.71, 4.64]; $P < .001$) were associated with higher odds of full adherence (vs partial or nonadherence) (Table 3). All other factors, including experiencing homelessness (OR, 0.28), higher body mass index (OR, 0.84), having multiple comorbidities (OR, 0.73), current smoking status or smoking history (OR, 0.40 and 0.52, respectively), current or prior illicit drug use (OR, 0.22 and 0.33, respectively), current or prior alcohol use disorder (OR, 0.26 and 0.39, respectively), hepatitis C virus infection (OR, 0.44), and alcohol-related liver disease (OR, 0.49) were associated with lower odds of full adherence (Table 3).

For the multivariable model of full adherence (vs partial or nonadherence), alcohol use disorder was not included in the model due to multicollinearity issues with alcohol-related liver disease (variance inflation factor ≥4 but $r < 0.6$). HBV-related etiology of liver disease was also not included due to strong correlation with Asian or Pacific Islander race ($r \geq 0.6$). At multivariable analysis, older age (OR, 1.20 per decade [95% CI: 1.03, 1.40]), male sex (OR, 1.62 [95% CI: 1.18, 2.36]), hepatology specialty clinic attendance (OR, 3.81 [95% CI: 2.80, 5.20]), and US examination in the past year (OR, 2.44 [95% CI: 1.82, 3.28]) were positively associated with full adherence, whereas current or prior smoking were negatively associated with full adherence (OR, 0.39 [95% CI: 0.26, 0.60] and 0.50 [95% CI: 0.34, 0.73], respectively) (Table 3).

Discussion

The US LI-RADS algorithm reduces variability in US reporting, promoting communication between the ordering provider and the radiologist, and may improve equity by ensuring uniform recommendations in management options for patients at risk for developing HCC. In this study of a diverse and vulnerable patient sample, we found that the overall adherence rate to US LI-RADS recommendations was 38.8%. Access to hepatology specialty care was associated with higher adherence, while certain patient characteristics (younger age, female sex, and not having undergone a US examination in the past year) and health risk behaviors (smoking history) were associated with lower adherence to US LI-RADS recommendations.

This observed suboptimal adherence rate for 6-month interval imaging surveillance is similar to prior experiences at non–safety-net institutions or health systems, with adherence rates ranging from 24.4% in a cohort of 2366 patients from 2001 to 2015 (26) to 36% in a cohort of 848 patients in 2016 (27) and 39.3% in a multi-institution study of 6831 patients from 2014 to 2018 (28). Although a control group could not be assessed in this study due to universal implementation of US LI-RADS, two prior studies in patients with chronic HBV infection receiving care at this safety-net health care system showed HCC imaging surveillance rates to be 23.9% in 1727 patients between 2008 and 2010 (20) and 36.9% in 947 patients from 1997 to 2008 (29). While the adherence rate is higher in our cohort with a large proportion of patients with chronic HBV infection, it remains suboptimal at below 50%. Similar findings were observed with implementation of the Lung Imaging Reporting and Data System, where adherence rates remained suboptimal but slightly improved (30). Potential reported barriers included lack of communication, lack of symptoms, lack of transportation, and financial cost of follow-up examinations, factors disproportionally experienced by socioeconomically disadvantaged populations (31). Additionally, the COVID-19 pandemic that coincided with implementation of US LI-RADS at the study institution may have impacted adherence. Indeed, HCC surveillance imaging rates decreased with the COVID-19 pandemic onset nationwide (32–34). While the study institution prioritized HCC surveillance, with minimal or no delay in scheduling, and data analysis accounted for the timing of US examinations from the onset of the pandemic, temporary interruption of services may have influenced adherence rates. Thus, longer follow-up evaluation during the postpandemic era will be required to further delineate the impact of US LI-RADS reporting in this population long-term and is currently planned.

Similar to prior studies (20,29), older age and male sex were associated with increased adherence to surveillance recommendations. Older age and male sex are known risk factors for HCC (35,36), suggesting that provider perception of higher HCC risk may influence adherence to HCC surveillance recommendations. Smoking, a negative health behavior, was associated with lower odds of full adherence. Smoking is associated with lower health responsibility and lower rates of follow-up to lung cancer screening (37,38). Considering that smoking is associated with HCC risk, targeted interventions that include behavioral modifications along with promotion of HCC surveillance may be needed to reduce HCC risk and allow early HCC detection in this population (39–41). While homelessness was negatively associated with full adherence at univariable analysis, this relationship was not statistically significant in our adjusted model. This was likely due to the low number of patients experiencing homelessness in our study ($n = 74$). Larger studies of underrepresented populations, such as those experiencing homelessness, may be needed to better define the influence of social determinants of health on adherence to US LI-RADS recommendations.

Table 3: Univariable and Multivariable Analyses of Demographic, Social, and Clinical Characteristics Associated with Full Adherence versus Partial or Nonadherence

Variable	Univariable Analysis	*P* Value	Multivariable Analysis	*P* Value
Age*	1.20 (1.07, 1.35)	.002	1.20 (1.03, 1.40)	.02
Male sex (vs female)	0.77 (0.60, 0.98)	.03	1.62 (1.18, 2.36)	.003
Race or ethnicity (vs non-Hispanic White)				
Asian or Pacific Islander	3.12 (2.16, 4.50)	<.001	1.47 (0.90, 2.43)	.13
Black	0.86 (0.48, 1.50)	.57	1.00 (0.56, 1.87)	.94
Hispanic	1.33 (0.81, 2.17)	.26	0.80 (0.46, 1.42)	.45
Other	1.25 (0.52, 2.99)	.62	1.01 (0.35, 2.91)	.98
Experiencing homelessness (vs not experiencing homelessness)	0.28 (0.15, 0.50)	<.001	0.62 (0.29, 1.34)	.23
BMI, per 5 points†	0.84 (0.75, 0.95)	.004	0.91 (0.78, 1.06)	.22
Comorbidities (>2 vs ≤2)	0.73 (0.53, 1.00)	.05	0.86 (0.59, 1.24)	.42
Smoking (vs never)				
Current	0.40 (0.28, 0.56)	<.001	0.39 (0.26, 0.60)	<.001
Past	0.52 (0.39, 0.70)	<.001	0.50 (0.34, 0.73)	<.001
Illicit drug use (vs none)				
Current	0.22 (0.11, 0.42)	<.001	0.87 (0.38, 1.96)	.73
Past	0.33 (0.21, 0.51)	<.001	0.64 (0.37, 1.13)	.11
Alcohol use disorder (vs none)				
Current	0.26 (0.15, 0.43)	<.001	…	…‡
Past	0.39 (0.27, 0.56)	<.001	…	
Cirrhosis	0.79 (0.61, 1.02)	.07	1.12 (0.77, 1.61)	.56
Etiology of liver disease§				
HBV	2.81 (2.16, 3.66)	<.001	…	…‖
HCV	0.44 (0.31, 0.60)	<.001	1.06 (0.65, 1.72)	.81
Alcohol-related liver disease	0.49 (0.33, 0.73)	<.001	0.90 (0.52, 1.57)	.71
Metabolic-associated liver disease	1.58 (1.17, 2.12)	.002	1.05 (0.73, 1.50)	.81
Hepatology clinic attendance	4.49 (3.41, 5.90)	<.001	3.81 (2.80, 5.20)	<.001
Primary care location				
Outside (vs within institution)	1.21 (0.93, 1.56)	.16	…	…
None (vs within institution)	1.06 (0.60, 1.87)	.85	…	…
US examination in the past year	3.55 (2.71, 4.64)	<.001	2.44 (1.82, 3.28)	<.001
Days since COVID-19 pandemic onset	0.998 (0.996, 1.00)	.01	1.00 (1.00, 1.00)	.52

Note.—Unless otherwise specified, data are odds ratios, with 95% CIs in parentheses. BMI = body mass index, HBV = hepatitis B virus, HCV = hepatitis C virus.
* Odds ratio calculated for each 10-year increase in age.
† BMI was calculated as patient weight in kilograms divided by patient height in meters squared.
‡ Alcohol use disorder was not included in the model due to multicollinearity issues.
‖ Patients could have more than one etiology of liver disease; thus, the sum exceeds the number of patients.
§ HBV was not included due to strong correlation with Asian or Pacific Islander race ($r \geq 0.6$).

The strongest factor associated with completing recommended next-step surveillance imaging per US LI-RADS, nearly fourfold higher than other factors, was engagement with a hepatology specialty clinic, suggesting that access to liver care is important in undergoing HCC surveillance. While, in this urban safety-net setting, the majority (78%) of the study sample (ie, those who had undergone HCC surveillance) had attended the hepatology clinic at least once, other studies have reported that only 20%–40% of patients at risk for HCC are monitored by specialty care, and rural, safety-net, or community hospitals have limited access to specialists who may have more familiarity with HCC surveillance recommendations (15,17,42). Moreover, system-level factors, including US scheduling availability, may influence patient and provider ability to adhere to a short interval of US follow-up recommendations (17,43). Our finding that undergoing a prior US examination is associated with adherence to future surveillance suggests that provider implementation of HCC surveillance, patient knowledge and prior adherence to provider-recommended testing, and potentially lower perceived barriers such as transportation or

time away from work, may have influenced adherence to LI-RADS recommendations (44).

This study had limitations. This study is based on a single-center urban safety-net health care system in California, with a large Asian or Pacific Islander population, which may not be generalizable to safety-net settings in other regions. Due in part to the retrospective study design, a direct control group could not be assessed to evaluate for changes with and without US LI-RADS. The optimal time frame for the next imaging modality was agreed on through a multidisciplinary discussion, incorporating national guideline recommendations (8) that may differ from other institutional polices. As the imaging data were collected from this study's institutional radiology database, any subsequent imaging examinations performed outside our institution that were not linked to our institution's health system or accessible through our electronic medical record could not be included. It is, however, less likely that this influenced our findings, as patients engaged with safety-net services obtain radiology services mainly within the same setting. The study period also coincided with the onset of the COVID-19 pandemic; although no significant association was observed in timing of the US examinations from the pandemic onset, the study may not be generalizable to the current postpandemic era. Further studies are required to evaluate effects over a longer period of time. Nevertheless, this study included a relatively large and diverse vulnerable patient sample and highlights potential areas for targeted intervention in an at-risk population.

In conclusion, US LI-RADS-based HCC surveillance adherence was suboptimal and was influenced by biologic factors (age and sex), adverse health behavior (smoking), and liver care access (hepatology clinic visit). Multipronged, multifaceted interventions focusing on all patient-, provider-, and system-level factors are likely needed to enhance HCC surveillance in the US LI-RADS reporting era.

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