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Delphi survey to explore core curriculum for training the next generation of hepatologists

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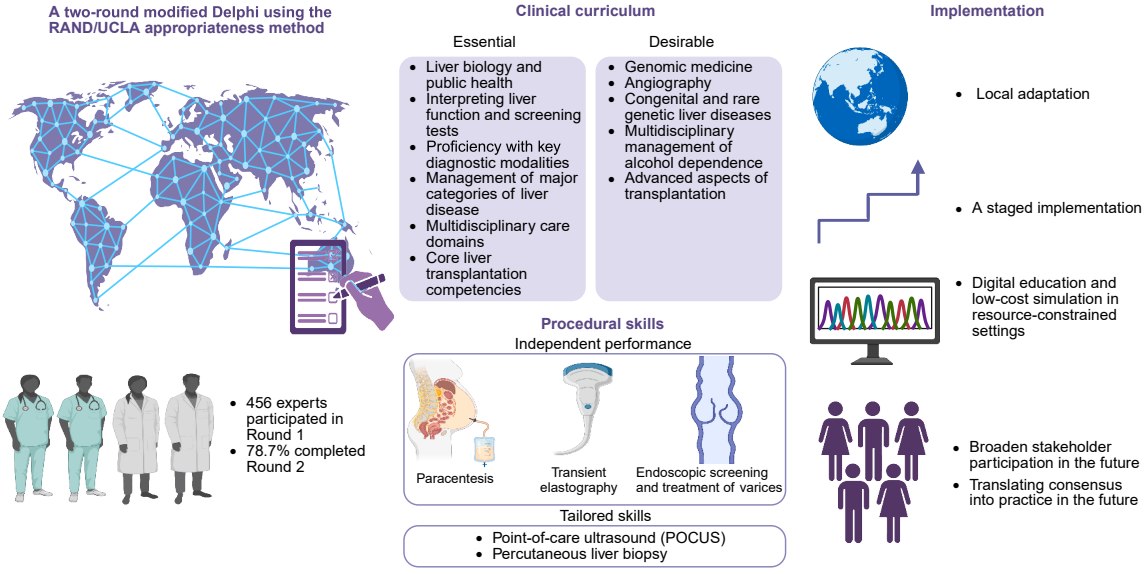
Graphical abstract



Highlights:

- This global Delphi consensus defines priority-stratified core hepatology training content.
- Essential competencies include diagnostic interpretation, disease management, and key procedures.
- Variability in advanced and resource-dependent areas highlights the need for adaptable, staged curriculum implementation.

Impact and implications:

Our study provides a consensus-based, priority-stratified framework for core hepatology training content that may inform curriculum development and local adaptation, given the growing global burden of liver disease and the heterogeneity of training standards. This framework may support curriculum mapping and local adaptation for trainees, program directors, professional societies, and policymakers, including in settings where structured hepatology training pathways are still evolving. In practical terms, these findings may assist educators and institutions in reviewing and refining national curricula and training structures. However, specific implementation decisions, including accreditation requirements and procedural training standards, will need to be adapted to local regulatory and resource contexts. Recognizing that these recommendations are based on expert consensus rather than outcome data and may be variably implementable in resource-limited settings, the next steps are pilot implementation in diverse settings, evaluation of trainee and patient outcomes, and iterative revision, supported by coordinated efforts from societies, governments, and training institutions.

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JHEP|Reports

Delphi survey to explore core curriculum for training the next generation of hepatologists☆

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Background & Aims: Hepatology is experiencing major shifts in disease etiologies and is raising demand for multidisciplinary care. However, a globally harmonized framework defining core training content remains lacking. We aimed to develop a globally informed expert consensus framework for the content of core hepatology training, to provide a structured foundation for curriculum development.

Methods: A two-round modified Delphi using the RAND/UCLA Appropriateness Method was conducted. A comprehensive list of curriculum items was developed from international training standards, refined by a steering committee, and rated by a stratified international panel. Consensus was determined using medians and a disagreement index (DI), which classified curriculum items as essential, desirable, or optional.

Results: A total of 456 experts completed Round 1, of whom 78.7% also completed Round 2. Consensus was strongest for foundational knowledge and core diagnostic skills, including interpretation of abnormal liver function and liver screening test results, and non-invasive fibrosis assessment (both DI = 0). Management of major liver diseases was consistently prioritized as essential. Procedures with the highest endorsement for independent performance were paracentesis, transient elastography, variceal screening, and endoscopic variceal therapy. Consensus was limited for conventional ultrasonography and advanced interventions, reflecting regional variability in resources and scope of practice. Most experts (79.1%) supported formal training in research methodology, and the median recommended fellowship length was 24 months. Subgroup differences were mainly observed in selected resource-dependent or highly specialized items.

Conclusions: This global consensus offers a priority-stratified outline of core hepatology training content providing a practical foundation for curriculum development and staged implementation across diverse health systems.

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Introduction

Liver disease represents a substantial and escalating global challenge: annual deaths rose from about 1.01 million in the 1990s to 1.47 million in 2019,[1] with an estimated 1.7 billion people currently affected by chronic liver disease.[2,3] The burden falls disproportionately on working-age adults and, despite a projected modest decline in age-standardized mortality to 156.29 per 100,000 person-years by 2050, the global incidence of liver disease is expected to continue rising.[2]

Clinical practice in liver diseases has been reshaped by curative therapy for HCV and immunization for HBV, alongside surges in harmful alcohol use, type 2 diabetes, and obesity.[4,5]

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Care has shifted upstream from managing end-stage complications to active screening and early intervention, and now routinely requires multidisciplinary collaboration across hepatology, metabolic care, and cancer services (*e.g.* metabolic dysfunction-associated steatotic liver disease [MASLD][6] and hepatocellular carcinoma [HCC]).[7] Even in end-stage liver disease, traditionally considered a core domain of hepatologists' service, a multidisciplinary understanding of organ cross-talk (*e.g.* renal, brain, circulatory, pulmonary, fat), as well as management options (*e.g.* intensive care medicine, infectious diseases, interventional radiology, surgery, transplantation medicine), is now routinely expected.[8]

Despite these growing challenges, the workforce needed to care for patients with liver diseases remains insufficient. Modeling in the USA projects shortages of adult hepatologists at 10%, 23%, and 35% in 2023, 2028, and 2033, respectively.[9] In the UK, long-standing vacancies, trainees' preference for hepatology posts in specialist liver centers over non-specialist centers[10] and impending retirements compound the gaps. Approximately 50% of current specialists are expected to retire within the next 10 years.[11–13] Shortages are starker in low- and middle-income countries (LMICs).

As the landscape evolves amid new challenges, the competencies for future hepatologists need to be redefined, yet no globally agreed framework aligns training with contemporary practice. In the USA, the Accreditation Council for Graduate Medical Education (ACGME) and the American Board of Internal Medicine (ABIM) offer an integrated 3-year pathway in gastroenterology and transplant hepatology.[14] However, the American Gastroenterological Association (AGA) core curriculum, developed in 2003, has not been updated.[15] In the European Union, programs are not harmonized, and hepatology is often embedded within gastroenterology, with variable attention to non-technical skills.[16] In the UK, the Gastroenterology Curriculum 2022, approved by the General Medical Council (GMC), anchors hepatology training, but it is designed for the National Health Service context and only partially covers emerging etiologies (*e.g.* MASLD, alcohol-related disease).[11]

Training in hepatology in LMICs appears even less structured. The burden in LMICs is driven by both viral and non-viral diseases. Ten countries account for nearly two-thirds of HBV/HCV infections and deaths. The WHO African Region accounts for about 63% of new HBV infections, with birth-dose vaccination coverage of only 18%. The Western Pacific accounts for 47% of HBV deaths with suboptimal treatment coverage.[17] MASLD prevalence is also high and rising across Latin America, the Middle East, North Africa, South Asia, and Southeast Asia.[18] However, hepatology training pathways are largely absent in LMICs.

Modern hepatology training is increasingly framed within competency-based medical education (CBME), rather than purely time-based training models.[19] These approaches aim to better align training structures with clinical practice and evolving health-system needs. In parallel, rapid advances in diagnostics, genomics, MASLD, and multidisciplinary cancer care, underscore the need for a structured, adaptable framework to define core hepatology training content.[6,7,20]

Despite this, substantial heterogeneity persists across regions in hepatology training pathways, and a globally harmonized framework for core training content remains lacking. This gap may contribute to inequities in access to core hepatology competencies, particularly in resource-limited settings and LMICs. Against this background, we conducted an international, RAND/UCLA-guided Delphi study among hepatology experts to develop a globally informed consensus framework that identifies and prioritizes core training content for the next generation of hepatologists, providing a foundation for subsequent competency-based curriculum development and local adaptation.

Materials and methods

Two-round modified Delphi using the RAND/UCLA Appropriateness Method

We used a two-round modified Delphi (Fig. 1) to identify and prioritize core training content, using anonymous expert ratings and structured inter-round feedback to minimize dominance bias and build consensus.[21] Disagreement was assessed using a modified Delphi approach informed by the RAND/UCLA Appropriateness Method (RAM),[22] which integrates structured expert ratings with predefined quantitative rules.[22] For each item, we reported the median and a disagreement index (DI). According to the RAND/UCLA Appropriateness Method, disagreement among panel ratings is assessed by comparing the interpercentile range (IPR, 30th–70th percentile) with the interpercentile range adjusted for symmetry (IPRAS).[22] The IPR reflects the dispersion of ratings across experts, with larger values indicating greater variability. However, dispersion alone does not necessarily imply true disagreement, as ratings may be widely distributed but consistently skewed toward one end of the scale. To account for this, the IPR is adjusted for asymmetry relative to the midpoint of the scale, generating the IPRAS. Disagreement is considered present when IPR >IPRAS and absent when IPR ≤IPRAS. Based on this framework, a DI, calculated as IPR/IPRAS, is <1 in the absence of disagreement and ≥1 when the RAM criterion for disagreement is met, and lower values reflect greater agreement among experts.

Item generation and steering

Candidate items were derived from existing curricula, including the AGA hepatology training materials and the US gastroenterology core curriculum, and supplemented by curriculum outlines from medical schools and professional societies across multiple regions, including the USA, Europe, and Asia-Pacific (Table S1). A steering committee of senior hepatology educators (M-HZ, YS, and JG) defined the scope and terminology, resolved overlapping content, and approved the Round 1 (R1) questionnaire.

Expert panel

We convened an international expert panel using stratified purposive sampling, following RAM guidance to ensure legitimacy and broad dissemination.[22] To minimize selection bias, experts were selected to provide comprehensive representation across major international hepatology and gastroenterology societies, including the AASLD, EASL, Asian Pacific Association for the Study of the Liver (APASL), Latin American Association for the Study of the Liver (ALEH), and International Liver Transplantation Society (ILTS), as well as across geographic regions (Asia, Europe, Africa, and the Americas)

Fig. 1. Flowchart of the modified Delphi process. The figure illustrates the five sequential stages of the study. The process began with a preparation phase to generate items and assemble the expert panel. This was followed by the first survey in the Round 1 (R1) modified Delphi survey. An inter-round revision, informed by expert feedback from R1, preceded the Round 2 (R2) modified Delphi survey. The process concluded with the data analysis and consensus phase to define the final curriculum.

and World Bank income groups (low, lower middle, upper middle, and high income). Participants from both transplant and non-transplant centers were included to ensure the panel captured the full spectrum of clinical practice and variations in resource availability. Eligibility criteria included ≥3 years of post-training experience in hepatology or liver transplantation, active clinical and/or academic practice, prior involvement in education, guideline development, or consensus activities, and absence of conflicts of interest.

Rounds and analyses

The initial questionnaire was distributed via Google Forms to the invited experts to ensure anonymity and facilitate iterative feedback. In R1, 63 items (Table S2) were grouped into nine themes: (1) basic knowledge, (2) disease diagnosis, (3) disease management, (4) medications, (5) non-invasive testing, (6) imaging, (7) genomics, (8) research methods, and (9) procedures. Panel members rated each item on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). R1 results served as the reference for developing the Round 2 (R2) questionnaire. The R2 questionnaire was further refined through expert feedback, wording revisions, removal of redundancies, and the addition of a new topic.[23]

After completing R1, the study design was refined in line with predefined methodological considerations. Although the 5-point Likert scale captured the degree of agreement, it did not adequately reflect the prioritization required for curriculum development. Therefore, the objective of R2 was refined to classify items into priority categories for inclusion in the curriculum. Accordingly, questionnaire items were reviewed for clarity, and redundant items were removed. The response format for knowledge-based competencies was adapted to an essential-desirable-optional structure, whereas procedural competencies were classified as independent, performable, or not, to better align with curriculum prioritization objectives. Based on free-text expert feedback and a review of the latest literature and guidelines by the steering committee, a few new topics were added. The revised questionnaire, including supplementary topics and the controversial items retained for re-evaluation, is provided in the supplementary appendix (Table S3) and encompasses seven domains: (1) basic

knowledge, (2) diagnostic tools and approaches, (3) management of liver diseases and complications, (4) expertise in liver transplantation, (5) procedural skills, (6) research activities, and (7) training duration and clinical exposure.

Items with a DI <1 were considered to meet the prespecified threshold for absence of disagreement. Curricular items were further classified as essential (median = 3), desirable (median = 2), or optional (median = 1). Procedural skills items were classified based on whether independent performance during fellowship was endorsed. Items with DI≥1 were considered not to have reached consensus and were flagged for further discussion.[22]

Results

Delphi panel characteristics

A total of 456 experts completed Round 1 (R1) (Fig. S1). In Round 2 (R2), 359 participants (78.7% of R1 respondents) completed the survey (the full participant list is provided in the Supplementary Appendix). The Delphi panel included members of major international hepatology and gastroenterology societies (Fig. S2A). As shown in Table 1 and Fig. S2B, the panel was demographically and professionally diverse. Participants were from more than 50 countries (Fig. S2C). The majority (85.7%) were aged 35–65 years. Most experts were affiliated with academic institutions (55.4%), followed by the public sector (32.6%), the private sector (8.1%), and other settings (3.9%). A majority (68.5%) reported involvement in gastroenterology/hepatology training programs, followed by hepatology fellowships (11.1%) and transplant hepatology fellowships (10.0%). Most participants (72.5%) had more than 10 years of post-training experience.

Table 1. Demographic and professional characteristics of Round 2 panelists (n = 359).

Characteristics	
Sex	n (%)
Male	236 (65.7)
Female	117 (32.6)
Not available	6 (1.7)
Age, years	
<35	23 (6.4)
35–45	101 (28.1)
45–55	138 (38.4)
55–65	69 (19.2)
>65	22 (6.1)
Not available	6 (1.7)
Primary sector of employment	
Academic	199 (55.4)
Public	117 (32.6)
Private	29 (8.1)
Other	14 (3.9)
Primary field/area of work	
Healthcare provider	236 (65.7)
Clinical research	105 (29.2)
Non-clinical research	3 (0.8)
Other	15 (4.3)
Training experience of hepatologist fellowship program	
GI and hepatology fellowship program	246 (68.5)
Independent hepatology fellowship program	40 (11.1)
Transplant hepatology fellowship program	36 (10.0)
None	15 (4.2)
Other	22 (6.2)
Years working in the field post-training	
<5	42 (11.7)
5–10	51 (14.2)
10–20	136 (37.9)
20–30	90 (25.1)
>30	34 (9.5)
Not available	6 (1.7)
% of work in hepatology-related clinical care, research, or both	
0–25	42 (11.7)
26–50	55 (15.3)
51–75	123 (34.3)
76–100	133 (37.0)
Not available	6 (1.7)

Consensus outcomes

Curricula

Both domains within 'Basic Knowledge' were deemed essential (DI <1; median = 3), namely liver anatomy and physiology and the public health dimensions of liver diseases (Fig. 2A).

Within 'Diagnostic Tools and Approaches', the interpretation of abnormal liver function and liver screen test results, and non-invasive fibrosis assessment, achieved complete agreement (DI = 0; median = 3). Interpretation of liver imaging, liver biopsy, and hepatic venous pressure gradient (HVPG) was also consistently rated as essential (DI = 0.41–0.43; median = 3), whereas interpretation of genomics testing and angiography was considered desirable (DI = 0.41-0.85; median = 2) (Fig. 2).

'Management of Liver Diseases and Complications' showed a uniformly high level of consensus for core hepatology conditions, including major viral, metabolic, alcohol-related, autoimmune, drug-induced, and cholestatic liver diseases, as well as acute liver failure and acute-on-chronic liver failure (DI = 0; median = 3). Broader clinical domains encompassing multidisciplinary management of obesity, IgG4-related sclerosing cholangitis, critical care hepatology, nutrition and frailty, palliative care, pregnancy-related liver disease, hepatobiliary malignancies, liver benign tumors, vascular inherited hepatobiliary conditions, hepatobiliary bacterial infections, systemic diseases, cholelithiasis, and parasitic liver diseases were also predominantly rated as essential (DI = 0.41-0.43; median = 3). A smaller subset of items, including rare genetic and congenital hepatobiliary disorders and multidisciplinary management of alcohol dependence/relapse, was rated as desirable (DI = 0.41–0.82; median = 2) (Fig. 2).

In 'Liver Transplantation', core competencies included candidate evaluation, waitlist management, prioritization in resource-limited settings, early surgical and medical complications, and management of long-term complications (DI = 0.41-0.82; median = 3). More specialized areas, including allocation policy, transplant immunology, ethics and legal issues, live donor-liver transplantation assessment, marginal liver grafts, procurement and transplant operations, and perfusion preservation strategies, were considered desirable (all DI = 0.82; median = 2) (Fig. 2).

Procedural skills

For procedural skills, several core competencies were strongly endorsed for independent performance during fellowship, including abdominal paracentesis (95.5%, DI = 0.21), transient elastography (FibroScan® [Echosens, Paris, France] 91.1%, DI = 0.93), endoscopic screening or assessment of varices (83.3%, DI = 0.93), and endoscopic variceal therapy (81.1%,

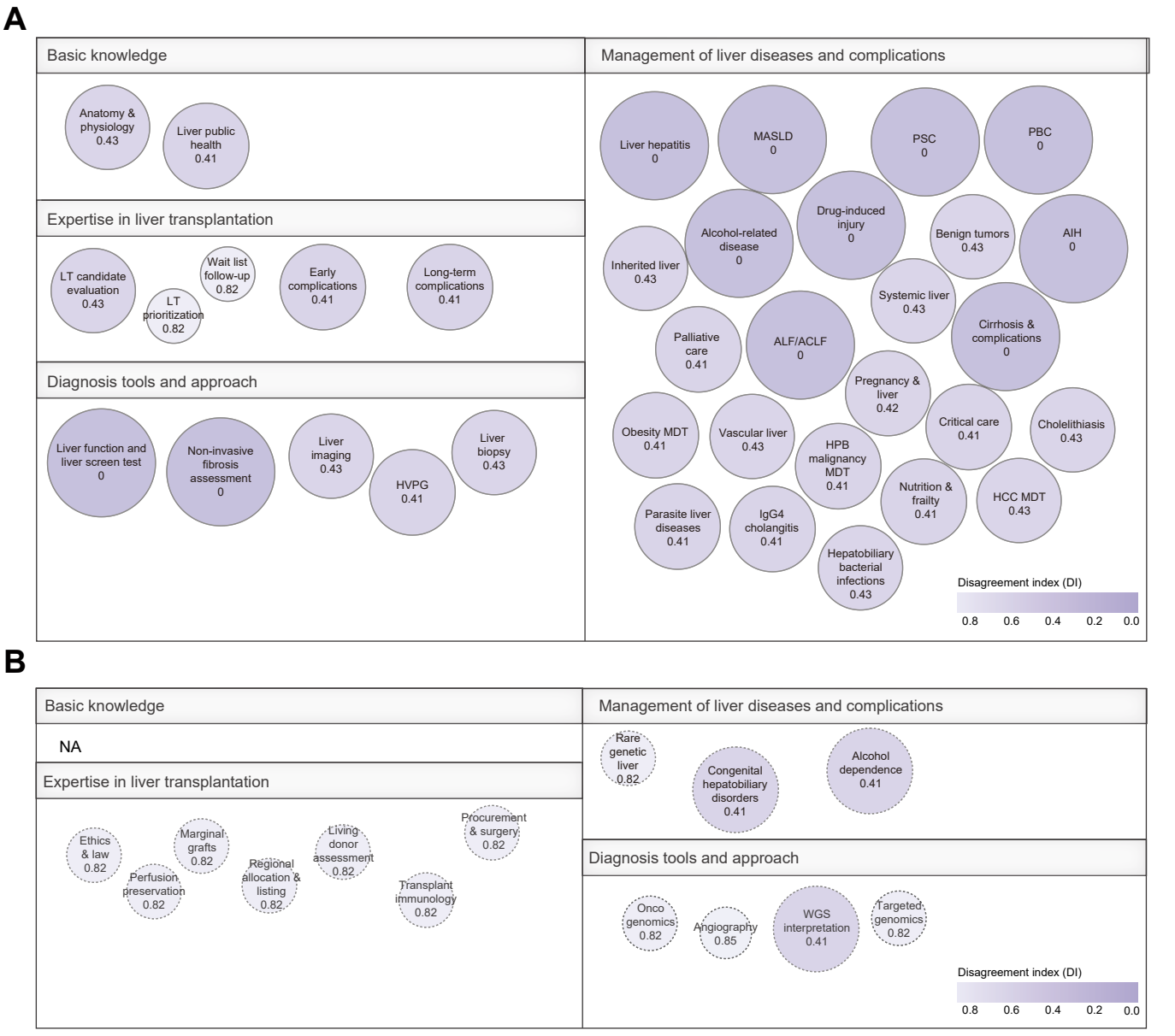

Fig. 2. Global consensus map of curriculum items across four domains. Each circle represents one curriculum item (panels: Basic knowledge; Diagnosis tools and approach; Management of liver diseases and complications; Expertise in liver transplantation). Circle size and color intensity are inversely proportional to the Disagreement Index (DI), and larger and darker circles indicate lower disagreement. In this study, DI <1 was used as the prespecified operational threshold for no disagreement/consensus. (A) Circles with solid outlines present essential items (DI <1 and median = 3). (B) Circles with dashed outlines indicate desirable items (DI <1 and median = 2). Labels show the short item name and its DI value. The DI was defined as the interpercentile range (30th to 70th) divided by the interpercentile range adjusted for symmetry (IPRAS). Detailed item descriptions are provided in Tables S4A–D. ACLF, acute-on-chronic liver failure; AIH, autoimmune hepatitis; ALF, acute liver failure; DI, Disagreement Index; HCC, hepatocellular carcinoma; HPB, hepatopancreatobiliary; HVPG, hepatic venous pressure gradient; LT, liver transplantation; MASLD, metabolic dysfunction-associated steatotic liver disease; MDT, multidisciplinary team; PBC, primary biliary cholangitis; PSC, primary sclerosing cholangitis; WGS, whole-genome sequencing.

DI = 0.31). Moderate support was observed for point-of-care ultrasound (POCUS) (66.0%, DI = 0.93) and percutaneous liver biopsy (64.4%, DI = 0.21). In contrast, conventional ultrasonography did not meet the prespecified threshold for absence of disagreement (65.2%, DI = 8.51). More advanced interventions, including advanced endoscopic techniques (27.0%, DI = 0.93), catheter drainage of liver abscess (24.8%, DI = 0.16), artificial liver support (21.7%, DI = 0.21), transjugular liver biopsy (19.8%, DI = 0.42), interventional procedures for HCC (16.4%, DI = 0.42) and specialized procedures for portal hypertension (15.3%, DI = 0.42), received substantially lower endorsement overall (Fig. 3).

Research activities

Most experts (79.1%) supported inclusion of formal research methodology training, with a median training duration of 6 months. Among preferred research topic areas, clinical trials (74.65%) and translational science (57.39%) were most frequently endorsed, followed by data science (48.94%) and

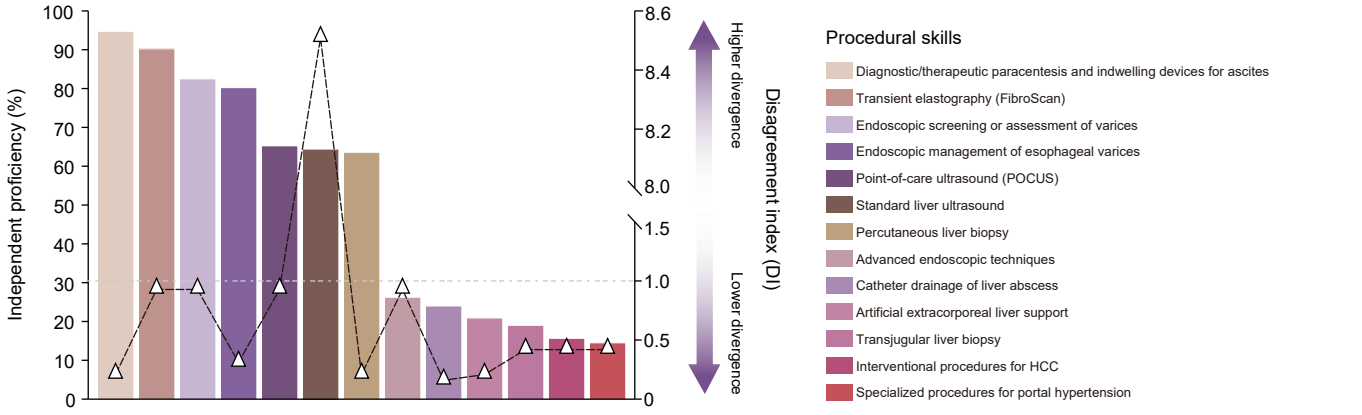

Fig. 3. Consensus on procedural skills for independent performance during fellowship. The bars (left y-axis) represent the percentage of experts who endorsed that trainees should be able to perform each procedure independently. The line plot (right y-axis) displays the Disagreement Index (DI) for each item, with lower values indicating stronger consensus (less divergence) among the experts. A DI <1 was used as the prespecified operational threshold for no disagreement/consensus. The DI was defined as the interpercentile range (30th to 70th) divided by the interpercentile range adjusted for symmetry (IPRAS). DI, Disagreement Index; HCC, hepatocellular carcinoma.

basic science (38.73%) (Fig. 4A). Research methodologies emphasized evidence-based medicine (85.92%), academic writing (73.94%), clinical epidemiology and biostatistics (71.13%), and study design (70.77%). Lower endorsement was observed for artificial intelligence (45.77%), bioethics (33.80%), bench research skills (28.52%), and health care economics (24.30%) (Fig. 4B).

Training duration and clinical exposure

Panelists also rated key elements of program design, including total training duration and the time allocated to outpatient and inpatient settings. The median recommended total training duration was 24 months, with 9 months of outpatient training and 12 months of inpatient training.

Subgroup analyses

By region, most core curriculum items showed consistent ratings across geographic groups, with differences largely confined to resource-dependent or highly specialized areas (Table 2). African experts assigned lower priority to independent HVPG performance than did Western and Asian experts (p <0.001), whereas obesity management was rated higher in Asia and Africa (p <0.001). Modest regional variation was observed for genomic topics, such as whole-genome sequencing (p = 0.011) and genomic testing for hepatobiliary malignancies (p = 0.028), although these items generally remained within the desirable range. Core bedside procedures were broadly consistent across regions. In contrast, substantial heterogeneity was observed for more advanced interventions, including liver abscess drainage, interventional

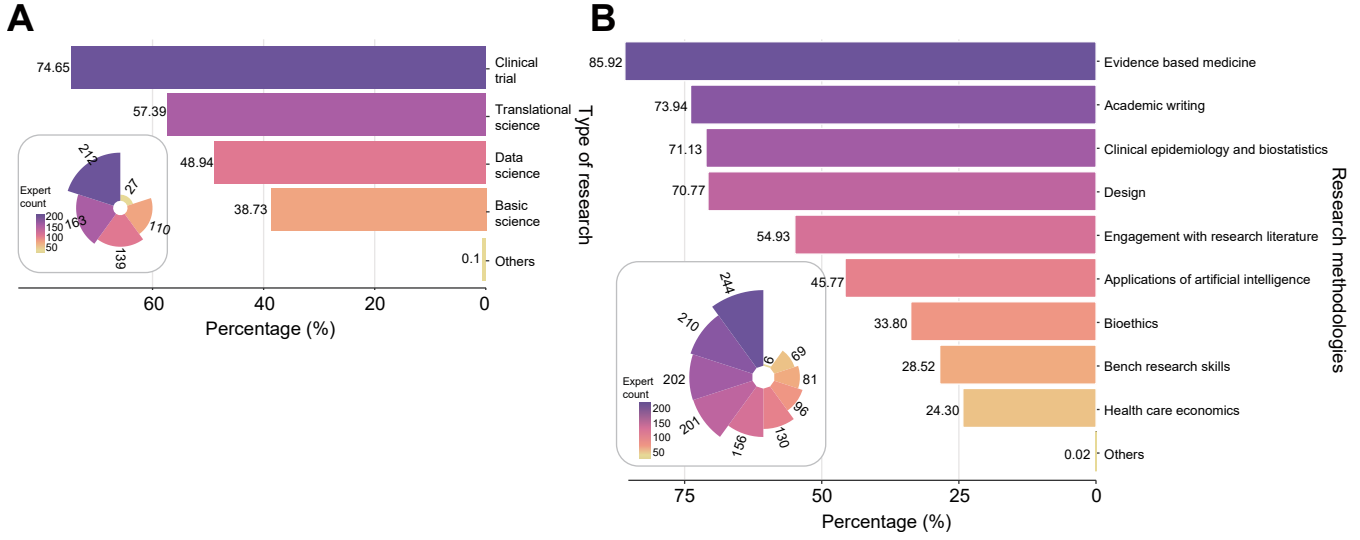

Fig. 4. Expert consensus on priorities for research training. The charts display the preferences of experts who supported making formal research training a compulsory component of specialized courses (n = 284). (A) Preferred types of research. The horizontal bar chart shows the percentage of experts endorsing each research type. The radial bar chart at the bottom left displays the corresponding absolute number of experts, with color gradients indicating the count. (B) Essential research methodologies. The charts are similarly structured to show the percentage and absolute number of experts endorsing each methodology. As experts could make multiple selections, the percentages do not sum to 100%.

Table 2. Subgroup analysis by geographic region.

	Asia-specific	Western countries	Africa-specific	*p* values
Basic knowledge				
Liver anatomy and physiology	3	3	3	0.274
Public health aspects of obesity, alcohol, viral hepatitis, and HCC: epidemiology/burden, social and economic impact, prevention strategies, and healthcare policies	3	3	3	0.834
Diagnosis tools and approach				
Liver biopsy (indications, contraindications, complications, and report interpretation)	3	3	3	0.013*
Interpretation of abnormal liver function and liver screen test results	3	3	3	0.008**
Interpretation of sequencing report of target genes (*e.g.* ATP7B mutations for Wilson's disease)	2	2	2	0.324
Interpretation of WGS	2	1	2	0.011*
Interpretation of genomic tests on hepatobiliary malignancies	2	2	2	0.028*
Interpretation of liver imaging (US, CT, MR, and MRCP)	3	3	3	0.228
Interpretation of angiography	2	2	2	0.314
Interpretation of non-invasive tests for fibrosis assessment	3	3	3	0.007**
HVPG: indications, contraindications, complications, and report interpretation	3	3	2	<0.001***
Management of liver diseases and complications				
Viral hepatitis (hepatitis A, B, C, D, E) and non-hepatotropic viral hepatitis	3	3	3	0.581
MASLD	3	3	3	0.050
Multidisciplinary management of obesity	3	2	3	<0.001***
Congenital hepatobiliary disorders	2	2	2	0.761
Alcoholic hepatitis and alcohol-related liver disease	3	3	3	<0.001***
Multidisciplinary management of alcohol dependence/relapse	3	2	3	0.051
Drug-induced liver injury	3	3	3	0.462
Autoimmune hepatitis	3	3	3	0.335
Primary biliary cholangitis	3	3	3	0.072
Primary sclerosing cholangitis	3	3	3	0.029*
IgG4-related sclerosing cholangitis	3	3	3	0.451
Inpatient and outpatient management of cirrhosis and its complications (such as ascites, hydrothorax, hyponatremia, spontaneous bacterial peritonitis, hepatic encephalopathy, varices/variceal bleeding, and hepatorenal syndrome-acute kidney injury)	3	3	3	0.006**
Acute liver failure and acute-on-chronic liver failure	3	3	3	0.561
Intensive care of critically ill patients with liver diseases	3	2	3	<0.001***
Symptom-based and palliative care of end-stage liver diseases	3	3	3	0.108
Screening, assessment, and multidisciplinary management of malnutrition, sarcopenia, and frailty in patients with chronic liver diseases	3	3	3	0.954
Evaluation, follow-up, and management of pregnancy-related liver diseases (*e.g.* acute fatty liver of pregnancy, intrahepatic cholestasis of pregnancy) and chronic liver diseases during pregnancy	3	3	3	0.182
Screening, diagnosis, and management of hepatocellular carcinoma, and MDT working on HCC treatment modalities	3	3	3	0.068
Diagnosis and management of other hepatobiliary malignancies (*i.e.* cholangiocarcinoma, metastatic liver tumors, and gallbladder cancer), and MDT working on treatment modalities	3	3	3	0.961
Diagnosis of benign tumors of the liver (*e.g.* hemangioma, hepatocellular adenoma, focal nodular hyperplasia)	3	3	3	<0.001***
Vascular liver disorders (*e.g.* Budd–Chiari syndrome, portal vein thrombosis, portosinusoidal obstruction syndrome, idiopathic non-cirrhotic portal hypertension)	3	3	3	0.133
Inherited liver diseases (Wilson's disease, hemochromatosis, and alpha-1 antitrypsin deficiency)	3	3	3	0.003**
Other rare genetic liver diseases (*e.g.* Alagille syndrome, Caroli disease, Caroli syndrome, and progressive familial intrahepatic cholestasis)	2	2	2	0.182
Hepatobiliary bacterial infections (*e.g.* liver abscess and bacterial cholangitis)	3	3	3	0.840
Parasite liver diseases (*e.g.* echinococcosis of the liver)	3	2	3	0.237
Cholelithiasis	3	3	3	0.446

(*continued on next page*)

Table 2. (*continued*)

	Asia-specific	Western countries	Africa-specific	*p* values
Liver involvement of systemic diseases (*e.g.* sepsis, heart failure, malignancies, sarcoidosis, cystic fibrosis)	3	3	3	0.569
Expertise in liver transplantation				
Evaluation and selection of eligible candidates for liver transplantation	3	3	3	0.591
Working knowledge of transplant immunology (*e.g.* tissue compatibility/typing, infectious and malignant complications of immunosuppression)	2	2	2.5	0.078
Regional organ allocation policy, allocation, and listing policies	2	2	2	0.474
Prioritize patients for liver transplantation in resource-limited settings	3	2	3	0.258
Legal, social, ethical, and cultural issues in liver transplantation	3	2	2.5	0.118
Assessment of recipients and donors for live donor-liver transplantation	3	2	3	<0.001***
Perfusion preservation strategies	2	2	2	0.002**
Use of marginal liver grafts	2	2	2	0.128
Liver procurements and transplant operations	2	2	2	0.055
Management and follow-up of patients on the waiting list	3	3	3	0.048*
Recognition of early surgical and medical complications (infection, acute rejection)	3	3	3	0.465
Management of long-term complications (*e.g.* chronic rejection, disease recurrence, renal dysfunction, cardiovascular diseases, new-onset diabetes)	3	3	3	0.497

Statistical analysis was performed using the Kruskal–Wallis test. All *p* values reported are two-tailed, with statistical significance set at $p < 0.05$. * $0.01 < p < 0.05$, ** $0.001 < p < 0.01$, *** $p < 0.001$.

CT, computed tomography; DI, Disagreement Index; HCC, hepatocellular carcinoma; HVPG, hepatic venous pressure gradient; MASLD, Metabolic dysfunction-associated steatotic liver disease; MDT, multidisciplinary team; MR, magnetic resonance imaging; MRCP, magnetic resonance cholangiopancreatography; US, ultrasound, WGS, whole-genome sequencing.

procedures for HCC, advanced endoscopy, procedures for portal hypertension, artificial liver support, and variceal interventions (all $p < 0.01$) (Fig. 5A).

By income group, a similar pattern was observed, with overall consistency for core curriculum items and divergence mainly in advanced or resource-dependent domains (Table 3). Whole-genome sequencing was rated lower in high-income settings than in middle- and low-income settings ($p < 0.001$), whereas liver biopsy was rated lower in low-income settings ($p = 0.003$). Experts from low-income countries placed greater emphasis ($p = 0.017$) on transplant-related issues in resource-limited contexts, including ethical considerations and living-donor assessment ($p < 0.001$). Core bedside procedures again showed minimal variation across income groups. However, advanced procedures showed marked heterogeneity. Trainees in low-income settings were more often considered capable of independent performance, whereas experts in high-income settings adopted a more conservative approach, particularly for advanced imaging, liver biopsy, interventional procedures for HCC, advanced endoscopy, portal hypertension procedures, and artificial liver support (Fig. 5B).

Discussion

This study presents a globally informed, priority-stratified outline of core hepatology training content, bridging the widening gap between the rising burden of liver disease and existing national pathways. Our consensus preserves core clinical and procedural competencies while incorporating key advances over the past two decades, including non-invasive fibrosis assessment, prioritization of MASLD and obesity management, training across the transplant continuum,[6] and a greater emphasis on genomics.[20,24] These updates reflect evolving clinical practice: curative antivirals have shifted focus from interferon-era complications to long-term outcomes and HCC surveillance, non-invasive tools increasingly replace biopsy, and the rising burden of metabolic and alcohol-related liver disease underscores the need for multidisciplinary care.[25,26] The expanding use of molecular diagnostics for inherited disorders further reinforces the importance of genomics training. Within this framework, essential liver test interpretation, management of major hepatology conditions, and foundational transplant medicine are reaffirmed as core components, alongside procedural competencies, such as abdominal paracentesis, endoscopic variceal screening and therapy, and elastography, that should be performed independently during fellowship. In contrast, advanced endoscopic techniques are recommended for optional training in specialized centers, and interventional procedures are not expected for independent practice. Collectively, this structured yet flexible framework provides a practical foundation for curriculum development across diverse healthcare settings.

Overall, the international consensus was strong, though subgroup analyses revealed regional heterogeneity. African experts placed less emphasis on HVPG training, likely reflecting limited availability. Obesity management was prioritized in Asia and Africa but considered desirable in Western settings, possibly reflecting the rising burden of MASLD and gaps in multidisciplinary care pathways in these regions.[27] Conversely, support for whole-genome sequencing was lower in high-income countries, where interpretation is typically performed by clinical geneticists, whereas in lower-resource settings, hepatologists may engage more directly through

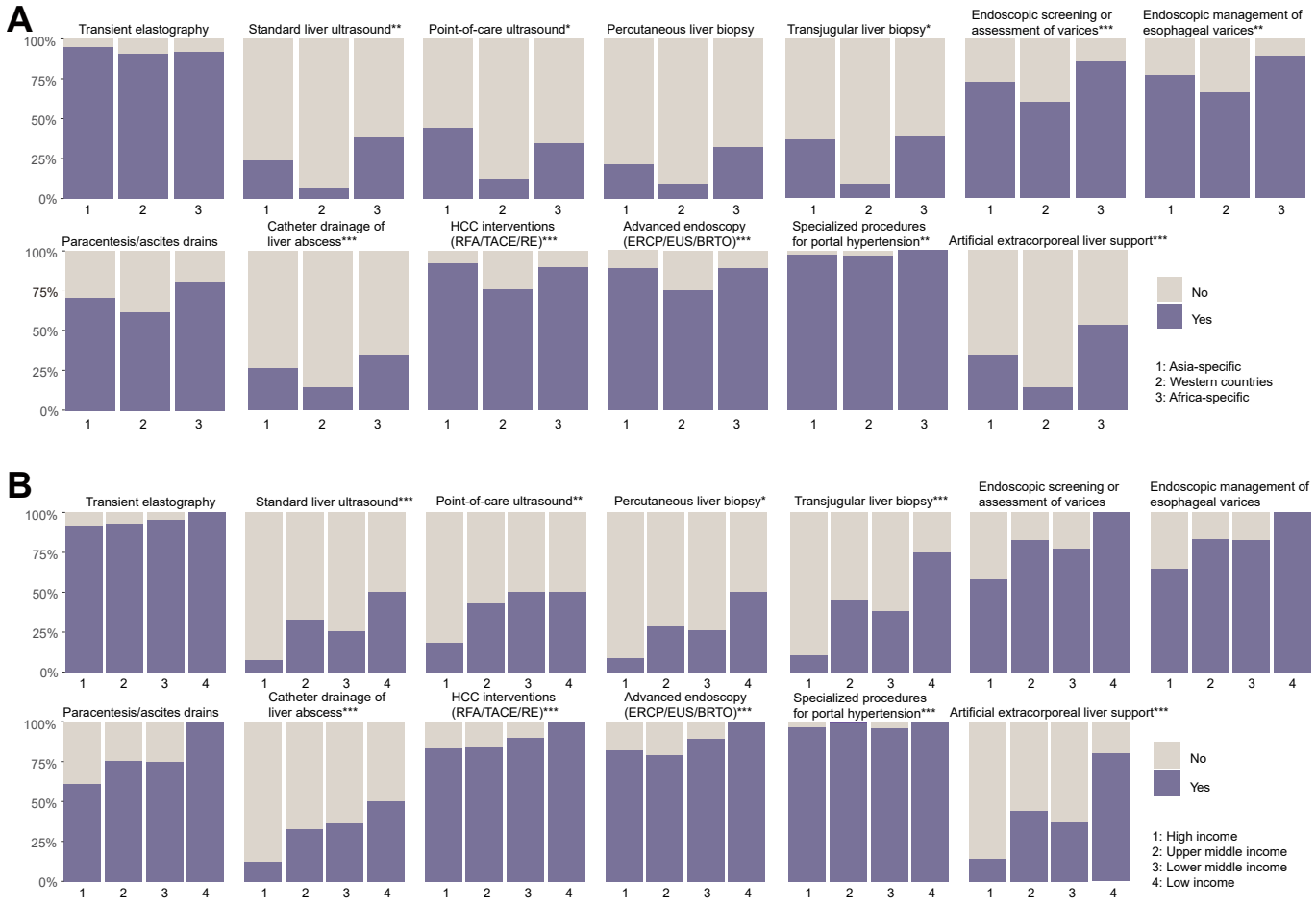

Fig. 5. Subgroup analysis of expert consensus on independent performance of procedural skills. The stacked bar charts illustrate the proportion of experts who endorsed or did not endorse the view that a trainee should be able to perform each procedure independently by the end of the fellowship. The analysis is presented across two different subgroup comparisons: (A) by geographic region (Asia-Specific, Western countries, Africa-Specific) and (B) by World Bank income group (high, upper-middle, lower-middle, and low income). Asterisks denote statistical significance: *p <0.05, **p <0.01, ***p <0.001, no asterisk indicates no significant difference. BRTO, balloon-occluded retrograde transvenous obliteration; ERCP, endoscopic retrograde cholangiopancreatography; EUS, endoscopic ultrasound; HCC, hepatocellular carcinoma; RE, radioembolization; RFA, radiofrequency ablation; TIPS, transjugular intrahepatic portosystemic shunt.

research networks. Experts from low-income regions also placed greater emphasis on transplant ethics, allocation, and living-donor assessment, despite limited local programs, reflecting aspirational, forward-looking training priorities.

Implementation remains challenging because of persistent disparities in access and system capacity. Although transient elastography is designated as a core skill, its availability remains limited in many regions due to cost and supply constraints.[28] Multidisciplinary training presents an additional challenge. For instance, MASLD and obesity management require input from endocrinology and other disciplines, whereas HCC care depends on imaging and oncology. Yet stable multidisciplinary team structures are often lacking. Structural differences in healthcare systems further shape training exposure. For example, hepatology training within infectious diseases in China may limit experience in endoscopy and metabolic liver disease. Transplantation competencies remain essential, but in regions without local programs, training often relies on external rotations, scholarships, and exchange-based models. Highly specialized procedures, such as transjugular intrahepatic portosystemic shunt (TIPS) and transarterial chemoembolization (TACE), are therefore better suited as advanced skills delivered in specialized centers rather than expected to be performed independently during fellowship.

Building on this globally informed, priority-stratified framework, the next step is to develop context-sensitive training pathways at the national and regional levels and translate these recommendations into locally adaptable programs. Depending on health-system structures, training may be delivered through gastroenterology or dedicated hepatology centers, with multidisciplinary input from imaging, pathology, endoscopy, interventional radiology, oncology, and endocrinology. A staged implementation strategy is likely the most feasible approach.

A core hepatology fellowship should first provide an essential clinical curriculum that defines the universal competencies expected of all trainees upon completion. This should include foundational knowledge of liver biology and public health, competence in interpreting liver function and screening tests, and proficiency with key diagnostic modalities, including imaging, liver biopsy, HVPG, and non-invasive fibrosis

Table 3. Subgroup analysis by World Bank income group.

	High income	Upper middle income	Lower-middle income	Low income	*p* values
Basic knowledge					
Liver anatomy and physiology	3	3	3	3	0.464
Public health aspects of obesity, alcohol, viral hepatitis, and hepatocellular carcinoma: epidemiology/burden, social and economic impact, prevention strategies, and healthcare policies	3	3	3	3	0.436
Diagnosis tools and approach					
Liver biopsy (indications, contraindications, complications, and report interpretation)	3	3	3	2	0.003**
Interpretation of abnormal liver function and liver screen test results	3	3	3	3	0.034*
Interpretation of sequencing report of target genes (*e.g.* ATP7B mutations for Wilson's disease)	2	2	2	2	0.099
Interpretation of WGS	1	2	2	2	<0.001***
Interpretation of genomic tests on hepatobiliary malignancies	2	2	2	2	0.003**
Interpretation of liver imaging (US, CT, MR, and MRCP)	3	3	3	3	0.020*
Interpretation of angiography	2	2	2	2	0.005**
Interpretation of non-invasive tests for fibrosis assessment	3	3	3	3	0.228
HVPG: indications, contraindications, complications, and report interpretation	3	2	3	2	0.003**
Management of liver diseases and complications					
Viral hepatitis (hepatitis A, B, C, D, E) and non-hepatotropic viral hepatitis	3	2	3	3	0.708
MASLD	3	3	3	3	0.023*
Multidisciplinary management of obesity	3	3	3	2.5	<0.001***
Congenital hepatobiliary disorders	2	2	2	2	0.280
Alcoholic hepatitis and alcohol-related liver disease	3	3	3	3	0.086
Multidisciplinary management of alcohol dependence/relapse	2	3	3	2	0.156
Drug-induced liver injury	3	3	3	3	0.340
Autoimmune hepatitis	3	3	3	3	0.416
Primary biliary cholangitis	3	3	3	3	0.075
Primary sclerosing cholangitis	3	3	3	3	<0.001***
IgG4-related sclerosing cholangitis	3	3	3	3	0.676
Inpatient and outpatient management of cirrhosis and its complications (such as ascites, hydrothorax, hyponatremia, spontaneous bacterial peritonitis, hepatic encephalopathy, varices/variceal bleeding, and hepatorenal syndrome-acute kidney injury)	3	3	3	3	0.023*
Acute liver failure and acute-on-chronic liver failure	3	3	3	3	0.124
Intensive care of critically ill patients with liver diseases	2	3	3	3	<0.001***
Symptom-based and palliative care of end-stage liver diseases	3	3	3	2.5	<0.001***
Screening, assessment, and multidisciplinary management of malnutrition, sarcopenia, and frailty in patients with chronic liver diseases	3	3	3	2.5	0.374
Evaluation, follow-up, and management of pregnancy-related liver diseases (*e.g.* acute fatty liver of pregnancy, intrahepatic cholestasis of pregnancy) and chronic liver diseases during pregnancy	3	3	3	2.5	0.078
Screening, diagnosis, and management of hepatocellular carcinoma, and MDT working on HCC treatment modalities	3	3	3	3	0.040*
Diagnosis and management of other hepatobiliary malignancies (*i.e.* cholangiocarcinoma, metastatic liver tumors, and gallbladder cancer), and MDT working on treatment modalities	3	3	3	2.5	0.674
Diagnosis of benign tumors of the liver (*e.g.* hemangioma, hepatocellular adenoma, focal nodular hyperplasia)	3	3	3	3	<0.001***
Vascular liver disorders (*e.g.* Budd–Chiari syndrome, portal vein thrombosis, portosinusoidal obstruction syndrome, idiopathic non-cirrhotic portal hypertension)	3	3	3	2.5	0.007**
Inherited liver diseases (Wilson's disease, hemochromatosis, and alpha-1 antitrypsin deficiency)	3	3	3	3	0.002**
Other rare genetic liver diseases (*e.g.* Alagille syndrome, Caroli disease, Caroli syndrome, and progressive familial intrahepatic cholestasis)	2	2	2	2	0.619
Hepatobiliary bacterial infections (*e.g.* liver abscess and bacterial cholangitis)	3	3	3	3	0.341
Parasite liver diseases (*e.g.* echinococcosis of the liver)	2	3	3	2.5	0.018*
Cholelithiasis	3	3	3	3	0.306
Liver involvement of systemic diseases (*e.g.* sepsis, heart failure, malignancies, sarcoidosis, cystic fibrosis)	3	3	3	3	0.114
Expertise in liver transplantation					
Evaluation and selection of eligible candidates for liver transplantation	3	3	3	3	0.404

(*continued on next page*)

Table 3. (*continued*)

	High income	Upper middle income	Lower-middle income	Low income	*p* values
Working knowledge of transplant immunology (*e.g.* tissue compatibility/typing, infectious and malignant complications of immunosuppression)	2	2	3	3	0.017*
Regional organ allocation policy, allocation, and listing policies	2	2	3	3	0.094
Prioritize patients for liver transplantation in resource-limited settings	2	2	3	3	0.005**
Legal, social, ethical, and cultural issues in liver transplantation	2	2	3	3	0.017*
Assessment of recipients and donors for live donor-liver transplantation	2	2	3	3	<0.001***
Perfusion preservation strategies	2	2	2	2	<0.001***
Use of marginal liver grafts	2	2	2	2	0.003**
Liver procurements and transplant operations	3	2	2	2	<0.001***
Management and follow-up of patients on the waiting list	3	2	3	3	<0.001***
Recognition of early surgical and medical complications (infection, acute rejection)	3	3	3	2.5	0.013*
Management of long-term complications (*e.g.* chronic rejection, disease recurrence, renal dysfunction, cardiovascular diseases, new-onset diabetes)	3	3	3	2.5	0.203

Statistical analysis was performed using the Kruskal–Wallis test. All *p* values reported are two-tailed, with statistical significance set at $p < 0.05$. * $0.01 < p < 0.05$, ** $0.001 < p < 0.01$, *** $p < 0.001$.

CT, computed tomography; DI, Disagreement Index; HCC, hepatocellular carcinoma; HVPG, hepatic venous pressure gradient; MASLD, Metabolic dysfunction-associated steatotic liver disease; MDT, multidisciplinary team; MR, magnetic resonance imaging; MRCP, magnetic resonance cholangiopancreatography; US, ultrasound, WGS, whole-genome sequencing.

assessment. Core training should also encompass management of major categories of liver disease, including advanced liver disease, as well as multidisciplinary care domains such as metabolic health, critical care, nutrition, and hepatobiliary malignancies. Essential competencies in liver transplantation, including candidate evaluation, prioritization in resource-limited settings, waiting list management, and long-term complication care, should also be included.

Beyond this core, desirable competencies should be delivered through structured exposure domains, with training depth tailored to local resources and trainees' career goals. These may include genomic medicine, angiography, congenital and rare genetic liver diseases, multidisciplinary management of alcohol dependence, and advanced aspects of transplantation, such as immunology, organ allocation, ethical considerations, and donor assessment.

Procedural training should be developed in parallel, within a separate framework aligned with the expected level of independence. Core procedures to be performed independently include paracentesis, transient elastography, and endoscopic screening and treatment of varices. Additional procedures, such as POCUS and percutaneous liver biopsy, can be incorporated into the fellowship, with progression tailored to local expertise and trainee capabilities. More advanced procedures are better suited to advanced center-based training or post-fellowship pathways.

In resource-constrained settings where advanced diagnostics and procedures remain unavailable, external rotations, institutional partnerships, and phased mentorship may further facilitate implementation, whereas digital education and low-cost simulation offer scalable complementary approaches. Overall, these considerations support a staged rather than uniform implementation, positioning the framework as a flexible reference for locally adapted curriculum development rather than a mandate for standardized training across all settings.

Several limitations should be acknowledged. First, the panel predominantly comprised senior academic hepatology experts, likely over-representing tertiary centers and high-income settings. As a result, the findings may reflect a more specialized and aspirational vision of liver disease training, with potential over-prioritization of resource-intensive competencies such as transplantation, advanced procedures, and genomics, whose feasibility remains limited in many settings. However, subgroup analyses stratified by region and income showed largely consistent consensus. In addition, the relatively high proportion of panelists with advanced liver disease and cirrhosis may have influenced prioritization patterns, potentially contributing to stronger endorsement of competencies related to advanced disease management. Second, this study was intentionally designed as an expert Delphi survey to define core curriculum content from the perspective of hepatology educators. Accordingly, key stakeholder groups, including trainees, early-career physicians, allied health professionals, educational administrators, and policymakers, were not included, thereby limiting insight into learner-centered priorities and implementation feasibility. Third, heterogeneity in training pathways, particularly those embedded within gastroenterology, internal medicine, or infectious diseases, was not fully characterized. Fourth, modifying the scoring approach between Delphi rounds may have contributed to an apparent increase in consensus. Finally, this work should not be interpreted as a fully operational CBME curriculum. It does not define entrustable professional activities (EPAs), milestones, or assessment frameworks, nor does it establish validated links to educational or patient-level outcomes. Rather, it should be regarded as a priority-stratified outline of core training content based on expert consensus.

In conclusion, this Delphi-based study defines a globally informed framework for hepatology training that clarifies 'what should be taught', updates core competencies, and accommodates flexibility for advanced, resource-dependent skills. Future work should focus on translating this consensus into practice through multi-regional pilot implementation across diverse resource settings, followed by a systematic evaluation of

feasibility, implementation burden, trainee experience, and patient and educational outcomes. These data should inform iterative refinement of the framework and support its progressive evolution toward a CBME-oriented model for hepatology training. To enhance generalizability and implementation relevance, subsequent studies should also broaden stakeholder participation to include trainees, early-career physicians, allied health professionals, educational administrators, and policymakers.

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Abbreviations

ABIM, American Board of Internal Medicine; ACG, American College of Gastroenterology; ACGME, Accreditation Council for Graduate Medical Education; ACLF, acute-on-chronic liver failure; AEEH, Spanish Association for the Study of the Liver; AGA, American Gastroenterological Association; AIH, autoimmune hepatitis; AISF, Italian Association for the Study of the Liver; ALEH, Latin American Association for the Study of the Liver; ALF, acute liver failure; AMAGE, The Africa-Middle East Association of Gastroenterology; APASL, Asia-Pacific Association for the Study of the Liver; BASL, British Association for the Study of the Liver; BRTO, balloon-occluded retrograde transvenous obliteration;

CBME, competency-based medical education; CSH, Chinese Society of Hepatology; DI, Disagreement Index; EPAs, entrustable professional activities; ERCP, endoscopic retrograde cholangiopancreatography; ESOT, European Society for Organ Transplantation; EUS, endoscopic ultrasound; GMC, General Medical Council; HCC, hepatocellular carcinoma; HPB, hepatopancreatobiliary; HVPG, hepatic venous pressure gradient; ILCA, International Liver Cancer Association; ILTS, International Liver Transplantation Society; INASL, Indian National Association for Study of the Liver; IPR, interpercentile range; IPRAS, interpercentile range adjusted for symmetry; JSH, The Japan Society of Hepatology; KASL, The Korean Association for the Study of the Liver; LMICs, low- and middle-income countries; LT, liver transplantation; MASLD, metabolic dysfunction-associated steatotic liver disease; MDT, multidisciplinary team; MSGH, Malaysian Society of Gastroenterology and Hepatology; PBC, primary biliary cholangitis; POCUS, point-of-care ultrasound; PSC, primary sclerosing cholangitis; RAM, RAND/UCLA Appropriateness Method; RE, radioembolization; RFA, radiofrequency ablation; SAASL, South Asian Association for Study of the Liver; SASLT, Saudi Association for the Study of Liver Diseases and Transplantation; SLSG, Sri Lanka Society of Gastroenterology; TACE, transarterial chemoembolization; TASL, Turkish Association for the Study of the Liver; THASL, Thai Association for the Study of the Liver; TIPS, transjugular intrahepatic portosystemic shunt; UK, United Kingdom; USA, United States of America; WGS, whole-genome sequencing.

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Conflicts of interest

M-HZ has received honoraria for lectures from AstraZeneca, Hisky Medical Technologies and Novo Nordisk, consulting fees from Boehringer Ingelheim, and serves as a consultant for Eieling Technology. WL has received travel grants from Dr Falk, Novo Nordisk. SR in the past 5 years received research grants from Novo Nordisk and AstraZeneca for basic science research on steatotic liver disease, and has been a consultant for AstraZeneca, GSK, Celgene Corporation, Ribocure AB, Madrigal, Ultragenyx, Amgen, Sanofi, Wave Life Sciences, Lipigon, Novartis, Profluent, Aina, Echosense, and Chiesi in the last 5 years; declares equity from Heptabio; and is inventor on a Patent with title 'Method for treating fatty liver disease', on PSD3, US application number 17,480266 filed on 21st September 2021. CWS has received honoraria for lectures from Gilead Sciences, Sanofi, and Novo Nordisk; and Travel grants to AASLD 2023 and 2024 from Gilead Sciences. W-KC has been a consultant or advisory board member for Abbott, Abbvie, Boehringer Ingelheim, IPSEN, Kowa, Novo Nordisk, Roche, and Zuellig Pharma and a speaker for Abbott, Echosens, Hisky Medical, Novo Nordisk, Roche, and Viatris, and has received research grants from Abbott and Roche. CDB has received research grant support from Echosens. The other authors declare no competing interests.

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

Authors' contributions

Guarantor of the article: M-HZ. Full access to all of the data in the study and took responsibility for the integrity of the data and the accuracy of the data analysis: YS, XX. Concept and design: all authors. Drafting of the manuscript: Xinyi Xu, YS, JG, M-HZ. Critical review of the manuscript for important intellectual content: all authors. Statistical analysis: Xinyi Xu, YS, JG, M-HZ.

Administrative, technical, or material support: all authors. Supervision: Xinyi Xu, YS, FT, VW-SW, WL, CDB, GT, JG, M-HZ.

Data availability

The datasets generated and analyzed in the current study are not publicly available. Access to the data can be provided by the corresponding author upon reasonable request.

Ethics approval and consent to participate

This study did not involve patients, interventions, or patient-identifiable data. In accordance with institutional and national regulations, formal ethics committee approval and patient consent were not required. Expert participation was voluntary, and completion of the online questionnaire constituted informed consent.

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Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author used ChatGPT (OpenAI) to improve the manuscript's clarity and grammar. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Supplementary data

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Author names in bold designate shared co-first authorship

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