

# Landscape of alcohol-related hepatocellular carcinoma in the last 15 years highlights the need to expand surveillance programs

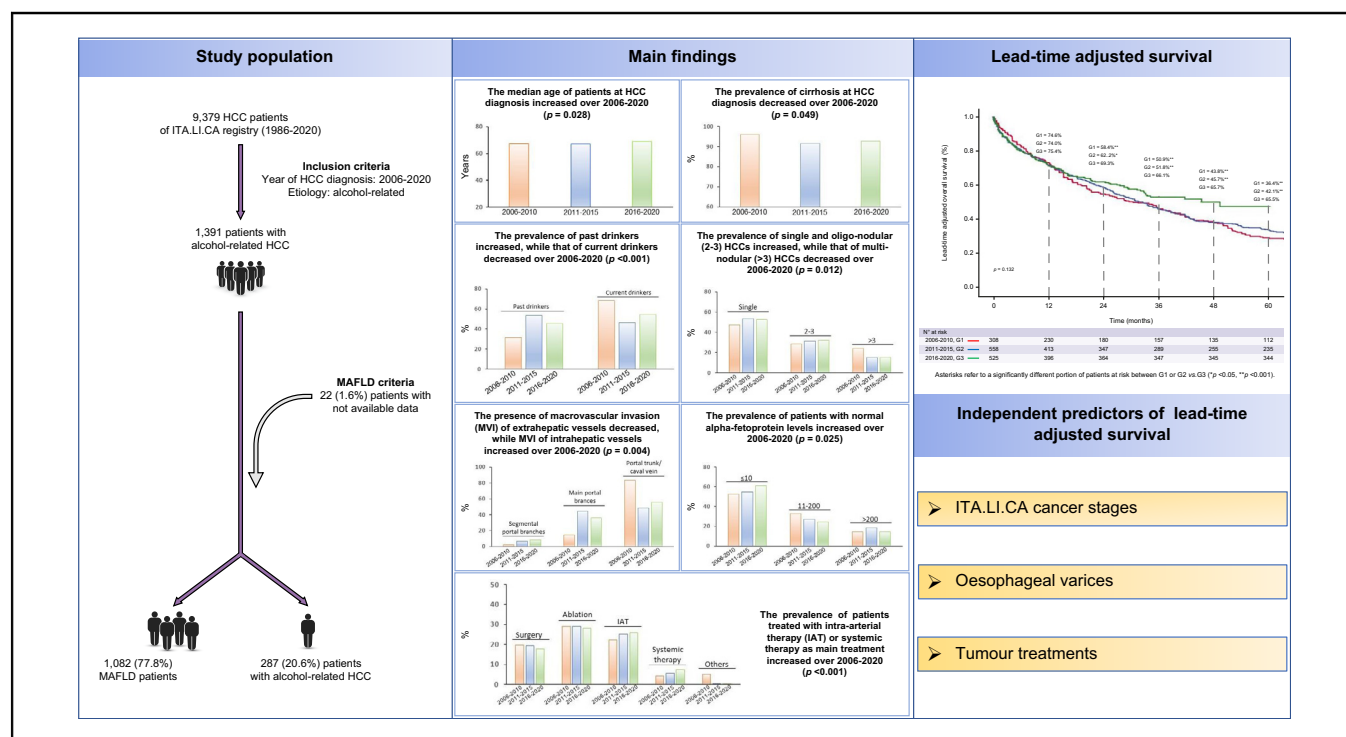
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## Graphical abstract



## Highlights

- Alcohol-related HCC is increasing in incidence and has a poor prognosis.
- Signs of metabolic dysfunction are present in most patients with HCC.
- The rate of alcohol-related HCC diagnosed by ultrasound surveillance is <50%.
- Only a modest survival improvement has been achieved in the last 15 years.
- Cancer stage, oesophageal varices, and treatment were predictors of survival.

## Impact and Implications

Alcohol abuse is a leading and growing cause of hepatocellular carcinoma (HCC) worldwide and is associated with a worse prognosis compared with other aetiologies. We assessed the evolutionary landscape of alcohol-related HCC over 15 years in Italy. A high cumulative prevalence (78%) of metabolic dysfunction-associated fatty liver disease, with signs of metabolic dysfunction, was observed in HCC patients with unhealthy excessive alcohol consumption. The alcohol + metabolic dysfunction-associated fatty liver disease condition tended to progressively increase over time. A modest improvement in survival occurred over the study period, likely because of the persistent underuse of surveillance programmes and, consequently, the lack of improvement in the cancer stage at diagnosis and the patients' eligibility for

curative treatments. Alongside the known prognostic factors for HCC (cancer stage and treatment), the presence of oesophageal varices was an independent predictor of poor survival, suggesting that this clinical feature should be carefully considered in patient management and should be included in prognostic systems/scores for HCC to improve their performance.



# Landscape of alcohol-related hepatocellular carcinoma in the last 15 years highlights the need to expand surveillance programs

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**Background & Aims:** Alcohol abuse and metabolic disorders are leading causes of hepatocellular carcinoma (HCC) worldwide. Alcohol-related aetiology is associated with a worse prognosis compared with viral agents, because of the lower percentage of patients diagnosed with HCC under routine surveillance and a higher burden of comorbidity in alcohol abusers. This study aimed to describe the evolving clinical scenario of alcohol-related HCC over 15 years (2006–2020) in Italy.

**Methods:** Data from the Italian Liver Cancer (ITA.LI.CA) registry were used: 1,391 patients were allocated to three groups based on the year of HCC diagnosis (2006–2010; 2011–2015; 2016–2020). Patient characteristics, HCC treatment, and overall survival were compared among groups. Survival predictors were also investigated.

**Results:** Approximately 80% of alcohol-related HCCs were classified as cases of metabolic dysfunction-associated fatty liver disease. Throughout the quinquennia, <50% of HCCs were detected by surveillance programmes. The tumour burden at diagnosis was slightly reduced but not enough to change the distribution of the ITA.LI.CA cancer stages. Intra-arterial and targeted systemic therapies increased across quinquennia. A modest improvement in survival was observed in the last

Keywords: Hepatocellular carcinoma; Alcohol abuse; ITA.LI.CA staging system; Metabolic dysfunction-associated fatty liver disease; Surveillance programs; Oesophageal varices.

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quinquennia, particularly after 12 months of patient observation. Cancer stage, HCC treatment, and presence of oesophageal varices were independent predictors of survival.

**Conclusions:** In the past 15 years, modest improvements have been obtained in outcomes of alcohol-related HCC, attributed mainly to underuse of surveillance programmes and the consequent low amenability to curative treatments. Metabolic dysfunction-associated fatty liver disease is a widespread condition in alcohol abusers, but its presence did not show a pivotal prognostic role once HCC had developed. Instead, the presence of oesophageal varices, an independent poor prognosticator, should be considered in patient management and refining of prognostic systems.

**Impact and Implications:** Alcohol abuse is a leading and growing cause of hepatocellular carcinoma (HCC) worldwide and is associated with a worse prognosis compared with other aetiologies. We assessed the evolutionary landscape of alcohol-related HCC over 15 years in Italy. A high cumulative prevalence (78%) of metabolic dysfunction-associated fatty liver disease, with signs of metabolic dysfunction, was observed in HCC patients with unhealthy excessive alcohol consumption. The alcohol + metabolic dysfunction-associated fatty liver disease condition tended to progressively increase over time. A modest improvement in survival occurred over the study period, likely because of the persistent underuse of surveillance programmes and, consequently, the lack of improvement in the cancer stage at diagnosis and the patients' eligibility for curative treatments. Alongside the known prognostic factors for HCC (cancer stage and treatment), the presence of oesophageal varices was an independent predictor of poor survival, suggesting that this clinical feature should be carefully considered in patient management and should be included in prognostic systems/scores for HCC to improve their performance.

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## Introduction

Hepatocellular carcinoma (HCC) is the second leading cause of death from cancer worldwide.<sup>1</sup> Almost 90% of HCCs develop in the setting of chronic liver disease, usually within the context of advanced fibrosis or cirrhosis.<sup>2,3</sup>

The incidence of this tumour varies markedly across geographic regions according to the prevalence of its risk factors.<sup>4</sup> Chronic viral hepatitis and alcohol-related liver disease are the main risk factors; however, in high-income countries, the rising prevalence of metabolic disorders has led to an increasing prevalence of HCCs associated with non-alcoholic fatty liver disease (NAFLD).<sup>5,6</sup>

Approximately 30% of HCC cases worldwide are attributable to alcohol abuse,<sup>7</sup> ranging from 20% in Southern European countries (e.g. Italy and Spain) to 63% in Eastern countries.<sup>8</sup> Heavy alcohol consumption is associated with a relative risk of 2.07 for the development of this tumour compared with non-consumers, and the annual incidence of HCC in patients with alcohol-related cirrhosis is approximately 3%.<sup>8,9</sup> It is expected that the relative and absolute causative roles of alcohol will increase in the future, as alcohol consumption is rising in many countries,<sup>10</sup> whereas the frequency of potentially causative HBV and HCV viral infections is declining because of the decreased incidence of new infections and the efficacy of antiviral treatments.<sup>11</sup> This changing aetiological scenario has been recently confirmed by a retrospective analysis of the Italian Liver Cancer (ITA.LI.CA) database, showing that the proportion of non-viral HCCs, and particularly of 'metabolic' or 'metabolic + alcohol-related' tumours, is rapidly growing and is challenging that of HCV-related HCCs, which is still the largest aetiological subgroup in Italy.<sup>12</sup>

The prognosis of patients with alcohol-related HCC is worse than that of non-alcohol-related cases because of more frequent delayed detection rates rather than greater cancer aggressiveness or poorer treatment outcomes.<sup>13,14</sup> Indeed, in alcohol abusers a HCC diagnosis is more often made outside surveillance programmes and in the setting of more advanced cirrhosis.<sup>8,15,16</sup> This combination entails a more advanced cancer stage at the time of diagnosis, with a lower amenability to curative treatments, and hence, worse survival.<sup>13</sup> Moreover, a more conservative therapeutic approach to alcohol-related HCCs may be

motivated by the higher prevalence of extrahepatic comorbidities and poorer social conditions of patients, limiting access to a cure. This assumption is supported by the results of a multicentre prospective study conducted in patients with alcohol-related cirrhosis who were periodically screened for HCC; only 56% of these patients underwent curative treatments, despite 77% of the cases having been diagnosed with a tumour within the Milan criteria.<sup>9</sup> Therefore, the above-mentioned unfavourable characteristics of alcohol abusers could have prevented or limited any prognostic improvement reported in an unselected case series of patients with HCC.<sup>17</sup> Despite the growing importance of alcohol abuse in HCC development and its alarming features, this topic has received less attention than other causes of HCC, with research interest mainly focused on the challenging problem of liver damage associated with metabolic disorders.

Recently, a new taxonomy of liver diseases has been proposed that includes the setting of metabolic syndrome, named metabolic dysfunction-associated fatty liver disease (MAFLD).<sup>18</sup> Unlike NAFLD, which was conceived as a diagnosis of exclusion,<sup>19</sup> this new entity includes patients with metabolic dysfunction and liver disease, regardless of the concurrent presence of other causative factors. In Italy, MAFLD accounts for >50% of patients with HCC, and this condition is expected to be detectable in the vast majority of cases of HCC in the forthcoming years.<sup>20</sup> However, the prevalence of MAFLD and its prognostic impact in patients with alcohol-related HCC remains unclear.

This study aimed to describe the evolving landscape of alcohol-related HCC over 15 years (calendar years: 2006–2020) in Italy, where approximately 15% of HCC have been attributed to alcohol abuse.<sup>12</sup>

## Patients and methods

### Patients

Data were extracted from the ITA.LI.CA registry which currently includes 9,379 patients with HCC consecutively evaluated from January 1986 to December 2020 in 24 medical institutions in Italy. Data were collected prospectively and updated every 2 years. After a biennial control of data quality by the coordinating centre (Semeiotics Unit, Bologna University), the database was available for use for new studies. The participating ITA.LI.CA

centres collected patient data at the time of HCC diagnosis (baseline) and during follow-up. For those patients initially managed outside the ITA.LI.CA network, baseline and follow-up data until the first access to the ITA.LI.CA network were retrospectively obtained. To avoid selection bias, no patient was excluded from the registry as a result of incomplete data ('all comers' recruitment). The management of the ITA.LI.CA database conforms to the current Italian legislation on privacy. According to Italian law, patient consent is not required for retrospective data analysis. Nonetheless, all patients provided written informed consent to undergo each diagnostic and therapeutic procedure and for having their clinical data recorded anonymously in the ITA.LI.CA database. The database used for scientific research was approved by the Institutional Review Board of the ITA.LI.CA Coordinating Center (approval number 99/2012/O/Oss) and the study was conducted following the ethical guidelines of the 1975 Declaration of Helsinki.

For this study, a total of 1,391 consecutive patients with alcohol-related HCC diagnosed from 1 January 2006 to 31 December 2020 were selected. The patients were allocated to three groups according to the year of cancer diagnosis:

- G1 = 2006–2010: n = 308 (22.1%) patients
- G2 = 2011–2015: n = 558 (40.1%) patients
- G3 = 2016–2020: n = 525 (37.8%) patients.

We analysed the following variables: age, sex, alcohol consumption (expressed as alcohol units [AU] per week), drinking habit at the time of HCC diagnosis (categorised as past [abstainers at the cancer diagnosis] or current drinkers), smoking habit (categorised as never, past [had quit smoking before the HCC diagnosis], or current smokers at the time of HCC detection), presence of MAFLD, type 2 diabetes (diabetes or active glucose-lowering therapy) and cirrhosis, Charlson Comorbidity Index, modality of HCC diagnosis (under surveillance, incidental, symptomatic), surveillance interval (categorised as  $\leq 6$  months and others), Child-Pugh (C–P) class, albumin/bilirubin (ALBI) grade, Aspartate aminotransferase–Platelet Ratio Index (APRI), Model for End-stage Liver Disease (MELD) score, ECOG Performance Status (PS, categorised as 0, 1, and  $\geq 2$ ), presence of oesophageal varices, platelet count (threshold  $\leq 100,000/\mu\text{l}$ , below which the presence of clinically significant portal hypertension can be suspected in liver cirrhosis), tumour gross pathology (monofocal, multifocal, 'spreading mass' infiltrative or massive), number of lesions (categorised as 1, 2–3 and  $>3$ ), size of the greatest lesion (categorised as  $\leq 2$ , 2.1–5 and  $>5$  cm), presence of portal or caval macrovascular invasion (MVI) and its site (categorised as segmental, main portal branches and portal trunk/caval vein), presence of metastases, serum alpha-fetoprotein (AFP) levels (categorised as  $\leq 10$ , 11–200, and  $>200$  ng/ml), ITA.LI.CA<sup>21</sup> tumour stage, HCC main treatment (the administered treatment with highest efficacy), causes of death, and patient survival. All these variables were available for  $>80\%$  of the cases, except for weekly alcohol consumption and surveillance interval.

### Aetiology of liver disease

In all patients, the diagnosed liver disease was classified as 'alcohol-related' if the daily ethanol intake was  $>20$  g for women and  $>30$  g for men, for at least 10 years, and no other causes of liver injury, except for features of metabolic syndrome, were found. Such a choice allowed us to enrol patients with both pure

alcohol-related liver disease and alcohol-related/metabolic liver damage.

As in our previous study,<sup>20</sup> MAFLD was defined as the presence of type 2 diabetes and/or previous or current overweight or obesity (defined as BMI  $>25$  kg/m<sup>2</sup>), or at least 2 of the following hallmarks of metabolic dysfunction:

- impaired fasting glucose (fasting glucose between 100 and 125 mg/dl) or receiving antidiabetic therapy;
- triglycerides  $>150$  mg/dl or receiving specific therapy;
- HDL cholesterol  $<50$  mg/dl in women or  $<40$  mg/dl in men or specific lipid-lowering therapy;
- current or past hypertension (defined as blood pressure  $>130/85$  mmHg) or current antihypertensive treatment.

A subanalysis of the baseline characteristics of the patients was also performed according to the presence or absence of MAFLD.

The presence of cirrhosis was confirmed by histology in 59 (4.3%) patients and by laparotomy or laparoscopy in nine (0.7%) patients; in the remaining cases, the diagnosis was made according to clinical, laboratory, endoscopic, and imaging findings.

If a recent description of oesophageal varices was lacking at the time of HCC diagnosis, endoscopy was considered mandatory. Moreover, when a previously unreported portal vein thrombosis was detected on imaging, the endoscopic examination was repeated regardless of the date of the previous examination. Varices were graded and managed according to the Baveno guidelines available at the time of HCC diagnosis.

### Diagnosis and staging

The diagnosis of HCC was classified as follows:

- under surveillance, if HCC was detected during an ultrasound (US)-based surveillance programme ( $\pm$ AFP determination) started at least 1 year before HCC diagnosis. Patients were subgrouped according to the surveillance interval ( $\leq 6$  months/others). To minimise the effect of length bias, patients under surveillance were maintained in their original group even if the occurrence of symptoms anticipated the scheduled US.
- incidental, when the diagnosis was made during investigations of other diseases or a general check-up outside of regular surveillance.
- symptomatic, if HCC was detected through investigations motivated by the appearance of cancer-related symptoms in patients outside regular surveillance.

A subanalysis of the main characteristics of the patient according to the type of diagnosis (surveillance or no surveillance) was performed. Moreover, the evolution of the modality of HCC diagnosis through the 3 quinquennia was reported for NAFLD + cryptogenic and viral aetiologies.

The diagnosis of HCC was based on typical features of one or more imaging techniques (dynamic computed tomography [CT], magnetic resonance imaging [MRI], and contrast-enhanced US [CEUS]) and/or histological findings according to the European and American guidelines available at the time of patient recruitment.

Cancer burden was assessed using liver CT and/or MRI, and further investigations were systematically performed aimed at detecting extrahepatic involvement for patients with advanced

HCC or for those eligible for liver transplant (LT). In addition, these explorations were also repeated when clinically indicated.

HCC was staged according to the ITA.LI.CA staging system.<sup>21</sup>

### Treatment

If patients were subjected to multiple treatments, they were classified considering the most effective treatment (named 'main'), following this hierarchical order: LT, hepatic resection, radiofrequency ablation (RF), percutaneous ethanol injection ablation (PEI), intra-arterial treatment ([IAT], including transarterial chemoembolisation [TACE], transarterial embolisation [TAE], and transarterial radioembolisation [TARE]), systemic therapy, or other therapies and best supportive care (BSC).<sup>22</sup>

### Lead-time estimation

For each period, patients diagnosed with HCC during surveillance or incidentally were compared with those with a symptomatic diagnosis for lead-time estimation.<sup>23</sup> The mean  $\pm$  standard deviation (SD) of lead times for the surveyed patients or those diagnosed incidentally were as follows:

- 8.6  $\pm$  2.1 months and 4.6  $\pm$  1.1 months in G1
- 8.2  $\pm$  2.7 months and 4.4  $\pm$  1.3 months in G2
- 7.7  $\pm$  2.6 months and 4.3  $\pm$  1.3 months in G3.

### Statistical analysis

Continuous variables are expressed as median and 25th–75th percentiles and discrete variables as absolute and relative frequencies. Kruskal–Wallis and Mann–Whitney *U* tests were used to compare continuous variables among the three periods or between two periods. The  $\chi^2$  test or Fisher's exact test was used to compare discrete variables, as appropriate. Data missing from covariates included in the ITA.LI.CA staging system were estimated using the maximum likelihood estimation method<sup>24</sup> to obtain a sample size large enough to be representative of the original patient population and not to limit the number of cases included in the multivariate analysis. The lack of significant data distortion as a result of imputation was confirmed by comparing the results obtained with raw and imputed data (Table S1).

Overall survival (OS) was defined as the time elapsed between HCC diagnosis and the patient's death, the last follow-up evaluation, or data censoring (31 December 2020), whichever occurred first, and was reported as the median and 95% CI. OS was calculated according to the Kaplan–Meier method and was compared using the Log-rank test. If the potential for non-proportionality of hazards was evident, piecewise hazard ratios (HRs) were calculated over distinct periods using time-varying Cox regression analysis.

The 'lead-time adjusted' OS (a-OS) was calculated by subtracting the relevant lead-time from the OS obtained from surveyed or incidentally diagnosed patients. Survival rates at 1, 2, 3, 4, and 5 years were also reported, and the proportions of patients alive at any time in the 3 quinquennia were compared using the  $\chi^2$  test.

To provide a more comprehensive picture of the changing HCC scenario in the 3 quinquennia, a subanalysis of the evolution of main treatment, causes of death, and a-OS in patients with NAFLD + cryptogenetic and viral HCC was also performed.

Baseline characteristics (except for alcohol consumption and surveillance interval) were tested using univariate and multivariate Cox analyses to identify their associations with a-OS.

Variables associated with a-OS in the univariate analysis ( $p < 0.10$ ) were entered into the multivariate models. Adjusted HR and 95% CI were reported for each prognostic factor. To avoid collinearity between covariates, the components of the ITA.LI.CA staging system (PS, tumour burden, AFP, and liver function tests) were excluded from the model that included this system. Moreover, we created two additional models to test the prognostic significance of the C–P classes and ALBI grades. The three models tested were as follows:

**Model 1 (C–P-based)** included age, MAFLD, cirrhosis, modality of HCC diagnosis, **C–P class**, Eastern Cooperative Oncology Group–Performance Status (ECOG PS), platelet count, oesophageal varices, AFP levels, gross tumour pathology, size of the greatest lesion, metastases, MVI, and the main treatment.

**Model 2 (ALBI-based)** included age, MAFLD, cirrhosis, modality of HCC diagnosis, **ALBI grade**, ECOG PS, platelet count, oesophageal varices, AFP levels, gross tumour pathology, size of the greatest lesion, metastases, MVI, and the main treatment.

**Model 3 (ITA.LI.CA-based)** included age, MAFLD, cirrhosis, modality of HCC diagnosis, platelet count, oesophageal varices, **ITA.LI.CA cancer stage**, and the main treatment.

A two-tailed  $p$  value  $< 0.05$  was considered statistically significant. All statistical analyses were performed with SPSS v28.0 (Apache Software Foundation, Chicago, IL, USA).

Details of the deposited data, software, and corresponding methods are reported in the [CTAT Table](#).

## Results

### Demographic and clinical characteristics

We observed an increase in the median age at HCC diagnosis, from 67 years in G1–G2 to 69 years in G3 ( $p = 0.028$ ), whereas the large predominance of males ( $\geq 92\%$ ) did not change over time (Table 1).

The distribution of the weekly median AU did not change over time ( $p = 0.313$ ), with 56 (40–56), 46 (30–60), and 50 (30–70) in G1, G2, and G3, respectively. However, the proportion of current drinkers was significantly higher in G1 ( $p < 0.001$ ).

Smoking habits varied ( $p < 0.001$ ), showing a reduction in never-smokers (from 56.7% in G1 to 47.7% in G3) and current smokers (from 30.9% to 25.5%), and an increase in the proportion of people who had quit smoking before HCC diagnosis (from 12.4% to 26.8%).

The overall prevalence of patients fulfilling MAFLD criteria was very high (77.8%) (Fig. 1), and tended to increase across quinquennia (76.0%, 79.5%, and 80.0%). The comparison of baseline characteristics between patients with MAFLD and 'non-MAFLD' alcohol-related HCC is reported in Table S2. In patients with MAFLD, the prevalence of type 2 diabetes and comorbidities was significantly higher, whereas the prevalence of cirrhosis and the median MELD score were lower than those observed in the counterpart (Table S2).

Considering the entire population (Table 1), after the first calendar period the proportion of patients with cirrhosis decreased from 96.1% to 92.8% ( $p = 0.049$ ).

Comorbidity burden, measured using the Charlson Comorbidity Index, maintained a median score of 3 during the study period.

**Table 1. Demographic and clinical characteristics of patients with alcohol-related hepatocellular carcinoma in the 3 quinquennia.**

Variables	Available	2006–2010	2011–2015	2016–2020	p value
	N (%)	n (%) 308 (22.1)	n (%) 558 (40.1)	n (%) 525 (37.7)	
Demographic and clinical features					
Age, years					
Median (25th–75th)	1,391 (100)	67.5 (60–73)	67 (63–73)	69 (63–75)	0.028
Sex (M/F)	1,391 (100)	284/24 (92.2/7.8)	523/35 (93.7/6.3)	486/39 (92.6/7.4)	0.641
Alcohol consumption (AU/week)	808 (58.1)	178 (57.8)	310 (55.6)	320 (61.0)	0.313
Median (25th–75th)		56 (40–56)	46 (30–60)	50 (30–70)	
Drinking habit	1,391 (100)	308 (22.2)	558 (40.1)	525 (37.7)	<0.001
Past		98 (31.8)	298 (53.4)	240 (45.7)	
Current		210 (68.2)	260 (46.6)	285 (54.3)	
Smoking habit	1,149 (82.6)	233 (74.9)	465 (83.3)	451 (85.9)	<0.001
Never		132 (56.7)	258 (55.5)	215 (47.7)	
Past		29 (12.4)	83 (17.8)	121 (26.8)	
Current		72 (30.9)	124 (26.7)	115 (25.5)	
MAFLD	1,369 (98.4)	308 (100)	550 (98.6)	511 (97.3)	0.301
Yes		234 (76.0)	437 (79.5)	411 (80.0)	
Type 2 diabetes	1,391 (100)	308 (100)	558 (100)	525 (100)	0.208
Yes		116 (37.7)	241 (43.2)	228 (43.4)	
Cirrhosis	1,369 (98.4)	305 (99.0)	550 (98.6)	514 (97.9)	0.049
Yes		293 (96.1)	504 (91.6)	477 (92.8)	
Charlson Comorbidity Index	1,391 (100)	308 (100)	558 (100)	525 (100)	0.204
Median (25th–75th)		3 (2–4)	3 (2–4)	3 (2–4)	
Modality of HCC diagnosis	1,270 (91.3)	282 (91.6)	502 (90.0)	486 (92.6)	0.250
Under surveillance		107 (37.9)	228 (45.4)	221 (45.5)	
Incidental		121 (42.9)	192 (38.2)	190 (39.1)	
Symptomatic		54 (19.1)	82 (16.3)	75 (15.4)	
Surveillance interval	392 (70.5) <sup>a</sup>	65 (60.7)	153 (67.1)	174 (78.7)	0.010
≤6 months		41 (63.1)	119 (77.8)	142 (81.6)	
Others		24 (36.9)	34 (22.2)	32 (18.4)	
Child–Pugh class	1,391 (100.0)	308 (100.0)	558 (100.0)	525 (100.0)	0.567
A		175 (56.8)	298 (53.4)	277 (52.8)	
B		107 (34.7)	218 (39.1)	212 (40.4)	
C		26 (8.4)	42 (7.5)	36 (6.9)	
ALBI grade	1,391 (100.0)	308 (100.0)	558 (100.0)	525 (100.0)	0.270
Grade 1, ≤–2.60		52 (16.9)	105 (18.8)	108 (20.6)	
Grade 2, >–2.60 ≤–1.39		212 (68.8)	397 (71.1)	352 (67.2)	
Grade 3, >–1.39		44 (14.3)	56 (10.0)	64 (12.2)	
APRI	1,155 (83.0)	261 (84.7)	456 (81.7)	438 (83.4)	0.603
First tertile		75 (28.7)	158 (34.6)	146 (33.3)	
Second tertile		94 (36.0)	149 (32.7)	147 (33.6)	
Third tertile		92 (35.2)	149 (32.7)	145 (33.1)	
MELD score	1,391 (100.0)	308 (100.0)	558 (100.0)	525 (100.0)	0.156
Median (25th–75th)		11.0 (8.4–14.0)	10.3 (8.2–14.0)	10.2 (8.3–13.4)	
ECOG PS	1,391 (100.0)	308 (100.0)	558 (100.0)	525 (100.0)	0.113
0		196 (63.6)	370 (66.3)	376 (71.6)	
1		77 (25.0)	132 (23.7)	97 (18.5)	
≥2		35 (11.4)	56 (10.0)	52 (9.9)	
Oesophageal varices	1,391 (100.0)	308 (100.0)	558 (100.0)	525 (100.0)	0.238
Yes		140 (45.5)	255 (45.7)	264 (50.3)	
Platelet count	1,391 (100.0)	308 (100.0)	558 (100.0)	525 (100.0)	0.075
≤100,000/μl		102 (33.1)	195 (34.9)	211 (40.2)	
Tumour burden and stage					
Gross pathology	1,391 (100.0)	308 (100.0)	558 (100.0)	525 (100.0)	0.684
Monofocal		135 (43.8)	279 (50.0)	255 (48.6)	
Multifocal		151 (49.0)	241 (43.2)	229 (43.6)	
Infiltrative		14 (4.2)	20 (3.6)	22 (4.2)	
Massive		9 (2.9)	18 (3.2)	19 (4.2)	
Number of lesions	1,290 (92.7)	286 (92.9)	520 (93.2)	484 (92.2)	0.012
1		135 (47.2)	279 (53.7)	255 (52.7)	
2 or 3		82 (28.7)	162 (31.2)	156 (32.2)	
>3		69 (24.1)	79 (15.2)	73 (15.1)	
Size of the greatest lesion	1,376 (98.9)	307 (99.7)	553 (99.1)	516 (98.3)	0.091
≤2 cm		71 (23.1)	150 (27.1)	156 (30.2)	
2.1–5.0 cm		154 (50.2)	253 (45.8)	248 (48.1)	
>5 cm		82 (26.7)	150 (27.1)	112 (21.7)	
MVI	1,391 (100.0)	308 (100.0)	558 (100.0)	525 (100.0)	0.717

(continued on next page)

Table 1 (continued)

Variables	Available	2006–2010	2011–2015	2016–2020	p value
	N (%)	n (%) 308 (22.1)	n (%) 558 (40.1)	n (%) 525 (37.7)	
Yes		42 (13.6)	87 (15.6)	81 (15.4)	
MVI site	210 (100.0)	42 (100.0)	87 (100.0)	81 (100.0)	0.004
Segmental		1 (2.4)	6 (6.9)	7 (8.6)	
Main portal branches		6 (14.3)	39 (44.8)	29 (35.8)	
Portal trunk/caval vein		35 (83.3)	42 (48.3)	45 (55.6)	
Metastases	1,391 (100.0)	308 (100.0)	558 (100.0)	525 (100.0)	0.028
Yes		10 (3.2)	33 (5.9)	15 (2.9)	
Alpha-foetoprotein levels	1,391 (100.0)	308 (100.0)	558 (100.0)	525 (100.0)	0.025
≤10 ng/ml		162 (52.6)	305 (54.7)	321 (61.1)	
11–200 ng/ml		101 (32.8)	151 (27.1)	128 (24.4)	
>200 ng/ml		45 (14.6)	102 (18.3)	76 (14.5)	
ITA.LI.CA tumour stage	1,391 (100)	308 (100.0)	558 (100.0)	525 (100.0)	0.136
0		52 (16.9)	115 (20.6)	120 (22.9)	
A		71 (23.1)	129 (23.1)	58 (11.0)	
B1		42 (13.6)	74 (13.3)	93 (17.7)	
B2		44 (14.3)	51 (9.1)	53 (10.1)	
B3		12 (3.9)	39 (7.0)	26 (5.0)	
C		36 (11.7)	69 (12.4)	50 (9.5)	
D		51 (16.6)	81 (14.5)	86 (16.4)	

Levels of significance: <0.05 (Kruskal–Wallis test and  $\chi^2$  test).

Among patients under surveillance, the interval was specified in 392 cases, representing the 70.5% of these patients.

ALBI, albumin–bilirubin; APRI, AST to Platelet Ratio Index; ECOG-PS, Eastern Cooperative Oncology Group Performance Status; HCC, hepatocellular carcinoma; ITA.LI.CA, Italian Liver Cancer; MAFLD, metabolic dysfunction associated fatty liver disease; MELD, model for end-stage liver disease; MVI, macrovascular Invasion.

Overall, the severity of liver disease, as assessed by the C–P class distribution, MELD score, and ALBI grade, and the prevalence of clinically significant portal hypertension (highlighted by

the presence of oesophageal varices) remained unchanged over time. Similarly, the ECOG PS did not change significantly, despite an increasing trend in the proportion of PS 0 (63.6%, 66.3%, and 71.6%).

Regarding the modality of HCC diagnosis, both symptomatic (19.1%, 16.3%, and 15.4%) and incidental diagnoses (42.9%, 38.2%, and 39.1%) tended to decrease after the first quinquennium, favouring diagnoses made under surveillance (37.9%, 45.4%, and 45.5%); however, these trends did not reach statistical significance ( $p = 0.250$ ). Among the patients surveyed, the predominant surveillance interval was always ≤6 months, and the prevalence of HCC detected under this surveillance programme progressively increased (63.1%, 77.8%, and 81.6%;  $p = 0.010$ ).

Overall, the surveyed patients showed a significantly better distribution of baseline C–P classes, ECOG PS, tumour burden, AFP levels and ITA.LI.CA stages, so that they were more frequently suited for curative treatments (56.1% vs. 38.8%), and their median a–OS was longer (34.7 vs. 28.4 months) than their counterpart (Table S3).

Table S4 shows the evolution of diagnostic modalities in contemporary patients with non-alcohol-related HCC. In the NAFLD + cryptogenic population ( $n = 628$ ), the proportion of HCC detected under surveillance was similar to that observed in alcohol-related disease, and did not significantly change across quinquennia (41.5%, 47.9%, and 44.9%). Instead, in viral patients ( $n = 4,296$ ), the proportion of HCC detected under surveillance was always >60%, showing its nadir (61.2%) in the last quinquennium.

### Tumour burden

The prevalence of patients with monofocal HCC tended to be higher (albeit not significantly) after the first quinquennium (from 43.8% to approximately 50% in G2 and G3) at the expense of multinodular tumours (particularly of those with more than three nodules), whereas the proportion of infiltrative or massive HCC remained very low over time (Table 1).

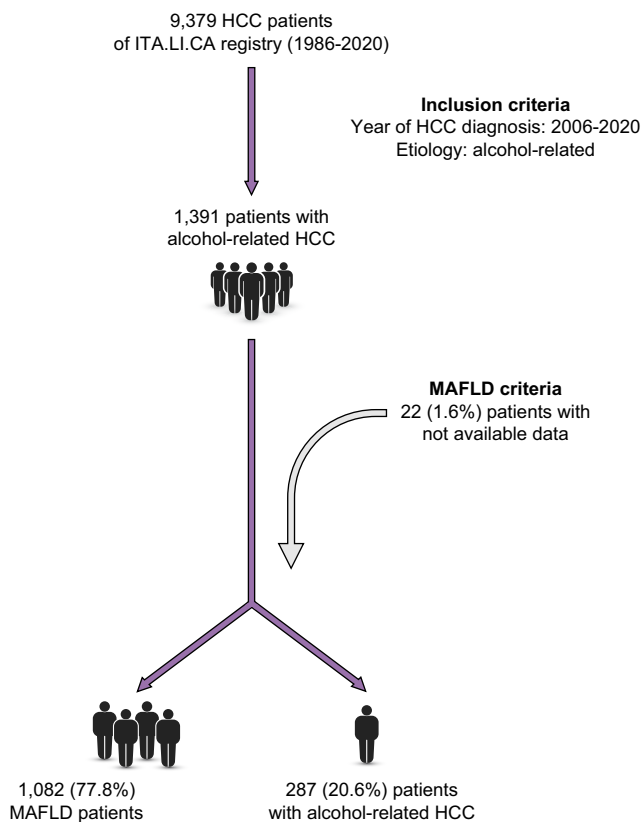


Fig. 1. Metabolic dysfunction-associated fatty liver disease (MAFLD) prevalence among patients with hepatocellular carcinoma originally considered as merely alcohol-related.



**Table 2. Main treatments performed for hepatocellular carcinoma and causes of death.**

	Available	2006–2010	2011–2015	2016–2020	p value
	N (%)	n (%)	n (%)	n (%)	
<b>Main treatment</b>	1,385 (99.6)	308 (100.0)	558 (100.0)	519 (98.9)	<0.001
Liver transplant		12 (3.9)	25 (4.5)	21 (4.6)	
Resection		49 (15.9)	83 (14.9)	69 (13.3)	
Ablation		90 (29.2)	162 (29.0)	147 (28.3)	
IAT		69 (22.4)	141 (25.3)	135 (26.0)	
Systemic therapy		13 (4.2)	32 (5.7)	38 (7.3)	
Others		16 (5.2)	1 (0.2)	2 (0.4)	
BSC		52 (16.9)	95 (17.0)	91 (17.5)	
Not known		7 (2.3)	19 (3.4)	16 (3.1)	
<b>Causes of death</b>	771 (100.0)	239 (31.0)	350 (45.4)	182 (23.6)	<0.001
Tumour progression		109 (45.6)	155 (44.3)	72 (39.6)	
Liver failure		39 (16.3)	75 (21.4)	47 (25.8)	
Haemorrhage		5 (2.1)	10 (2.9)	7 (3.8)	
Kidney failure		4 (1.7)	10 (2.9)	1 (0.5)	
Infection		1 (0.4)	10 (2.9)	15 (8.2)	
Embolism		1 (0.4)	0 (0.0)	4 (2.2)	
Other		70 (29.3)	58 (16.6)	22 (12.6)	
Not known		10 (4.2)	32 (9.1)	13 (7.1)	

Levels of significance: <0.05 ( $\chi^2$  test).

BSC, best supportive care; IAT, intra-arterial therapy.

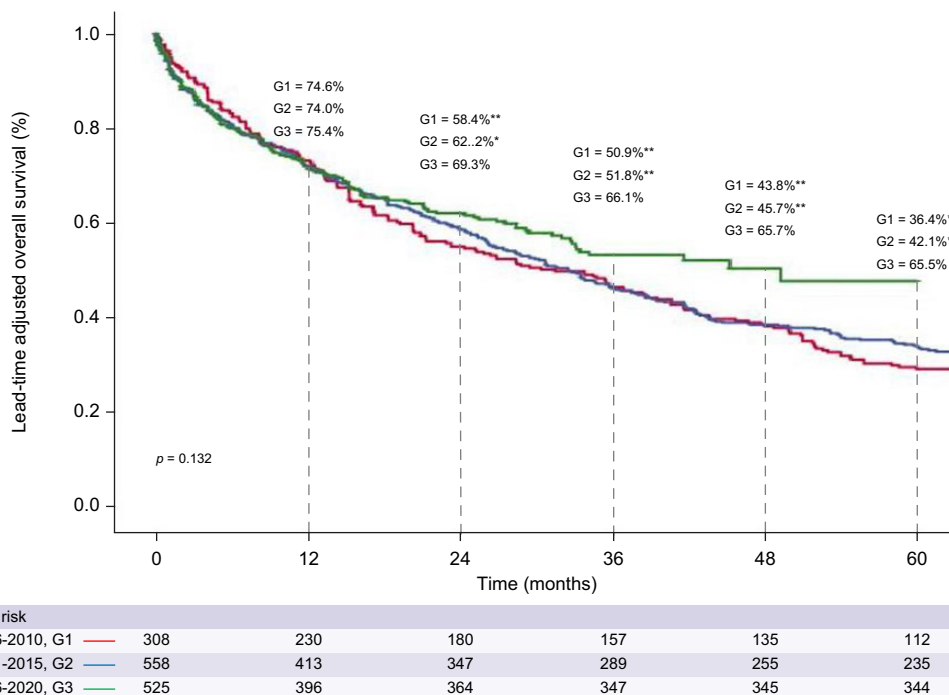
Concomitantly, a tendency toward a more favourable distribution of cancer size with a progressive increase in tiny tumours ( $\leq 2$  cm) was observed (from 23.1% to 27.1% and 30.2% ( $p = 0.091$ )).

The proportion of patients with MVI remained stable at approximately 15% throughout the study. Nevertheless, among patients with MVI, there was a significant ( $p = 0.004$ ) shift in the site of vascular invasion from extrahepatic vessels (portal trunk

and caval vein, 83.3%, 48.3%, and 55.6%) to the main portal branches (14.3%, 44.8%, and 35.8%) through the 3 quinquennia.

The prevalence of extrahepatic spread was low and stable, with its nadir in G3 (2.9%).

The distribution of AFP levels favourably changed ( $p = 0.025$ ), as the proportion of patients with a normal value ( $\leq 10$  ng/ml) progressively increased (52.6%, 54.7%, and 61.1%) at the expense



**Fig. 2. Lead-time adjusted overall survival according to quinquennia.** Levels of significance:  $p < 0.05$  (log-rank test). Asterisks refer to a significantly different proportion of at-risk patients between G1 or G2 vs. G3: \* $p < 0.05$ , \*\* $p < 0.001$ .

**Table 3. Univariate Cox proportional hazard regression analysis of factors affecting the lead time-adjusted survival.**

Univariate analysis				
Variables		Exp(B)	95% CI	p value
Age (years)		1.013	1.005–1.022	0.002
Sex				
F	Ref. Cat.	–	–	
M		1.017	0.773–1.339	0.902
Drinking habit				
Past	Ref. Cat.	–	–	
Current		0.946	0.821–1.090	0.444
Smoking habit				
Never	Ref. Cat.	–	–	
Past		1.065	0.867–1.307	0.549
Current		0.958	0.795–1.154	0.651
Modality of HCC diagnosis				
Surveillance	Ref. Cat.	–	–	
Incidental		0.975	0.826–1.150	0.760
Symptomatic		1.780	1.460–2.169	<0.001
Type 2 diabetes		0.975	0.846–1.125	0.731
MAFLD		0.806	0.681–0.954	0.012
Cirrhosis		1.390	1.028–1.878	0.032
Child–Pugh class				
A	Ref. Cat.	–	–	
B		1.705	1.467–1.983	<0.001
C		4.343	3.414–5.523	<0.001
MELD score		1.062	1.048–1.076	<0.001
ALBI grade				
Grade 1, ≤-2.60	Ref. Cat.	–	–	
Grade 2, >-2.60 ≤-1.39		1.580	1.292–1.932	<0.001
Grade 3, >-1.39		3.791	2.941–4.888	<0.001
APRI				
First tertile	Ref. Cat.	–	–	
Second tertile		1.118	0.921–1.358	0.259
Third tertile		1.627	1.346–1.966	<0.001
ECOG PS				
0	Ref. Cat.	–	–	
1		1.933	1.635–2.285	<0.001
≥2		4.566	3.722–5.601	<0.001
Charlson Comorbidity Index		1.058	1.016–1.102	0.006
Oesophageal varices		1.496	1.298–1.724	<0.001
Platelet count				
>100,000/μl	Ref. Cat.	–	–	
≤100,000/μl		1.174	1.015–1.359	0.031
Alpha-foetoprotein levels				
≤10 ng/ml	Ref. Cat.	–	–	
11–200 ng/ml		1.377	1.169–1.620	<0.001
>200 ng/ml		1.973	1.632–2.386	<0.001
Tumour gross pathology				
Single	Ref. Cat.	–	–	
Multifocal		1.636	1.408–1.900	<0.001
Infiltrative		4.818	3.491–6.651	<0.001
Massive		4.016	2.780–5.800	<0.001
Number of lesions				
1	Ref. Cat.	–	–	
2–3 lesions		1.408	1.187–1.671	<0.001
>3 lesions		2.189	1.804–2.657	<0.001
Size of the greatest lesion				
≤2.0 cm	Ref. Cat.	–	–	
2.1–5.0 cm		1.214	1.012–1.457	0.037
>5 cm		2.283	1.873–2.782	<0.001
MVI				
No	Ref. Cat.	–	–	
Segmental		2.186	1.131–4.226	0.020
Main portal branches		2.282	1.714–3.039	<0.001
Portal trunk/caval vein		2.960	2.362–3.709	<0.001
Metastases		3.075	2.286–4.138	<0.001
ITA.LI.CA tumour stage				
0	Ref. Cat.	–	–	
A		1.103	0.865–1.408	0.429

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Table 3 (continued)

Univariate analysis			
Variables	Exp(B)	95% CI	p value
B1	1.567	1.192–2.062	0.001
B2	1.670	1.264–2.205	<0.001
B3	2.289	1.618–3.239	<0.001
C	3.559	2.719–4.658	<0.001
D	4.426	3.479–5.629	<0.001
Main treatment			
BSC	Ref. Cat.	–	–
Liver transplant	0.024	0.012–0.048	<0.001
Resection	0.086	0.066–0.113	<0.001
Ablation	0.118	0.095–0.147	<0.001
IAT	0.211	0.172–0.259	<0.001
Systemic therapy	0.457	0.339–0.616	<0.001
Others	0.799	0.479–1.331	0.389

Levels of significance: <0.05 (Cox regression model).

ALBI, albumin–bilirubin; APRI, AST to Platelet Ratio Index; BSC, best supportive care; ECOG-PS, Eastern Cooperative Oncology Group Performance Status; HCC, hepatocellular carcinoma; IAT, intra-arterial therapy; ITA.LI.CA, Italian Liver Cancer; MAFLD, metabolic dysfunction associated fatty liver disease; MELD, model for end-stage liver disease; MVI, macrovascular Invasion; Ref. Cat., reference category.

of those with values ranging from to 11–200 ng/ml (32.8%, 27.1%, and 24.4%).

The distribution of ITA.LI.CA stages did not change significantly over time ( $p = 0.136$ ).

### Treatment

The distribution of the main HCC treatments received by the patients changed significantly with time (Table 2). Namely, the proportion of curative treatments (surgery or ablation) and BSC did not change, whereas the proportion of both IAT (from 22.4% to 26.0%) and systemic treatment (from 4.2% to 7.3%) progressively increased ( $p < 0.001$ ). Notably, when sorafenib became available in clinical practice, it became the main systemic treatment, with other agents almost completely disappearing. As a result, in the last quinquennium, approximately 18% of patients underwent surgical interventions, 28% percutaneous ablation, 26% IAT, and 7% received systemic therapy with TKI.

The treatment allocation of patients with NAFLD + cryptogenic and viral HCC across the quinquennia is reported in Table S5.

### Causes of death and survival

During a median follow-up of 24.3 months (25th–75th, 8.1–47.1), 771 patients died (Table 2). The main causes of death were tumour progression (43.2%) and liver failure (21.2%). No differences in the causes of death were observed between patients with MAFLD and those non-MAFLD (Table S2). Their distribution changed across quinquennia ( $p < 0.001$ ), with an increasing death rate attributable to liver failure, bleeding, infections, and embolism; conversely, mortality from tumour progression, kidney failure, and other causes declined (Table 2).

The median a-OS improved in the last quinquennium, being 31.4 months (95% CI 22.6–40.2) in G1, 32.5 months (95% CI 27.6–37.4) in G2, and 49.2 months (n.d.) in G3, although this change did not reach statistical significance ( $p = 0.132$ ) (Fig. 2). The a-OS rates across quinquennia were: 74.6%, 74.0%, and 75.4% at 1 year, 58.4%, 62.2% and 69.3% at 2 years, and 36.4%, 42.1% and 65.5% at 5 years, respectively. The a-OS in the last quinquennium

was compared with the other time periods using a piecewise analysis (using as the starting point 1 year after HCC detection). This analysis showed a significant a-OS improvement (HR, 0.51; 95% CI 0.33–0.78;  $p = 0.002$ , compared with the first quinquennium, and HR, 0.63; 95% CI 0.43–0.94;  $p = 0.023$ , compared with the second quinquennium).

Sensitivity analyses performed in the entire population showed that both the ITA.LI.CA staging system and ALBI grades could efficiently stratify patients according to a-OS (Fig. S1).

Fig. S2 describes the changes over time in a-OS observed in patients with HCC originating from NAFLD + cryptogenic or viral liver disease.

### Uni- and multivariate analyses

In the univariate analysis, the variables associated with a-OS were age, the mode of diagnosis of HCC, the presence of MAFLD and cirrhosis, C–P class, MELD score, ALBI grade, ECOG PS, Charlson Comorbidity Index, presence of oesophageal varices, platelet count, AFP levels, gross pathology, number of lesions, size of the largest lesion, presence of MVI or metastases, ITA.LI.CA stage, and the main treatment for HCC (Table 3).

The independent prognostic factors identified by the three models of the multivariate analysis summarised in Table 4 (each including at least 88% of the initial cases) were as follows:

**Model 1 (C–P-based):** age, C–P class, ECOG PS  $\geq 2$ , oesophageal varices, platelet count, AFP levels, gross tumour pathology, size of the greatest lesion, MVI, and main treatment.

**Model 2 (ALBI-based):** ALBI grade, ECOG PS  $\geq 2$ , oesophageal varices, platelet count, AFP levels, gross tumour pathology, size of the largest lesion, MVI, and main treatment.

**Model 3 (ITA.LI.CA-based):** oesophageal varices, ITA.LI.CA tumour stage, and main treatment.

Notably, oesophageal varices and the main treatment were independent prognostic factors in all models. Variables related to tumour burden and liver function were independent prognosticators in Models 1 and 2 and, as components of the ITA.LI.CA stage, even in Model 3.

**Table 4. Multivariate analyses of factors affecting the lead time-adjusted survival, based on three different models.**

Multivariate models									
Variables	Model 1 n = 1,222 (87.9%)			Model 2 n = 1,222 (87.9%)			Model 3 n = 1,235 (88.8%)		
	Exp(B)	95% CI	p value	Exp(B)	95% CI	p values	Exp(B)	95% CI	p value
Age	1.010	1.000–1.020	0.044	1.007	0.998–1.017	0.126	1.006	0.997–1.016	0.187
MAFLD	0.928	0.770–1.119	0.434	0.919	0.764–1.106	0.371	0.910	0.760–1.090	0.307
Cirrhosis	0.960	0.688–1.340	0.811	0.940	0.671–1.317	0.720	1.007	0.723–1.402	0.968
Modality of HCC diagnosis									
Surveillance/Incidental	Ref. Cat.								
Symptomatic	0.980	0.800–1.200	0.841	0.955	0.778–1.173	0.663	1.112	0.912–1.355	0.293
Child–Pugh class				NA	NA	NA	NA	NA	NA
A	Ref. Cat.								
B	1.407	1.179–1.679	<0.001						
C	1.766	1.292–2.414	<0.001						
ALBI grade							NA	NA	NA
Grade 1, ≤-2.60	Ref. Cat.								
Grade 2, >-2.60				1.349	1.082–1.682	0.008			
Grade 3, >-1.39				1.820	1.346–2.460	<0.001			
ECOG PS							NA	NA	NA
0	Ref. Cat.								
1	1.102	0.909–1.336	0.325	1.119	0.924–1.356	0.249			
≥2	1.643	1.265–2.133	<0.001	1.712	1.326–2.211	<0.001			
Platelet count									
>100,000/μl	Ref. Cat.								
≤100,000/μl	1.225	1.035–1.450	0.019	1.214	1.025–1.439	0.025	1.177	0.998–1.387	0.053
Oesophageal varices	1.242	1.052–1.465	0.010	1.261	1.070–1.486	0.006	1.254	1.066–1.475	0.006
Alpha–foetoprotein levels							NA	NA	NA
≤10 ng/ml	Ref. Cat.								
11–200 ng/ml	1.054	0.878–1.266	0.574	1.068	0.890–1.281	0.479			
>200 ng/ml	1.325	1.053–1.667	0.016	1.315	1.044–1.656	0.020			
Tumour gross pathology							NA	NA	NA
Single	Ref. Cat.								
Multifocal	1.145	0.965–1.360	0.122	1.150	0.969–1.366	0.109			
Infiltrative	1.971	1.281–2.869	0.002	1.938	1.296–2.896	0.001			
Massive	1.842	1.165–2.912	0.009	1.931	1.218–3.005	0.005			
Size of the greatest lesion							NA	NA	NA
≤2.0 cm	Ref. Cat.								
2.1–5.0 cm	1.031	0.845–1.257	0.764	1.025	0.840–1.250	0.808			
>5 cm	1.439	1.133–1.827	0.003	1.445	1.138–1.835	0.002			
Metastases	0.991	0.698–1.408	0.960	0.888	0.627–1.260	0.506	NA	NA	NA
MVI							NA	NA	NA
No	Ref. Cat.								
Segmental	1.221	0.620–2.405	0.563	1.273	0.648–2.501	0.483			
Main portal branches	0.865	0.613–1.220	0.409	0.888	0.631–1.250	0.496			
Portal trunk/caval	1.327	1.016–1.734	0.038	1.351	1.036–1.762	0.026			
ITA.LI.CA tumour stage									
0	Ref. Cat.								
A							1.146	0.885–1.483	0.303
B1							1.451	1.070–1.969	0.017
B2							1.389	1.025–1.881	0.034
B3							1.452	0.994–2.121	0.054
C							1.988	1.454–2.718	<0.001
D							2.243	1.692–2.973	<0.001
Main treatment									
BSC	Ref. Cat.								
Liver transplant	0.039	0.019–0.077	<0.001	0.038	0.019–0.077	<0.001	0.035	0.017–0.069	<0.001
Resection	0.176	0.126–0.244	<0.001	0.166	0.120–0.230	<0.001	0.144	0.105–0.198	<0.001
Ablation	0.216	0.164–0.284	<0.001	0.204	0.156–0.267	<0.001	0.180	0.139–0.233	<0.001

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Table 4 (continued)

Variables	Multivariate models								
	Model 1 n = 1,222 (87.9%)			Model 2 n = 1,222 (87.9%)			Model 3 n = 1,235 (88.8%)		
	Exp(B)	95% CI	p value	Exp(B)	95% CI	p values	Exp(B)	95% CI	p value
IAT	0.343	0.267–0.440	<0.001	0.328	0.256–0.420	<0.001	0.286	0.227–0.362	<0.001
Systemic therapy	0.732	0.517–1.036	0.079	0.690	0.489–0.975	0.036	0.577	0.412–0.807	0.001
Others	0.830	0.454–1.517	0.545	0.766	0.422–1.392	0.382	0.886	0.487–1.614	0.693

**Model 1** includes: age, MAFLD, cirrhosis, modality of HCC diagnosis, **Child–Pugh class**, ECOG PS, platelet count, oesophageal varices, alpha-foetoprotein levels, tumour gross pathology, size of the greatest lesion, metastasis, MVI and main treatment.

**Model 2** includes: age, MAFLD, cirrhosis, modality of HCC diagnosis, **ALBI grade**, ECOG PS, platelet count, oesophageal varices, alpha-foetoprotein levels, tumour gross pathology, size of the greatest lesion, metastasis, MVI and main treatment.

**Model 3** includes: age, MAFLD, cirrhosis, modality of HCC diagnosis, platelet count, oesophageal varices, **ITA.LICA tumour stage** and main treatment. Levels of significance:  $p < 0.05$  (Cox regression model).

ALBI, albumin–bilirubin; BSC, best supportive care; HCC, hepatocellular carcinoma; IAT, Intra-arterial therapy; ITA.LICA, Italian Liver Cancer; MAFLD, metabolic associated fatty liver disease; MVI, macrovascular invasion; NA, not assessed; Ref. Cat., reference category.

## Discussion

This multicentre study, including a large cohort of patients managed in the ‘real world’ setting of clinical practice, provides a dynamic picture spanning 15 years of the clinical landscape of alcohol-related HCC in Italy. The ‘all comers’ strategy adopted for the inclusion of patients in the ITA.LICA network did not change over time and therefore the observed variations confidently reflect the evolving clinical scenario that occurred in this population rather than changes as a result of patient referral. Instead, these patients, as well as those with other aetiologies of HCC, could benefit from improvements in the management of HCC and cirrhosis during the data collection period.

All patients reported weekly alcohol intake far beyond the amount considered tolerable, although no healthy amount of alcohol intake exists;<sup>10</sup> indeed, the alcohol-related risk for malignancies starts at a daily dose as low as 10 g.<sup>25</sup> Moreover, as alcohol synergises with other liver carcinogens (infectious and metabolic),<sup>26</sup> its negative effects should be considered when defining a ‘tolerable’ amount of alcohol intake.

Taking these considerations into account, novel information provided by our study suggests that with the advent of the MAFLD definition, most patients with HCC previously classified as having a ‘merely’ alcohol-related disease (according to their alcohol abuse and the apparent absence of other causes of liver injury) migrated to this new taxonomic group (Fig. 1), and their prevalence tended to increase over time. The ‘epidemic’ expansion of metabolic traits among patients with HCC is not sparing other aetiologies.<sup>20</sup> Moreover, as mobility restrictions and social stress caused by the COVID-19 pandemic has led to increased alcohol consumption and increased incidence of metabolic disorders in the general population of many countries, a further increase in the prevalence of patients with chronic liver disease characterised by both offending factors can be anticipated. Our study indicates that dysmetabolic traits are present in most patients with dangerously unhealthy alcohol use, and the lower prevalence of cirrhosis in patients with ‘MAFLD’ compared with merely alcohol-related cases (Table S2) would suggest that these traits boost hepatocarcinogenesis, increasing the risk of HCC

development in pre-cirrhotic stages, as in patients with NAFLD.<sup>19</sup> Unexpectedly, MAFLD (*i.e.* the presence of features of metabolic syndrome) did not independently affect the prognosis of our patients, in whom the fundamental prognosticators remained those usually reported for HCC, such as PS, liver function tests, portal hypertension signs (oesophageal varices and low platelet counts), tumour burden, AFP levels, and HCC treatment. Thus, it can be inferred that once HCC appears in the context of alcohol-related liver disease, the co-presence of features of metabolic disorders does not seem to significantly affect the risk of death. The similar distribution of the causes of death between patients with alcohol-related and alcohol/MAFLD-related HCC supports this hypothesis.

Another meaningful finding of this study is that the proportion of alcohol-related HCC detected by regular surveillance remained below 50% across all 3 quinquennia evaluated. This figure was comparable to that observed in NAFLD + cryptogenic patients during the same study period and was considerably lower than that observed in patients with viral diseases (Table S4). This difference has various well-known causes, including lower awareness of underlying liver disease by patients and/or providers and poorer adherence to surveillance programmes among alcohol abusers.<sup>15</sup> As expected, HCC diagnoses made outside surveillance programmes were associated with worse oncologic profiles, lower amenability to curative treatments, and poorer survival compared with patients diagnosed within surveillance programmes (Table S3). Indeed, the protective role of periodic screening relies on an anticipated cancer diagnosis and increased amenability to curative/effective HCC treatments, as evidenced by the disappearance of the positive prognostic impact of surveillance when challenged by cancer stage in multivariate analysis. The persistent underuse of surveillance led to three sequentially associated key findings of our investigation: (i) modest improvement in cancer burden at the time of diagnosis, (ii) steady use of curative treatments for HCC, and (iii) modest improvement in patient survival. The lack of a significant overall prognostic improvement may rely on the stability of several prognostic determinants over time, such as liver

function, comorbidity burden, and ITA.LI.CA cancer stage, despite some, albeit modest, improvements in relieving tumour burden.

Nevertheless, it should not be overlooked that in the last quinquennium, the a-OS of patients significantly improved when the survival was calculated using as starting point 12 months after HCC diagnosis (Fig. 2). This "delayed" improvement could have several determinants: (a) better management of cirrhosis complications; (b) the observed decrease in tumours with more than three nodules, MVI of extrahepatic veins, and abnormal AFP levels; (c) the increased use of IAT (and its improved outcome);<sup>27</sup> and (d) the abandonment of systemic therapies with unproven efficacy in favour of sorafenib, and the improved results obtained with this therapy over time.<sup>28</sup>

In our study, all HCC treatments produced a benefit compared with BSC, with a clear hierarchical classification, confirming the utility of detecting HCCs in stages that allow to obtain the most effective responses to treatments. Moreover, HCC therapy was an independent prognostic factor in all multivariate models, even when challenged by the cancer stage. Such a finding lends support to the management of patients with HCC according to the 'therapeutic hierarchy' approach, that is treating every patient with the most effective treatment usable according to liver function, PS, tumour burden, and comorbidities, rather than according to a 'stage-dictated' strategy.<sup>22,29</sup>

Our study also showed that the ITA.LI.CA staging system and ALBI grade, both derived from a population of patients with HCC with different aetiologies, provide reliable prognostic information even for the subset of patients with alcohol-related HCC, and hence, can be confidently used in this setting.

Finally, as previously reported,<sup>30</sup> the presence of oesophageal varices is another independent prognostic factor. This is not surprising as varices, which reveal the presence of clinically significant portal hypertension, indicate a more advanced stage of liver disease and a lower amenability to HCC treatments compared with patients without varices. The prognostic significance of oesophageal varices emphasises two important aspects: first, their presence cannot be disregarded in the management of patients with HCC, as pointed out by a recent expert opinion article;<sup>31</sup> second, this variable should be included in prognostic scores for HCC to improve their performance.

Our study has several limitations. First, owing to its retrospective design, it was vulnerable to the effects of unintended biases and, therefore, its results should be scrutinised in this light. Second, an unavoidable drawback of multicentre databases established in clinical practice is the presence of missing data, which can be managed using data imputation methods.

However, these methods need to be carefully applied to avoid potential distortion of results, a risk which increases with the increasing percentage of missing data. Thus, we only applied imputation methods to covariates with <25% of missing data. Consequently, the BMI was excluded from this manipulation, making it impossible to determine its independent prognostic value. Third, analyses of *clinical* databases provide results that are vulnerable to selection bias, which does not disturb the reviews of population-based registries. Therefore, despite our investigation relying on a large, multicentre, and broadly distributed HCC population managed in both academic and non-academic hospitals, the results cannot be generalised to the entire HCC population. Indeed, the Italian population registry currently estimates a 5-year survival rate of approximately 20% for patients with primary liver cancer,<sup>32</sup> a figure much lower than that we observed in the last quinquennium. Fourth, some transient differences between the periods, although statistically significant, may not be clinically meaningful. Conversely, for variables showing a unidirectional trend that eventually reached statistical significance, it can be expected that this behaviour is predictive of forthcoming changes in outcomes of alcohol-related HCC. Fifth, data on alcohol intake after HCC diagnosis were not available and, although only one-fourth of patients were active consumers of alcohol at the time of cancer detection, this drawback prohibited the possibility of testing another potentially important predictor of outcome. Lastly, since the survival of patients with HCC is generally the composite result of a sequence of treatments, particularly in patients diagnosed at early or intermediate stages, the result achieved by any 'main' treatment should be interpreted in this light.

In conclusion, in patients with alcohol-related HCC, any improvement in cancer burden at diagnosis was limited by persistent underuse of surveillance programmes. Consequently, the amenability to curative treatments did not increase, and survival showed only modest improvement. Therefore, achieving marked prognostic improvement relies on the implementation of health policies that can expand the prescription of surveillance strategies and increase patient adherence to these programmes. Moreover, as the presence of oesophageal varices represents an independent negative prognostic factor, this clinical aspect should be carefully considered in the prognosis and management of patients with HCC. Lastly, the clinical features of metabolic disorders are extremely common in patients with alcohol-related liver disease; however, once HCC appears, these may not significantly affect the prognosis of these patients.

## Abbreviations

AFP, alpha-foetoprotein; ALBI, albumin/bilirubin; a-OS, adjusted overall survival; APRI, aspartate aminotransferase-Platelet Ratio Index; BCLC, Barcelona Clinic Liver Cancer; BSC, best supportive care; CCA, cholangiocarcinoma; CEUS, contrast-enhanced ultrasound; C-P, Child-Pugh; ECOG PS, Eastern Cooperative Oncology Group-Performance Status; CT, computed tomography; HCC, hepatocellular carcinoma; HCV, hepatitis C virus; HR, hazard ratio; IAT, intra-arterial treatment; LT, liver transplant;

MAFLD, metabolic dysfunction associated fatty liver disease; MELD, model for end-stage liver disease; MRI, magnetic resonance imaging; MVI, macrovascular invasion; NAFLD, non-alcoholic fatty liver disease; OS, overall survival; PEI, percutaneous ethanol injection; RF, radiofrequency ablation; TACE, transarterial chemoembolisation; TAE, transarterial embolisation; TARE, transarterial radioembolisation; TKI, tyrosine-kinase inhibitor; US, ultrasound.

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### Conflicts of interest

CC (speaker fees, advisory board): Eisai, Ipsen and MSD; EGG (advisory board, consulting fees): Astra Zeneca, Eisai, MSD, and Roche; FGF (advisory board, consulting fees): AbbVie, Bayer, Eisai, Gilead, MSD, and Intercept; FP (consulting or lecture fees): Astra Zeneca, Bayer, Bracco, Eisai, ESAOTE, Exact Sciences, IPSEN, MSD, Roche, Samsung, and Tiziana Life Sciences; GR (lectures, advisory board, consulting fees): Gilead, Alfa Wasserman, Intercept, and Eisai; FT (research grant, advisory board, consulting fees): Astra Zeneca, AbbVie, Bayer, Eisai, Gilead, MSD, and Roche.

Please refer to the accompanying ICMJE disclosure forms for further details.

### Authors' contributions

Concept of the study: FT, LB, NR, VS. Statistical analysis: LB. Drafting of the manuscript: FT, LB, NR, VS. Data collection, revision for important intellectual content and approval of the final manuscript: all authors. Guarantors of the article: NR, FT.

### Data availability statement

The data of this study were supplied by the ITA.LI.CA Consortium and confidential patient level data are available from this Consortium upon motivated request to the guarantor(s) (FT).

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### Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jhepr.2023.100784>.

### Appendix

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