

Surgical treatment of hepatocellular carcinoma: an expert consensus-based practical recommendation from the Korean Liver Cancer Association

Min-Su Park^{1*}, Jai Young Cho^{2*}, Eunju Kim³, Hee Young Na⁴, YoungRok Choi⁵, Na Reum Kim⁶, Young-In Yoon⁷, Boram Lee², Eun Sun Jang⁸, Yun Kyung Jung⁹, Kyung Sik Kim⁶

¹Department of Surgery, School of Medicine, KyungHee University, Seoul, Korea

²Department of Surgery, Seoul National University Bundang Hospital, Seoul National University College of Medicine, Seongnam, Korea

³Department of Gastroenterology, Chung-Ang University Gwangmyeong Hospital, Gwangmyeong, Korea

⁴Department of Pathology, Seoul National University Bundang Hospital, Seoul National University College of Medicine, Seongnam, Korea

⁵Department of Surgery, Seoul National University Hospital, Seoul National University College of Medicine, Seoul, Korea

⁶Department of Surgery, Severance Hospital, Yonsei University College of Medicine, Seoul, Korea

⁷Division of Hepatobiliary Surgery and Liver Transplantation, Department of Surgery, Asan Medical Center, University of Ulsan College of Medicine, Seoul, Korea

⁸Department of Internal Medicine, Seoul National University Bundang Hospital, Seoul National University College of Medicine, Seongnam, Korea

⁹Department of Surgery, Hanyang University College of Medicine, Seoul, Korea

Compared with other treatments, surgical resection is an effective treatment method with the lowest local recurrence rate and the highest survival rate for hepatocellular carcinoma (HCC). To achieve excellent results after surgical treatment, it is essential to carefully select patients who are suitable for hepatic resection and minimize postoperative complications and liver function decline through standardized surgical methods and pre- and postoperative management. However, domestic and international treatment guidelines only broadly recommend the application of hepatic resection for HCC with a single tumor and good liver function. Hence, practical treatment guidelines are required that can be standardized and used according to the varying clinical environments, including indications for hepatic resection, preoperative evaluation, basic principles of hepatic resection, minimally invasive hepatic resection, pre- and postoperative patient management, surgical treatment considerations in specific infection situations, and follow-up after surgical resection. Accordingly, an expert group from the Korean Liver Cancer Association Research Committee has developed practical recommendations based on expert consensus regarding the surgical treatment of HCC through a Delphi study.

[Ann Surg Treat Res 2025;109(3):123-143]

Key Words: Hepatocellular carcinoma; Practical recommendation; Surgery; Korea

Received July 17, 2025, Reviewed August 3, 2025,
Accepted August 3, 2025

Corresponding Author: Kyung Sik Kim

Division of Hepatobiliary and Pancreatic Surgery, Department of Surgery, Severance Hospital, Yonsei University College of Medicine, 50-1 Yonsei-ro, Seodaemun-gu, Seoul 03722, Korea

Tel: +82-2-361-5541, Fax: +82-2-313-8289

E-mail: kskim88@yuhs.ac

ORCID: https://orcid.org/0000-0001-9498-284X

*Min-Su Park and Jai Young Cho contributed equally to this work as co-first authors.

•This article is being published jointly in *Annals of Surgical Treatment and Research* and *Journal of Liver Cancer* with the agreement of the editors-in-chief of both journals.

Copyright 2025, the Korean Surgical Society

© Annals of Surgical Treatment and Research is an Open Access Journal. All articles are distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/4.0/>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

INTRODUCTION

Hepatocellular carcinoma (HCC) is one of the most prevalent cancers in Korea, accounting for 11.9% of all cancer-related deaths in 2023, with 10,136 individuals succumbing to liver cancer. Despite the advancements made in various treatment modalities, the overall 5-year survival rate remains at a mere 39.3%, with only 62.4% for patients with the disease confined to the liver [1]. Liver resection has been shown to be the most effective treatment for HCC in terms of reducing local recurrence and enhancing survival rates. The outcomes of liver resection have continually improved; prior to 2007, the 5-year disease-free survival rate after resection was 41.4%, which increased to 61.1% after 2017, with overall survival rates rising from 68.1% to >90% [2]. Furthermore, major complications leading to early postoperative mortality have decreased, with a current 30-day mortality rate around 2% [3,4]. In 2022, 21.3% of patients diagnosed with HCC in Korea will undergo liver resection as their initial treatment, a significant increase from the 12.2% reported previously [5].

To achieve optimal treatment outcomes, precise patient selection, standardized surgical techniques, and postoperative management are essential to minimize complications and deterioration of liver function. Nonetheless, current Korean and international clinical guidelines [6-9] broadly recommend liver resection for patients with preserved liver function and a single hepatocellular tumor, necessitating practical guidelines that can be standardized across various clinical settings.

Therefore, the Korean Liver Cancer Association has conducted a survey of experts to define the criteria for selecting patients for

liver resection in Korea, assessed procedures and postoperative care methods, and performed a literature review on the subject. This led to expert panel discussions and public hearings, culminating in a consensus on specific implementation methods for liver resection.

METHODS

Panel generation

A total of 37 panelists were selected from the Korean Liver Cancer Association, the Korean Association of Liver Surgery, and the Korean Association of Hepato-Biliary Pancreatic Surgery as experts in HCC management with diverse surgical backgrounds. The panelists included both radiologists and hepatologists. The consensus process used a modified Delphi method to incorporate inputs from literature and a diverse group of content experts, practitioners, and patient advocates.

Basic process (Fig. 1)

To provide clear clinical practice guidelines, the committee subdivided the study into 7 core domains: indications for hepatic resection, preoperative evaluation, basic principles of hepatic resection, minimally invasive hepatic resection, considerations in specific infectious settings, perioperative patient management, and follow-up.

These guidelines took a unique approach to production, incorporating 3 validated methods: the Scottish Intercollegiate Guidelines Network methodology for assessing evidence and developing the guideline statements, the Delphi method for establishing an expert consensus, and the AGREE II-GRS (Global

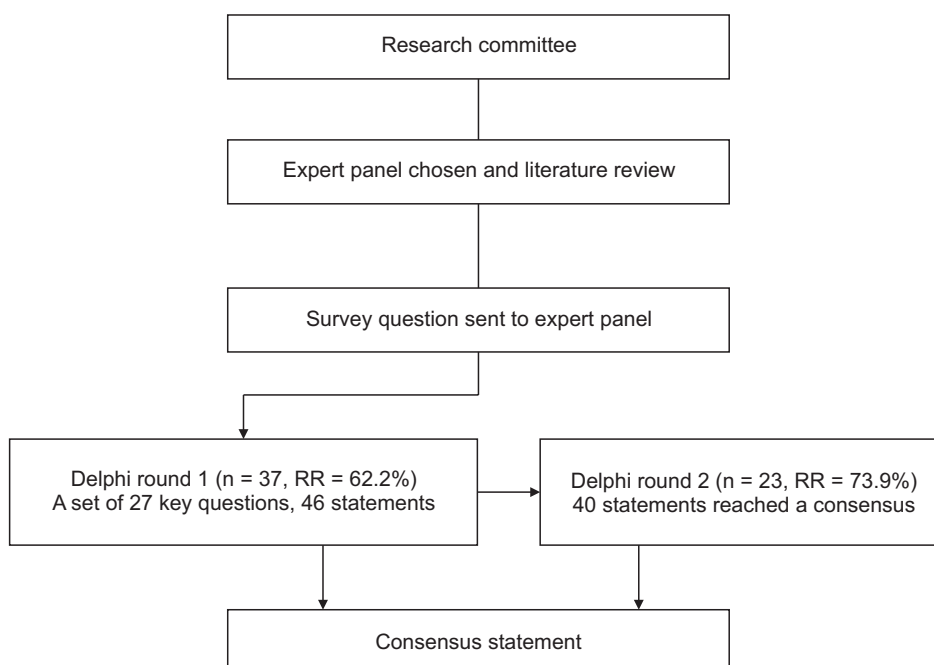


Fig. 1. Recommendation formulation and expert consensus process. RR, response rate.

Rating Scale) tool for assessing the methodological quality and external validation of the final statements.

A set of 27 key questions and 46 statements on the indications for hepatic resection, preoperative evaluation, basic principles of hepatic resection, minimally invasive hepatic resection, preoperative and postoperative management, and follow-up were determined. These statements were consolidated and disseminated to the entire expert panel for voting according to the Delphi methodology.

The expert panelists defined the level of agreement for each statement on a scale ranging from 0 (not at all appropriate) to 100 (completely appropriate). The panelists were blinded to the responses of other panelists. The survey results were collected and analyzed by non-voting members. Consensus agreement, indicating strong agreement on the appropriateness of the proposed recommendation, was met when 70% of the respondents made statements with ratings ≥ 75 , or the median rating was ≥ 80 . Conversely, disagreement agreement, indicating strong disagreement on the appropriateness of the proposed recommendation, was met when 70% of the respondents made statements with ratings ≤ 25 , or the median rating was < 20 . Statements that reached near agreement or disagreement tended toward consensus; however, there were significant outliers. Statements that did not reach consensus were redistributed in the online survey. The panelists evaluated the two-round survey statements and reached a consensus on several statements. After 2 rounds of the Delphi review, 40 statements reached a consensus, while 6 did not.

CLINICAL PRACTICE GUIDELINES

Indications of surgical resection

According to the updated 2022 guidelines of the Korean Liver Cancer Association-National Cancer Center and international consensus, surgical resection is recommended as the primary treatment for solitary HCC confined to the liver in patients without cirrhosis [10]. Even in cases of cirrhosis, surgical resection is prioritized in patients with Child-Pugh Class A liver function, provided there is no significant portal hypertension or hyperbilirubinemia and sufficient residual liver function is anticipated. Furthermore, selective consideration of surgical resection is advised for patients with mild portal hypertension or hyperbilirubinemia classified as Child-Pugh Class A or B7, provided the tumor is solitary.

The prognosis following surgical resection depends on the tumor size and vascular invasion. While smaller tumors generally predict better outcomes, recent studies have demonstrated favorable results in patients with tumors > 10 cm in size, particularly in cases without microscopic vascular invasion, which was observed in approximately 1/3 of these patients [11-13]. Consequently, current guidelines advocate

surgical resection for resectable HCC, irrespective of the tumor size.

A survey of the optimal surgical indications for HCC revealed strong support for resection of solitary tumors. In cases with preserved liver function, adequate residual liver volume, and the absence of portal hypertension, resection was recommended regardless of tumor size, including those > 2 cm. Among the respondents, 64.7% expressed "strong agreement," and 29.4% expressed "agreement," with no dissenting responses, highlighting a consensus favoring resection for solitary HCC in patients with well-preserved liver function.

For multinodular HCC, surgical resection has traditionally been limited; however, recent studies have demonstrated better outcomes with resection than with nonsurgical therapies in patients with 3 or fewer tumors [14-16]. In cases where liver transplantation is not feasible, surgical resection may be selectively considered for patients with 3 or fewer lesions. Major vascular invasion, previously considered a contraindication for surgical resection, has been reevaluated in light of recent evidence. Studies suggest that resection provides superior survival outcomes compared to nonsurgical treatments in cases without total main portal vein invasion [17-22]. Additionally, resection has shown promising 5-year survival rates in patients with HCC with bile duct invasion [23,24]. Thus, surgical resection may be considered for patients with vascular or bile duct invasion if their clinical condition permits and the resection is technically feasible.

In a survey addressing the role of resection in multifocal HCC or HCC with major vascular invasion, the responses were cautiously supportive. While 35.5% of respondents expressed "strong agreement" and 52.9% expressed "agreement" with selective resection for such cases, the respondents acknowledged the need for further evidence and discussion, emphasizing the uncertain efficacy of resection in these contexts. Although no respondents disagreed, concerns were raised regarding the lack of conclusive data on safety and effectiveness, warranting additional investigation.

Based on this study, a discussion of practical clinical guidelines regarding the indications for future hepatic resection is therefore necessary.

Considerations in specific infection contexts

Coronavirus disease 2019

Coronavirus disease 2019 (COVID-19) has significant implications for liver health. Severe acute respiratory syndrome coronavirus 2 infection may exacerbate liver damage in patients with chronic liver disease, leading to further hepatic dysfunction, potentially progressing to decompensated cirrhosis or liver failure [25]. Patients with chronic hepatitis B, hepatitis C, or nonalcoholic fatty liver disease are at a higher risk of liver damage due to inflammation and drug-induced hepatotoxicity

following infection. Moreover, the immune responses triggered by COVID-19 can worsen immunosuppression, raising concerns regarding the reactivation of viral hepatitis [26]. The use of antiviral agents and antibiotics may also contribute to hepatotoxicity [27,28]. These factors have been shown to increase the risk of severe COVID-19 complications in patients with chronic liver disease and potentially lead to life-threatening outcomes.

Delays in HCC treatment due to the COVID-19 pandemic have posed significant challenges, as disease progression can accelerate with treatment postponement. Resource limitations during the pandemic have led to increased waiting times for surgical interventions. Nevertheless, the guidelines from the Asia-Pacific Association for the Study of the Liver recommend prioritizing curative treatments, including liver resection and radiofrequency ablation, to minimize disease progression [29]. In patients at risk of COVID-19, rigorous infection control measures and preoperative screening are essential to mitigate postoperative complications. Case reports have demonstrated the feasibility of safe surgical procedures for HCC even in COVID-19-positive patients. For instance, a successful surgery was performed under stringent protective measures, including the use of negative-pressure operating rooms and proper personal protective equipment despite persistently positive PCR results. This highlights the possibility of safely performing HCC surgery during the COVID-19 pandemic with appropriate infection control protocol [30].

In a survey regarding HCC surgeries in COVID-19 patients, 11.8% of respondents "strongly agreed," and 88.2% "agreed" with the statement that curative surgery should not be delayed unless the patient has severe COVID-19. None of the respondents disagreed, thus indicating a consensus that HCC surgeries can proceed safely in noncritical COVID-19 cases when proper infection control measures are implemented.

HIV

Patients with HIV infection frequently experience co-infection with HBV or HCV, which increases the risk of HCC by approximately seven-fold compared to the general population [31]. Despite the advent of highly active antiretroviral therapy, the incidence of HCC has not significantly declined, particularly in patients with concurrent chronic liver disease, which accelerates hepatic dysfunction [32,33]. The clinical course of HCC in HIV-positive patients remains unclear, with small-scale studies reporting variable outcomes [34,35]. Careful evaluation of liver function and immune status is essential for determining treatment strategies in this patient population.

When considering indications for liver resection in HIV-positive patients, it is crucial to assess not only liver function and disease stage, but also the virological status [36]. Specific parameters, such as the MELD (model for end-stage liver

disease) scores, the degree of portal hypertension, and residual liver function, should be thoroughly evaluated. In cases where liver function is adequately preserved, surgical resection may be selectively attempted. Studies have shown that survival rates following curative liver resection are comparable between HIV-positive and HIV-negative patients [34,35]. Proper patient selection and diligent postoperative follow-up are critical to detecting early recurrence and providing timely additional treatment.

In a survey on liver resection for HCC in HIV-positive patients, 5.9% of respondents "strongly agreed," and 94.1% "agreed" with the statement that surgical resection should be selectively performed in patients with well-preserved liver function, early-stage HCC, and well-controlled viral status.

In conclusion, liver resection may be a viable option for selected HIV-positive patients with HCC with preserved liver function, early-stage disease, younger age, and stable virological and immune statuses.

HBV

HBV is a leading cause of HCC, accounting for approximately 50%–80% of HCC cases worldwide. Chronic HBV infection induces liver inflammation and fibrosis, which significantly increases the risk of HCC in patients who progress to cirrhosis. Key risk factors for HCC include HBV genotype, high serum HBV DNA levels, and HBeAg positivity [37]. Active HBV replication can cause liver damage, accelerate disease progression, and lead to complications [38]. Antiviral therapy plays a critical role in suppressing HBV DNA replication, improving liver function, and reducing the risk of cirrhosis and HCC development [39]. Thus, the early detection of HCC and prompt initiation of antiviral therapy are essential for HBV-infected patients.

In patients with HBV-related HCC, antiviral therapy enhances the success rate of surgical resection and other curative treatments. Reactivation of HBV replication and elevated HBV DNA levels can occur after liver resection, potentially leading to hepatic decompensation [40]. Suppression of HBV DNA replication before and after surgery protects liver function and reduces the risk of postoperative liver failure [41]. Studies have indicated that initiating antiviral therapy in cases with detectable HBV DNA can mitigate the risk of hepatitis reactivation and tumor recurrence. Moreover, long-term survival after liver resection is significantly improved in patients receiving antiviral therapy [42,43]. Consequently, the rapid evaluation of HBV infection status and concurrent antiviral treatment is imperative to optimize treatment outcomes in patients with HCC.

In a survey regarding antiviral therapy for patients with HBV-related HCC, 41.2% of respondents "strongly agreed," and 52.9% "agreed" that antiviral therapy should be initiated when HBV DNA is detected prior to surgery. These results indicate a strong

consensus regarding the active use of antiviral therapy in this patient population.

In conclusion, HBV reactivation is common after HCC treatment and prophylactic antiviral therapy can significantly reduce the risk of HBV reactivation, hepatitis, liver failure, and mortality. Therefore, oral antiviral therapy should be actively considered for the management of HBV-related HCC to optimize clinical outcomes.

HCV

HCV infection causes chronic liver inflammation and fibrosis that can progress to cirrhosis and HCC. Antiviral therapy, particularly with direct-acting antivirals (DAAs), effectively suppresses HCV RNA replication, reduces liver inflammation, improves liver function, and reduces the risk for HCC development [44]. However, the effect of DAA therapy on recurrence rates in patients with established HCC remains unclear, and evidence supporting prophylactic DAA therapy in this context is limited.

The optimal timing for initiating antiviral therapy in patients with HCV-related HCC after curative resection remains a topic of ongoing discussion. Some studies reported lower sustained virological response rates to DAA therapy in patients with HCC [45]. Concerns have also been raised regarding the potential for increased recurrence rates when DAA therapy is initiated immediately after HCC resection [46]. Consequently, current recommendations suggest initiating DAA therapy 3–6 months postoperatively in patients who achieve complete remission, ensuring no evidence of recurrence during the observation period [47]. This approach balances the careful monitoring of HCC recurrence along with suppressing ongoing HCV replication to preserve liver function.

In a survey on the timing of DAA therapy for HCV-related HCC, 11.8% of respondents "strongly agreed," and 82.4% "agreed" with deferring DAA treatment before surgery and implementing an observation period after resection. Most consensus statements support delaying DAA therapy and incorporating a monitoring phase to reduce the risk of premature treatment.

In conclusion, the evidence for prophylactic DAA therapy in HCV-related HCC is still insufficient. For patients who achieve complete remission after surgical resection, initiating DAA therapy after a defined observation period, provided that there is no recurrence, represents a cautious and balanced approach. This strategy aims to minimize the risk of recurrence while mitigating HCV-induced liver damage.

[Recommendations]

- In the era of COVID-19, liver resection with curative intent should not be delayed unless there is a high risk of decompensation or comorbidities that increase the risk of severe COVID-19; in which case, surgery should be

postponed or alternative treatments should be considered. (Level of evidence 5)

- In HCC patients with HBV, antiviral therapy should be initiated if HBV DNA is detected in the serum. (Level of evidence 3)
- There is no evidence to support preventive DAA therapy for HCC patients with HCV. Patients with HCV-related HCC who achieve a complete response after resection should receive DAAs after a 3–6-month observation period, provided no recurrence is detected. (Level of evidence 3)
- In HIV-infected HCC patients, liver resection could be a viable option in selecting patients who have well-preserved liver function, are at an early stage, are young, and have a stable viral immunological status. (Level of evidence 3)

PREOPERATIVE EVALUATION

Preoperative evaluation is crucial to minimize complications and improve outcomes in patients with HCC. It focuses on liver function assessment and disease staging, enabling the accurate evaluation of liver status and tumor progression to guide treatment plans. Liver function assessment predicts postoperative risk, whereas staging informs therapeutic decisions, both of which serve as key prognostic factors for overall survival [48].

Preoperative liver function assessment in patients with hepatocellular carcinoma

Preoperative liver function assessment is essential to minimize postoperative complications, particularly liver failure, in patients with HCC. The Child-Pugh score and indocyanine green retention rate at 15 minutes (ICG-R15) are key tools that are strongly recommended for evaluating liver function. The Child-Pugh score remains a fundamental method for assessing the severity of liver disease, although it has limitations in patients with advanced cirrhosis and those without cirrhosis, necessitating its combination with other tests [49–52]. The ICG-R15 provides a reliable quantitative evaluation of liver metabolic and excretory capacity, guiding surgical decisions on resectable liver volume [53,54]. However, its results can be affected by hemodynamic and cardiac factors, requiring integration with complementary evaluations such as the Child-Pugh score [55–57].

FibroScan (Echosens) and magnetic resonance (MR) elastography are noninvasive methods that serve as supplementary tools for assessing liver stiffness and fibrosis. FibroScan offers quick and noninvasive liver stiffness evaluation but may have reduced accuracy in patients with ascites or obesity [58,59]. MR elastography provides 3-dimensional (3D) imaging of liver stiffness and vascular structures, but its high cost and limited availability make it less feasible for routine use [60,61]. Although these tools enhance the evaluation process, they are considered

adjuncts to primary assessments such as the Child-Pugh score and ICG-R15.

[Recommendations]

- The Child-Pugh score is the most widely used method for assessing liver function and provides a quantitative evaluation, although it has limitations in patients without liver cirrhosis. (Level of evidence 3)
- The ICG-R15 is a useful test for predicting the risk of postoperative liver failure after liver resection. However, it is essential to interpret these results in conjunction with other liver function tests because various factors may influence the accuracy. (Level of evidence 3)
- FibroScan and MR elastography are noninvasive methods that assess liver stiffness and function. They can be used as adjunct tools for the preoperative evaluation of liver function. (Level of evidence 3)

Staging for determining treatment strategies in patients with hepatocellular carcinoma

Staging is crucial for predicting the outcomes and guiding treatment strategies for HCC. Although numerous staging systems have been developed to incorporate tumor characteristics and liver function, there is no consensus regarding the most effective system [62,63]. The modified International Union Against Cancer (mUICC) staging system, widely used for determining surgical and treatment options, provides a straightforward classification based on tumor size, vascular invasion, lymph node involvement, and metastasis [64-66]. It is particularly effective for assessing surgical resectability and is prioritized in the 2022 Korean Liver Cancer Association-National Cancer Center HCC Practice Guidelines.

The American Joint Committee on Cancer (AJCC)/International Union Against Cancer (UICC) staging system, based on the TNM framework, offers a detailed analysis of tumor invasion and metastasis, aiding in the prediction of long-term outcomes [67,68]. The Barcelona Clinic Liver Cancer (BCLC) staging system integrates liver function and tumor characteristics to recommend tailored treatments, including surgical, locoregional, and systemic therapies [69-71]. Together, these systems complement the mUICC system, enabling a comprehensive assessment for precise treatment planning and personalized care.

[Recommendations]

- The mUICC staging system is primarily used to guide treatment decisions for HCC, with the BCLC and AJCC/UICC staging systems as complementary tools when necessary to develop more precise treatment strategies. (Level of evidence 3)

FUNDAMENTAL PRINCIPLES OF HEPATECTOMY

Optimal surgical margins for hepatocellular carcinoma treatment

Approximately 70% of early recurrences following hepatic resection for HCC are attributed to microscopic residual disease [72-74]. To reduce this risk, wider surgical margins may be effective; however, excessively wide margins can result in inadequate liver parenchyma, significantly increasing the risk of postoperative liver failure [75,76]. Therefore, balancing surgical safety with oncologic efficacy is essential, although the optimal surgical margin for HCC remains a topic of ongoing debate [77-79].

Survey findings indicated that appropriate surgical margins should be determined based on the patient's liver function and tumor characteristics. For patients with normal liver function, 41.2% of respondents "strongly agreed" and 58.8% "agreed" that a margin of ≥ 1 cm is necessary to minimize recurrence risk. In cases with biologically aggressive tumors, such as those involving microvascular invasion, 23.5% "strongly agreed" and 76.5% "agreed" that wider margins positively affected long-term survival outcomes. In contrast, for patients with impaired liver function, 11.8% "strongly agreed" and 88.2% "agreed" that narrow surgical margins were an acceptable therapeutic strategy. None of the respondents disagreed with any survey statements, indicating a strong overall consensus.

In conclusion, findings suggest that achieving surgical margins of ≥ 1 cm is advisable for patients with HCC with normal liver function to minimize recurrence risk. For tumors with microvascular invasion, wider margins may contribute to improved long-term survival. Conversely, narrow margins are a feasible and acceptable option in patients with compromised liver function.

[Recommendations]

- The surgical strategy for patients with HCC should aim to achieve a resection margin of ≥ 1 cm to reduce the risk of recurrence, especially in patients with normal liver function. (Level of evidence 2)
- A wide resection margin positively affects the long-term survival of patients with HCC who exhibit biological aggressiveness, such as microvascular invasion. (Level of evidence 3)
- Narrow free-margin resection is an acceptable therapeutic strategy for patients with compromised liver function. (Level of evidence 3)

Technical strategies to prevent recurrence in hepatocellular carcinoma treatment

The 2 key surgical strategies for reducing recurrence and

improving long-term outcomes in HCC management are the anterior approach and anatomical resection (AR). Both techniques address the need to reduce the risk of postoperative recurrence, and the anterior approach involves delaying liver mobilization until vascular inflow is controlled, completing parenchymal transection, and controlling vascular outflow [80]. By securing vascular inflow and outflow before liver mobilization, this approach helps prevent the potential spread or dissemination of cancer cells through the blood or lymphatic vessels during mobilization [81-85].

AR entails the removal of the tumor-containing liver segment or subsegment along with its associated portal vein, hepatic artery, and biliary drainage. This approach is particularly effective for removing satellite lesions and infiltrating vessels, reducing recurrence rates, and improving overall survival. Additionally, AR is well-suited for eradicating microscopic metastases surrounding the tumor and aligns with the principles of radical resection [86,87].

In the survey regarding whether the anterior approach offers better survival rates compared to traditional methods, 11.8% of respondents "strongly agreed," 52.9% "agreed," and 35.3% selected "neither agree nor disagree." While the majority expressed agreement, a substantial proportion of neutral responses (35.3%) highlighted a lack of strong consensus on this viewpoint.

In contrast, there is overwhelming support for AR with wide margins as a priority for HCC treatment. Among respondents, 23.5% "strongly agreed," 70.6% "agreed," and 5.9% were neutral. None of the participants disagreed ("disagree" or "strongly disagree"), suggesting that this AR is widely accepted as a reliable treatment for HCC.

In conclusion, the evidence strongly suggests that AR with wide margins should be prioritized when feasible as it reduces the risk of recurrence and improves the long-term survival of patients with HCC. Therefore, AR is strongly recommended as the preferred surgical strategy.

[Recommendations]

- AR with a wide margin should be considered as the preferred surgical option for patients with HCC when feasible. (Level of evidence 2)

Recommendations for maintaining low central venous pressure during hepatectomy

Hepatectomy has become a cornerstone of the surgical treatment of liver cancer and other hepatic diseases. Advances in surgical techniques and perioperative management have significantly reduced the morbidity and mortality rates following hepatectomy. However, intraoperative bleeding remains a critical factor in determining surgical outcomes and patient prognoses. Numerous past studies have established

a strong association between intraoperative blood loss and increased postoperative complications and mortality, underscoring the importance of effective bleeding control for successful hepatectomy [88,89].

The Pringle maneuver is one of the most widely used methods for controlling intraoperative bleeding [90]. This method effectively reduces blood flow to the liver parenchyma by occluding hepatic inflow [91-93]. Although effective, this technique has limitations, including the potential to induce ischemia-reperfusion injury and adversely affect liver function [92]. Moreover, bleeding from the hepatic veins may persist even after occlusion of hepatic inflow, and effective control of hepatic vein bleeding remains a significant challenge during surgery.

Maintaining low central venous pressure (CVP) during hepatectomy is a critical strategy for bleeding management [94]. By reducing the CVP, this approach suppresses hepatic venous bleeding, minimizes blood loss, and improves surgical visibility [95,96]. In a survey on the efficacy of maintaining a low CVP in reducing bleeding and improving surgical visibility, 23.5% of the respondents "strongly agreed," while 35.3% "agreed," showing a generally positive response. However, 35.3% of the respondents selected "neither agree nor disagree," indicating a limited overall consensus. This lack of strong agreement suggests that while low-CVP management may be beneficial for bleeding control, clinical evidence supporting its routine application remains insufficient.

Additionally, regarding the statement that maintaining a low CVP often requires pharmacological interventions or fluid management, which must be tailored to the patient's individual cardiovascular status, 17.6% of respondents "strongly agreed" and 41.2% "agreed," but 35.3% expressed neutrality. These mixed responses reflect the absence of widespread consensus among clinicians on this matter.

Therefore, the use of low-CVP strategies during hepatectomy should be carefully evaluated. This requires a personalized approach that considers the patient's overall health, liver function, and cardiovascular status. Thus, further research and robust clinical data are essential to elucidate the efficacy and safety of maintaining a low CVP during liver resection, and standardized guidelines must be established for its use in the resection of liver cancer.

Recommendations for anatomical resection and nonanatomical resection (Fig. 2) [97]

The ideal liver resection aims to achieve curative tumor removal while preserving liver function. AR involves removing the liver segment containing the tumor along with its corresponding blood supply and biliary drainage structures [97]. This approach effectively eliminates satellite lesions and the infiltrated vasculature, thereby reducing recurrence rates and

HCC invades portal vein (PV).
HCC intrahepatically metastasizes.
HCC becomes a source of tumor thrombus.

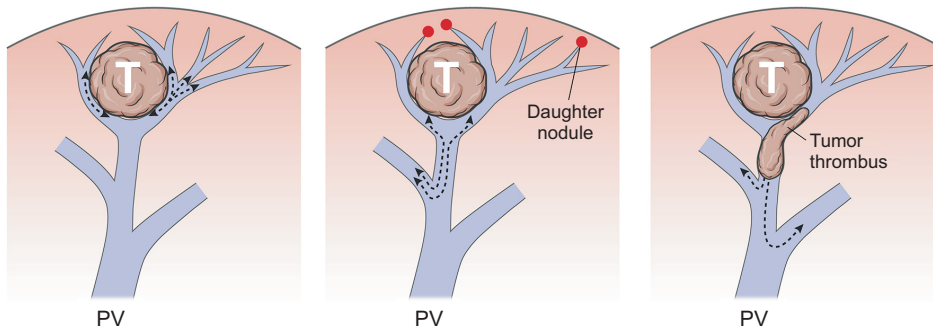


Fig. 2. Rationale of anatomical liver resection. HCC, hepatocellular carcinoma; T, tumor.

improving overall survival [86,87]. However, a wide extent of resection may increase the risk of posthepatectomy liver failure in patients with compromised liver function [76].

In contrast, non-AR (NAR), also referred to as parenchyma-sparing liver resection, focuses on preserving liver function by minimizing the amount of liver tissue removed. This method is often suitable for patients with impaired liver function and can be used when functional preservation is crucial. However, this carries the risk of leaving microscopic tumor cells around the resection margin, which may increase the risk of recurrence. Therefore, careful case selection and application are essential.

Survey results indicate that 94.1% of respondents agreed (5.9% "strongly agree," 88.2% "agree") that AR is superior to NAR in improving disease-free and overall survival. These findings highlight the clinical advantages of AR. Conversely, 88.3% of respondents stated that AR and NAR showed similar perioperative morbidity and mortality rates, suggesting that both approaches are comparable in terms of safety. Finally, in cases of limited liver reserve, 94.1% of respondents agreed (23.5% "strongly agree," 70.6% "agree") that NAR is a viable alternative to AR, underlining its utility in scenarios where preserving liver function is paramount.

In conclusion, AR is the preferred approach for improving disease-free and overall survival in patients with HCC. AR and NAR demonstrated comparable safety profiles in terms of perioperative morbidity and mortality rates. In addition, in patients with limited liver function, NAR may be an appropriate alternative to AR.

[Recommendations]

- AR offers advantages in terms of disease-free and overall survival for patients undergoing HCC resection when compared with NAR. (Level of evidence 2)
- The perioperative outcomes of the patients who underwent AR and NAR were comparable, with similar morbidity and mortality rates. (Level of evidence 2)

- NAR can be considered as an alternative to AR in patients with limited liver reserve function. (Level of evidence 2)

Recommendations for methods to increase functional residual liver volume

Insufficient functional residual liver volume (FRLV) is a major contributor to posthepatectomy liver failure and increased mortality, often posing a significant barrier to performing extensive liver resections. To address this challenge, various strategies have been developed to safely increase the FRLV and improve surgical outcomes. Traditionally, portal vein embolization (PVE) has been widely utilized; however, more recently [98-102], associating liver partitioning and portal vein ligation for staged hepatectomy (ALPPS) has emerged as a promising alternative [103,104].

A study based on the international ALPPS registry data and growing surgical expertise demonstrated improved short-term outcomes using this approach. Inter-stage morbidity rates declined from 10% to 3%, and 90-day mortality rates decreased from 17% to 4% [105]. These findings suggest that ALPPS has significant potential as an effective and robust method for enhancing FRLV.

The survey responses showed strong support for PVE as a reliable method for improving functional FRLV without adversely affecting oncological outcomes, even in patients initially deemed unresectable. A majority of respondents (5.9% "strongly agree," 82.4% "agree") endorsed its effectiveness and safety, and only 5.9% provided neutral responses ("neither agree nor disagree"), with no negative responses. This suggests that PVE is a critical and reliable technique for enhancing the safety of liver resection.

For ALPPS, 5.9% of respondents "strongly agreed," and 64.7% "agreed" that it could serve as an alternative to PVE. However, concerns remain regarding its superiority in terms of oncologic outcomes and FRLV augmentation, as reflected by 23.5% of the respondents who were neutral on the matter. This highlights

the need for careful patient selection and consideration of the timing and context in which ALPPS is applied, because its efficacy may be limited to specific patient populations.

In summary, PVE is recommended as a safe and reliable approach to significantly increase resectability by effectively increasing the FRLV without adversely affecting oncological outcomes in patients initially deemed ineligible for hepatectomy because of insufficient liver reserve. On the other hand, although ALPPS may be a viable alternative to PVE, there is ongoing debate over its oncologic efficacy and effectiveness in augmenting FRLV. Thus, decisions to utilize ALPPS should be made judiciously, considering patient-specific factors and overall surgical objectives.

[Recommendations]

- PVE increases the resectability of initially unresectable HCC owing to inadequate FRLV without having a deleterious oncological effect in patients with HCC. (Level of evidence 3)
- ALPPS can be an alternative to PVE; however, it is still controversial regarding its superiority, both in terms of oncological outcomes and the effect of hypertrophy on FRLV. (Level of evidence 3)

Indications for minimally invasive liver resection

Minimally invasive liver resection (MILR) is recommended for patients with solitary HCC with preserved liver function (Child-Pugh Class A or B) and sufficient future liver remnants, provided that there is no evidence of major vascular invasion [7,9]. While liver cirrhosis can increase mortality and complication rates in open liver surgery [106], past studies have shown that laparoscopic liver resection (LLR) is a safe and effective alternative in patients with cirrhosis, offering reduced complications and shorter hospital stays compared to open surgery [107,108]. Minimally invasive techniques include laparoscopic and robotic liver resection (RLR). Unlike conventional open surgery, these approaches have technical limitations that may result in varying indications depending on the tumor location and extent of resection.

Recommendations for minimally invasive liver resection based on tumor location (Fig. 3) [109]

Anterolateral segment (segments 2, 3, 4b, 5, 6)

The anterolateral segment was relatively accessible for LLR. Early studies demonstrated the safety of laparoscopic and robotic minor hepatectomies for lesions in this area, with advantages such as reduced complications, shorter hospital stays, and equivalent oncological outcomes when compared to open surgery. MILR is recommended for minor hepatectomies of HCC located in the anterolateral segment [110].

Posterosuperior segment (segments 1, 4a, 7, 8)

Accessing the posterosuperior segment laparoscopically is anatomically challenging. Although initially considered difficult, recent reports suggest that in appropriately selected patients, LLR in the posterosuperior segment, which is associated with longer operative times, higher blood loss, and increased rates of conversion to open surgery, does not compromise resection margins or long-term oncologic outcomes. Experienced surgeons should perform MILR in this area after careful patient selection [111-113].

Tumors in proximity to major blood vessels

Tumors located near major vessels (e.g., portal and hepatic veins) present an increased risk of bleeding and surgical difficulty. These patients require high surgical expertise [114,115]. While open surgery is typically recommended for cases involving thrombectomy, vascular resection, or reconstruction, as well as for tumors with complex anatomy, minimally invasive techniques can be safely and effectively performed in carefully selected patients. Expert surgical skills are essential to achieve optimal outcomes.

[Recommendations]

- MILR is recommended for minor liver resection of HCC in anterolateral segments that are relatively accessible. (Level of evidence 3)
- For HCC in posterosuperior segments, which is challenging owing to difficult exposure and resection, surgery should be performed by experienced surgeons with careful patient selection. (Level of evidence 3)
- An expert surgeon should perform MILR for HCC in proximity to major blood vessels. (Level of evidence 3)

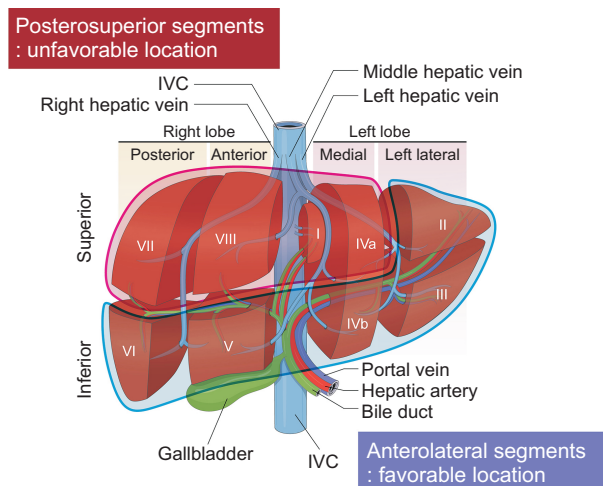


Fig. 3. Preferential location of hepatocellular carcinoma in minimally invasive hepatic resection. IVC, inferior vena cava.

Recommendations for minimally invasive liver resection based on tumor size

Liver resection is recommended for solitary HCC when sufficient future liver remnants are preserved. Studies have shown that for HCCs >5 cm, LLR offers benefits such as shorter hospital stays and reduced postoperative complications compared to open surgery, with no significant differences in long-term oncologic outcomes despite longer operative times [116-119]. In cases of very large HCCs (>10 cm), technical complexity and conversion rates to open surgery are higher. However, with skilled surgeons, LLR has been reported to be safe [120,121]. Thus, MILR may be considered for HCCs >5 cm in appropriately selected patients. For tumors >10 cm in size, open surgery is recommended because of its increased complexity and technical difficulty, and MILR should only be performed by experienced surgeons.

However, randomized controlled trials supporting the safety of MILR for large HCCs are lacking, highlighting the need for further high-quality studies.

[Recommendations]

- MILR can be performed for HCCs >5 cm in appropriately selected patients. (Level of evidence 3)
- For HCCs measuring >10 cm, MILR is recommended only for carefully selected patients and should be performed by expert surgeons. (Level of evidence 3)

Recommendations for minimally invasive liver resection based on the extent of liver resection

Major hepatectomy has been defined as the resection of 3 or more liver segments according to the Couinaud classification. This procedure is technically demanding and is typically performed in HCC with large tumors, multiple lesions, or in proximity to major vessels.

When compared with open surgery, laparoscopic major hepatectomy has been associated with longer operative times but offers advantages such as significantly reduced blood loss and shorter hospital stays. Open surgery may still be preferable for cases involving complex anatomical structures as it allows for faster resection [113]. However, laparoscopic procedures may have higher conversion rates to open surgery in patients with severe cirrhosis or tumors near the major vessels [114,122]. Oncological outcomes, including long-term survival and R0 resection rates, were comparable between the laparoscopic and open approaches [123]. For patients with HCC requiring major hepatectomy, MILR can be considered by experienced surgeons, provided that patient selection criteria account for factors such as proximity to major vessels and anatomical complexity.

[Recommendations]

- Major hepatectomy for HCC should be performed by expert

surgeons with careful consideration of the proximity to major vessels and the anatomical complexity. (Level of evidence 3)

Recommendations for robotic liver resection

While both laparoscopic and robotic approaches are used in MILR, laparoscopic surgery was initially more widely adopted in Korea owing to cost and insurance considerations. RLR has recently gained popularity. Comparative studies have shown that robotic surgery is associated with less blood loss, fewer major complications, reduced conversion rates to open surgery, and shorter hospital stays, making it particularly suitable for technically complex cases [124]. Despite these advantages, robotic surgery has limitations, including longer operative times depending on the surgeon's experience and higher costs [125-127]. Robotic systems are especially beneficial for complex cases such as lesions in the posterosuperior segments or near major vessels [124,125,128]. Owing to improved dexterity (7 degrees of freedom, EndoWrist function [Intuitive Surgical]), high-resolution 3D visualization, and reduced tremors. These advantages improve surgical precision and safety, even in challenging procedures requiring vascular or biliary reconstruction [129-132].

[Recommendations]

- RLR is recommended for complex cases involving vascular or biliary reconstruction or tumors in the posterosuperior segments, and should be performed by expert surgeons. (Level of evidence 4)
- The high cost of robotic surgery should be considered and patient preferences should be factored into the decision-making process. (Level of evidence 5)
- Because of the potential for longer operative times, robotic surgery should be initially applied to less complex cases to allow for skill development. (Level of evidence 3)

Minimally invasive hepatic resection using the surgical difficulty score

The difficulty scoring system (DSS) is a scoring system for systematically evaluating the difficulty of minimally invasive hepatic resection and is known to be helpful in establishing an appropriate surgical strategy that suits the surgeon's experience level and complexity of the patient's lesion. There are various DSS systems, and each evaluates the difficulty of minimally invasive hepatic resection using different criteria. The first DSS was the Ban DSS [133], in which the main variables were the extent of resection, tumor location, tumor size, liver function, and proximity to major blood vessels, which became the basis for other DSSs. Iwate DSS [134] is a modified DSS based on the Ban DSS, and hand-assisted laparoscopic surgery and hybrid surgery were included as factors that lowered difficulty.

Subsequently, depending on the purpose of evaluating the difficulty of the surgery, the Hasegawa DSS [135] is a scoring system designed to predict the operation time using the extent of resection, tumor location, obesity, and platelet count as the main variables. The Institut Mutualiste Montsouris (IMM) DSS [136] was introduced as a system to evaluate the correlation with the major complication rate using the operation time, amount of blood loss, and conversion to laparotomy as the main variables. The Southampton DSS [137], which focused on predicting intraoperative complications, evaluated the difficulty of using neoadjuvant chemotherapy, lesion type and size, and a history of previous hepatic resection as the main variables. The Ban DSS and Iwate DSS are the most widely verified systems for DSS validity, and they can predict various outcomes such as operation time, amount of blood loss, complications, and length of hospital stay. The IMM DSS and Hasegawa DSS were mainly verified for laparoscopic hepatic resection; however, some were also proven to be valid for robotic hepatic resection [138]. Recent studies have evaluated the difficulty of robotic hepatectomy and a prediction system is being developed that considers surgical time, blood loss, and complications as indicators of surgical complexity. However, further studies of its validity and reproducibility are required [139,140].

Meanwhile, in the questionnaire responses to the validity of the DSS, there was some controversy regarding the application of the DSS, and >50% responded "neither agree nor disagree," thus indicating a cautious stance. This suggests that DSS may have limited effectiveness in minimally invasive hepatic resection, and careful consideration is needed for its appropriate application.

The DSS is useful for systematically evaluating the difficulty of minimally invasive hepatectomy and can contribute to establishing surgical plans and improving patient safety. However, further studies are needed to expand the applicability of DSS to robotic hepatectomy and specific patient groups, and to consider standardized recommendations.

PERIOPERATIVE MANAGEMENT OF HEPATIC RESECTION

Hepatectomy in patients with morbid obesity

The increasing prevalence of morbid obesity worldwide has significant implications for surgical practices, including liver resection [141]. Morbid obesity complicates patient management by increasing the risk of complications both perioperatively and in the postoperative period [142-144]. Hepatic steatosis, a common finding in patients with obesity, can impair liver function and complicate surgical outcomes [145,146]. Additionally, obesity-related complications, such as diabetes mellitus or cardiovascular disease (CVD), may affect overall surgical risk and recovery [147]. Factors to consider when deciding on surgical

intervention for an obese patient include the potential for changes in anatomical landmarks [148], which may increase the technical difficulty during surgery, and the risk of obesity-related respiratory compromise, which may complicate anesthetic management and postoperative recovery [149]. Furthermore, the psychosocial aspects of morbid obesity, including compliance with postoperative care and rehabilitation, should be assessed. Therefore, the decision to perform hepatectomy in morbidly obese patients requires a thorough evaluation of both surgical feasibility and patient safety.

[Recommendations]

- Hepatectomy can be considered for patients with morbid obesity; however, careful patient selection is required. The decision should be based on a comprehensive evaluation of the patient's liver function, extent of hepatic steatosis, and presence of comorbidities such as diabetes mellitus and CVD. (Level of evidence 3)
- Postoperative care should include multidisciplinary management focusing on nutrition, metabolic control, and the monitoring of potential complications associated with morbid obesity, such as wound healing and infection. (Level of evidence 3)

Hepatectomy in older patients (age >75 years)

As the global population ages, the number of older patients requiring surgical interventions, including liver resection, increases [150]. Although older age is often associated with physiological changes that may increase the risk of surgical complications and recovery [151], recent evidence suggests that liver surgery can be safely performed in carefully selected patients over the age of 75 years with good outcomes [152-154]. Improved surgical techniques, anesthesia, and perioperative care, including the appropriate application of Enhanced Recovery After Surgery (ERAS) protocols, have significantly enhanced outcomes in this population [155,156].

Key factors to consider when evaluating an older patient for hepatectomy include the overall functional status, presence of comorbidities, and extent of liver disease [157]. Geriatric-specific assessment tools such as frailty indices, gait speed tests, and cognitive function evaluations can provide valuable insights into the physiological reserve of a patient and help identify appropriate candidates for surgery [158-160]. These tools enable a more precise assessment of the risks and benefits of hepatectomy in older patients, ensuring that surgical decisions are evidence-based and individualized.

[Recommendations]

- Hepatectomy can be considered in older patients over 75 years of age if they have a good overall functional status and preserved liver function. The decision should be

individualized, considering the comorbidities, extent of hepatic disease, and patient performance status. (Level of evidence 3)

- Preoperative assessments, including geriatric evaluations and risk stratification for surgery, should be thorough. Special attention should be paid to cardiovascular and pulmonary evaluations. (Level of evidence 3)
- ERAS protocols and postoperative care tailored to the older population are recommended to minimize complications and improve outcomes. (Level of evidence 3)

Hepatectomy in patients with severe cardiovascular disease

Patients with severe CVD face significant challenges when considering major surgical interventions such as hepatectomy. Cardiovascular complications are major causes of perioperative morbidity and mortality, particularly in procedures requiring extensive resection or prolonged operative times [161]. The physiological stress of hepatic resection may worsen the underlying CVD, including significant hemodynamic changes and potential blood loss, increasing the risk of adverse events such as myocardial infarction, arrhythmia, or heart failure [162].

Careful patient selection with a thorough preoperative assessment of cardiovascular function and individual risk-benefit analysis is essential. Multidisciplinary collaboration involving surgeons, cardiologists, anesthesiologists, and critical care physicians is important to determine whether surgery is a viable option. Nonsurgical treatment should be preferred in patients at significant cardiovascular risk unless the potential survival benefits of hepatectomy outweigh the risks [163,164]. For patients undergoing surgery, meticulous perioperative planning and management are required to optimize cardiovascular stability and ensure the best possible outcomes [165].

[Recommendations]

- Hepatectomy should be performed with caution in patients with severe CVD. These patients require thorough preoperative cardiovascular evaluation and risk stratification. The decision to proceed with surgery should involve a multidisciplinary team, including a cardiologist, to assess the risks and benefits. (Level of evidence 3)
- Nonsurgical treatments should be considered as first-line options for patients with significant cardiovascular risk unless hepatectomy offers a clear survival benefit and the cardiovascular condition is optimally managed. (Level of evidence 3)
- If hepatectomy is deemed necessary, perioperative management should focus on optimizing cardiovascular function with intensive monitoring during and after the procedure to minimize the risk of cardiac complications. (Level of evidence 3)

Hepatectomy in patients with chronic kidney disease or end-stage renal disease

Chronic kidney disease (CKD) and end-stage renal disease (ESRD) pose significant challenges for patients undergoing major surgeries including liver resection. These conditions increase the risk of perioperative complications including fluid overload, electrolyte imbalance, and acute kidney injury, which may negatively affect surgical outcomes [166]. Additionally, patients with ESRD have complex comorbidities, including CVD and changes in drug metabolism, which further complicate perioperative management [167].

When considering hepatic resection in patients with CKD or ESRD, it is essential to perform a comprehensive assessment of renal function and evaluate the potential risks and benefits of the procedure [168]. Collaboration with a multidisciplinary team, including nephrologists, is important to optimize patient care. Particular attention should be paid to perioperative management strategies that minimize renal stress, including ensuring adequate renal perfusion, avoiding nephrotoxic agents, and tailoring fluid and electrolyte management according to individual patient needs.

For patients undergoing dialysis, close coordination of the surgical timing and dialysis sessions is vital to avoid complications related to fluid shifts or uremia [169]. In this population, hepatectomy should be performed only when there is a clear survival benefit and nonsurgical options are not feasible [170]. Decision-making should also consider the patient's overall prognosis and potential improvement in quality of life following surgery.

[Recommendations]

- Hepatectomy should be considered with caution in patients with CKD or ESRD should be considered with caution. Preoperative evaluations should include a thorough assessment of renal function, and the potential impact of surgery on kidney health should be carefully evaluated. Multidisciplinary consultation with a nephrologist is strongly recommended. (Level of evidence 3)
- Perioperative management strategies should focus on maintaining adequate renal perfusion and minimizing exposure to nephrotoxins. In patients undergoing dialysis, scheduling dialysis sessions and adjusting fluid management are crucial for avoiding complications. (Level of evidence 3)
- In patients with ESRD, hepatectomy should be reserved for cases in which it offers a significant survival benefit and nonsurgical alternatives are not viable. The overall prognosis and potential improvements in quality of life should guide the decision-making process. (Level of evidence 3)

SURVEILLANCE FOLLOWING CURATIVE RESECTION FOR HEPATOCELLULAR CARCINOMA

Surveillance is crucial for patients who have undergone curative liver resection for HCC because of their high risk of recurrence. HCC is one of the leading causes of cancer-related deaths worldwide, with 5-year survival rates varying between 19% and 81% depending on early detection and treatment [171,172].

Following surgical resection, the risk of recurrence is significant, ranging from 50% to 70% within 5 years after surgery, with the highest risk occurring in the first year [173,174].

After resection, recurrences are typically localized in the liver, whereas recurrences following liver transplantation tend to be extrahepatic. Early detection of recurrence is essential to improve survival rates, as it allows for timely therapeutic intervention. However, there is no clear consensus regarding the optimal surveillance interval and modality after liver resection.

Most guidelines recommend a combination of biochemical markers and imaging modalities for effective surveillance. Commonly used strategies include serum α -FP testing and imaging studies, such as ultrasonography, CT, or MRI every 3–4 months during the first 3 years after surgery [171].

The American Association for the Study of Liver Diseases (AASLD) recommends regular imaging and serum α -FP testing every 3–6 months for the first 2 years after surgery to detect recurrence early, which is vital for improving patient outcomes [175]. Given the higher risk of HCC (older age, male sex, degree of liver dysfunction, tumor size, number, grade/differentiation, microvascular and macrovascular invasion, presence of satellite lesions, and α -FP level) compared with individuals without prior HCC, patients should undergo surveillance with cross-sectional imaging of the abdomen and chest plus serum α -FP every 3–6 months. Although the AASLD recommends indefinite surveillance, the current evidence does not support the survival benefit of more frequent surveillance [175].

Similarly, the European Association for the Study of the Liver (EASL) advocates a risk-based approach, emphasizing the use of ultrasonography, CT, or MRI combined with α -FP testing every 3–6 months during the initial 2 years to reduce mortality and enhance cost-effectiveness in HCC management. The EASL highlights follow-up intervals of 3–4 months in the first year as practical [176].

The interval of cancer surveillance should consider tumor doubling time, stage migration, cost-effectiveness, and impact on patient survival. Although the optimal surveillance intervals are unclear, most regional guidelines recommend intervals of 3–12 months [177–179]. Based on these guidelines and recent studies, monitoring every 3–6 months using imaging and α -FP

testing in the first 2 years after postresection ensures early detection and timely intervention, which are crucial for better patient outcomes.

Surveillance modalities

Imaging modalities play a pivotal role in surveillance because of their ability to detect recurrence at an early, treatable stage. Among the most effective imaging techniques for postoperative surveillance are multiphase CT and MRI, given their high sensitivity and specificity in detecting HCC recurrence [180]. These are complemented by ultrasonography, which is less costly and also more readily available, although it is generally less sensitive than CT or MRI for early-stage HCC. Advancements made in imaging technologies, such as diffusion-weighted imaging, gadoteric acid-enhanced MRI, and contrast-enhanced ultrasound, have significantly improved the early detection of recurrent HCC after liver resection [181,182]. MRI provides excellent soft tissue contrast, while multidetector CT provides high-resolution images and faster acquisition times. These innovations collectively enhance the sensitivity and specificity for detecting HCC recurrence, allowing for a more accurate assessment of liver tissues and better identification of subclinical lesions.

Current guidelines recommend using CT and MRI for surveillance postresection to spot residual disease or recurrence. Although ultrasound is useful for initial screening owing to its noninvasive nature and accessibility, CT and MRI are preferred because of their higher sensitivity and specificity in detecting HCC recurrence. Structured follow-up programs using these methods can significantly enhance early detection and management, potentially improving long-term survival outcomes [180,183–187].

[Recommendations]

- Routine postoperative surveillance should be performed to detect recurrence using contrast-enhanced multiphasic CT or MRI every 3–6 months in all patients with HCC after liver resection. (Level of evidence 3)

ASSESSMENT OF LONG-TERM OUTCOMES AND SURVIVAL POSTSURGERY FOR HEPATOCELLULAR CARCINOMA

Long-term outcomes and survival following surgery for HCC are best evaluated using recurrence-free survival (RFS) and overall survival metrics to provide a comprehensive understanding of patient prognosis. The Kaplan-Meier survival analyses estimate survival probabilities over time, whereas Cox proportional hazards models help identify the prognostic factors that influence these outcomes [188,189].

Stratifying patients based on recurrence risk and distinguish-

shing between early (within 2 years) and late recurrence allows for personalized follow-up strategies. Studies have indicated that remnant liver function after hepatectomy is significantly associated with survival outcomes, with a lower hepatic clearance correlating with shorter overall survival and RFS. Tumor characteristics, such as size, number, microvascular invasion, and elevated α -FP levels, critically determine survival after resection. High-risk factors correlate with increased recurrence and reduced survival rates. Recurrence is common after hepatectomy, with most cases occurring within the first 2 years of surgery. Understanding the timing and patterns of recurrence is vital for implementing effective surveillance and treatment strategies. Advances in surgical techniques and improved patient selection criteria have improved survival rates, underscoring the need for continuous evaluation and adaptation of treatment protocols [190-192].

[Recommendations]

- Long-term outcomes and survival were best assessed by combining RFS and overall survival metrics. The Kaplan-Meier survival analyses supplemented by Cox proportional hazards models can help identify prognostic factors that influence outcomes. Stratification based on recurrence risk, such as early (within 2 years) versus late recurrence, allows for personalized follow-up. (Level of evidence 3)

ACKNOWLEDGEMENTS

Fund/Grant Support

None.

Conflicts of Interest

No potential conflict of interest relevant to this article was reported.

ORCID iD

Min-Su Park: <https://orcid.org/0000-0002-0707-2969>

Jai Young Cho: <https://orcid.org/0000-0002-1376-956X>

Eunju Kim: <https://orcid.org/0000-0002-3620-8175>

Hee Young Na: <https://orcid.org/0000-0002-2464-0665>

YoungRok Choi: <https://orcid.org/0000-0003-2408-7086>

Na Reum Kim: <https://orcid.org/0000-0001-7268-8543>

Young-In Yoon: <https://orcid.org/0000-0002-9308-0366>

Boram Lee: <https://orcid.org/0000-0003-1567-1774>

Eun Sun Jang: <https://orcid.org/0000-0003-4274-2582>

Yun Kyung Jung: <https://orcid.org/0000-0002-5193-5418>

Kyung Sik Kim: <https://orcid.org/0000-0001-9498-284X>

Author Contribution

Conceptualization, Methodology, Supervision: MSP, JYC, KSK

Data curation, Formal analysis, Investigation: All authors

Writing – Original Draft: All authors

Writing – Review & Editing: MSP, JYC, KSK

REFERENCES

- Korean Statistical Information Service. Relative survival rate for 5 years by 24 kinds of cancer, cancer occurrence time and gender [Internet]. Statistics Korea; 2021 [cited 2024 Dec 14]. Available from: https://kosis.kr/statHtml/statHtml.do?orgId=117&tblId=DT_117N_A00021&conn_path=I2&language=en
- Kim NR, Choi GH, Han DH, Kim KS, Choi JS. Significant improvement in long-term survival after liver resection for hepatocellular carcinoma: evolving outcomes over 20 years. *Yonsei Med J* 2025;66:e62.
- Kim KS. Current status of hepatic surgery in Korea. *Korean J Hepatol* 2009;15 Suppl 6:S60-4.
- Nicolazzi M, Di Martino M, Baroffio P, Donadon M. 6,126 hepatectomies in 2022: current trend of outcome in Italy. *Langenbecks Arch Surg* 2024;409:211.
- Han JW, Sohn W, Choi GH, Jang JW, Seo GH, Kim BH, et al. Evolving trends in treatment patterns for hepatocellular carcinoma in Korea from 2008 to 2022: a nationwide population-based study. *J Liver Cancer* 2024;24:274-85.
- Korean Liver Cancer Association (KLCA) and National Cancer Center (NCC) Korea. 2022 KLCA-NCC Korea practice guidelines for the management of hepatocellular carcinoma. *Clin Mol Hepatol* 2022;28:583-705.
- Cho Y, Kim BH, Park JW. Overview of Asian clinical practice guidelines for the management of hepatocellular carcinoma: an Asian perspective comparison. *Clin Mol Hepatol* 2023;29:252-62.
- Kudo M, Kawamura Y, Hasegawa K, Tateishi R, Kariyama K, Shiina S, et al. Management of hepatocellular carcinoma in Japan: JSH consensus statements and recommendations 2021 update. *Liver Cancer* 2021;10:181-223.
- Reig M, Forner A, Rimola J, Ferrer-Fàbrega J, Burrel M, Garcia-Criado Á, et al. BCLC strategy for prognosis prediction and treatment recommendation: the 2022 update. *J Hepatol* 2022;76:681-93.
- Korean Liver Cancer Association (KLCA) and National Cancer Center (NCC) Korea. 2022 KLCA-NCC Korea practice guidelines for the management of hepatocellular carcinoma. *Korean J Radiol* 2022;23:1126-

- 240.
11. Zhou YM, Li B, Xu DH, Yang JM. Safety and efficacy of partial hepatectomy for huge (≥ 10 cm) hepatocellular carcinoma: a systematic review. *Med Sci Monit* 2011;17:RA76-83.
12. Hwang S, Lee YJ, Kim KH, Ahn CS, Moon DB, Ha TY, et al. Long-term outcome after resection of huge hepatocellular carcinoma ≥ 10 cm: single-institution experience with 471 patients. *World J Surg* 2015;39:2519-28.
13. Wei CY, Chen PC, Chau GY, Lee RC, Chen PH, Huo TI, et al. Comparison of prognosis between surgical resection and transarterial chemoembolization for patients with solitary huge hepatocellular carcinoma. *Ann Transl Med* 2020;8:238.
14. Yue YY, Zhou WL. Hepatic resection is associated with improved long-term survival compared to radio-frequency ablation in patients with multifocal hepatocellular carcinoma. *Front Oncol* 2020;10:110.
15. Lu L, Zheng P, Wu Z, Chen X. Hepatic resection versus transarterial chemoembolization for intermediate-stage hepatocellular carcinoma: a cohort study. *Front Oncol* 2021;11:618937.
16. Fukami Y, Kaneoka Y, Maeda A, Kumada T, Tanaka J, Akita T, et al. Liver resection for multiple hepatocellular carcinomas: a Japanese nationwide survey. *Ann Surg* 2020;272:145-54.
17. Kokudo T, Hasegawa K, Matsuyama Y, Takayama T, Izumi N, Kadoya M, et al. Survival benefit of liver resection for hepatocellular carcinoma associated with portal vein invasion. *J Hepatol* 2016;65:938-43.
18. Lee JM, Jang BK, Lee YJ, Choi WY, Choi SM, Chung WJ, et al. Survival outcomes of hepatic resection compared with transarterial chemoembolization or sorafenib for hepatocellular carcinoma with portal vein tumor thrombosis. *Clin Mol Hepatol* 2016;22:160-7.
19. Kokudo T, Hasegawa K, Matsuyama Y, Takayama T, Izumi N, Kadoya M, et al. Liver resection for hepatocellular carcinoma associated with hepatic vein invasion: a Japanese nationwide survey. *Hepatology* 2017;66:510-7.
20. Zhang ZY, Dong KS, Zhang EL, Zhang LW, Chen XP, Dong HH. Resection might be a meaningful choice for hepatocellular carcinoma with portal vein thrombosis: a systematic review and meta-analysis. *Medicine (Baltimore)* 2019;98:e18362.
21. Mei J, Li SH, Wang QX, Lu LH, Ling YH, Zou JW, et al. Resection vs. sorafenib for hepatocellular carcinoma with macroscopic vascular invasion: a real world, propensity score matched analytic study. *Front Oncol* 2020;10:573.
22. Govalan R, Lauzon M, Luu M, Ahn JC, Kosari K, Todo T, et al. Comparison of surgical resection and systemic treatment for hepatocellular carcinoma with vascular invasion: national cancer database analysis. *Liver Cancer* 2021;10:407-18.
23. Kim DS, Kim BW, Hatano E, Hwang S, Hasegawa K, Kudo A, et al. Surgical outcomes of hepatocellular carcinoma with bile duct tumor thrombus: a Korea-Japan multicenter study. *Ann Surg* 2020;271:913-21.
24. Moon DB, Hwang S, Wang HJ, Yun SS, Kim KS, Lee YJ, et al. Surgical outcomes of hepatocellular carcinoma with bile duct tumor thrombus: a Korean multicenter study. *World J Surg* 2013;37:443-51.
25. Xu Z, Shi L, Wang Y, Zhang J, Huang L, Zhang C, et al. Pathological findings of COVID-19 associated with acute respiratory distress syndrome. *Lancet Respir Med* 2020;8:420-2.
26. Kumar D, Tellier R, Draker R, Levy G, Humar A. Severe acute respiratory syndrome (SARS) in a liver transplant recipient and guidelines for donor SARS screening. *Am J Transplant* 2003;3:977-81.
27. Royal College of Radiologists. Statement on use of CT chest to screen for COVID-19 in pre-operative patients [Internet]. Royal College of Radiologists; 2020 [cited 2025 Jul 17]. Available from: <https://www.rcr.ac.uk/posts/statement-use-ct-chest-screen-covid-19-pre-operative-patients>
28. American College of Radiology (ACR). ACR recommendations for the use of chest radiography and computed tomography (CT) for suspected COVID-19 infection [Internet]. ACR; 2020 Mar 11 [cited 2025 Jul 17]. Available from: <https://www.acr.org/Advocacy/Position-Statements/Recommendations-for-Chest-Radiography-and-CT-for-Suspected-COVID19-Infection>
29. Shiina S, Gani RA, Yokosuka O, Maruyama H, Nagamatsu H, Payawal DA, et al. APASL practical recommendations for the management of hepatocellular carcinoma in the era of COVID-19. *Hepatol Int* 2020;14:920-9.
30. Sugita A, Inagaki FF, Takemura N, Nakamura M, Ito K, Mihara F, et al. Liver resection in a patient with persistent positive PCR test for coronavirus disease 2019 (COVID-19): a case report. *Surg Case Rep* 2022;8:200.
31. Smukler AJ, Ratner L. Hepatitis viruses and hepatocellular carcinoma in HIV-infected patients. *Curr Opin Oncol* 2002;14:538-42.
32. Bosch FX, Ribes J, Díaz M, Cléries R. Primary liver cancer: worldwide incidence and trends. *Gastroenterology* 2004;127:S5-S16.
33. Clifford GM, Rickenbach M, Polesel J, Dal Maso L, Steffen I, Ledergerber B, et al. Influence of HIV-related immunodeficiency on the risk of hepatocellular carcinoma. *AIDS* 2008;22:2135-41.
34. Bräu N, Fox RK, Xiao P, Marks K, Naqvi Z, Taylor LE, et al. Presentation and outcome of hepatocellular carcinoma in HIV-infected patients: a U.S.-Canadian multicenter study. *J Hepatol* 2007;47:527-37.
35. Berretta M, Garlassi E, Cacopardo B, Cappellani A, Guaraldi G, Cocchi S, et al. Hepatocellular carcinoma in HIV-infected patients: check early, treat hard. *Oncologist* 2011;16:1258-69.
36. D'amico G, Tarantino G, Ballarin R, Serra V, Pecchi AR, Guaraldi G, et al. Liver resection for HCC in HIV-infected patients: a single center experience. *WCRJ* 2015;2:e490.
37. Korean Association for the Study of the Liver (KASL). KASL clinical practice guidelines for management of chronic

- hepatitis B. *Clin Mol Hepatol* 2022;28:276-331.
38. Fattovich G. Natural history and prognosis of hepatitis B. *Semin Liver Dis* 2003; 23:47-58.
 39. Lok AS, McMahon BJ, Brown RS, Wong JB, Ahmed AT, Farah W, et al. Antiviral therapy for chronic hepatitis B viral infection in adults: a systematic review and meta-analysis. *Hepatology* 2016;63:284-306.
 40. Papatheodoridi M, Tampaki M, Lok AS, Papatheodoridis GV. Risk of HBV reactivation during therapies for HCC: a systematic review. *Hepatology* 2022;75: 1257-74.
 41. Lee JI, Kim JK, Chang HY, Lee JW, Kim JM, Chung HJ, et al. Impact of postoperative hepatitis B virus reactivation in hepatocellular carcinoma patients who formerly had naturally suppressed virus. *J Gastroenterol Hepatol* 2014;29:1019-27.
 42. Wu CY, Chen YJ, Ho HJ, Hsu YC, Kuo KN, Wu MS, et al. Association between nucleoside analogues and risk of hepatitis B virus-related hepatocellular carcinoma recurrence following liver resection. *JAMA* 2012;308:1906-14.
 43. Yin J, Li N, Han Y, Xue J, Deng Y, Shi J, et al. Effect of antiviral treatment with nucleotide/nucleoside analogs on postoperative prognosis of hepatitis B virus-related hepatocellular carcinoma: a two-stage longitudinal clinical study. *J Clin Oncol* 2013;31:3647-55.
 44. Bang CS, Song IH. Impact of antiviral therapy on hepatocellular carcinoma and mortality in patients with chronic hepatitis C: systematic review and meta-analysis. *BMC Gastroenterol* 2017;17:46.
 45. He S, Lockart I, Alavi M, Danta M, Hajarizadeh B, Dore GJ. Systematic review with meta-analysis: effectiveness of direct-acting antiviral treatment for hepatitis C in patients with hepatocellular carcinoma. *Aliment Pharmacol Ther* 2020;51:34-52.
 46. Nault JC, Colombo M. Hepatocellular carcinoma and direct acting antiviral treatments: controversy after the revolution. *J Hepatol* 2016;65:663-5.
 47. Singal AG, Lim JK, Kanwal F. AGA clinical practice update on interaction between oral direct-acting antivirals for chronic hepatitis c infection and hepatocellular carcinoma: expert review. *Gastroenterology* 2019;156:2149-57.
 48. Primavesi F, Maglione M, Cipriani F, Denecke T, Oberkofler CE, Starlinger P, et al. E-AHPBA-ESSO-ESSR Innsbruck consensus guidelines for preoperative liver function assessment before hepatectomy. *Br J Surg* 2023;110:1331-47.
 49. Brown RS, Kumar KS, Russo MW, Kinkhabwala M, Rudow DL, Harren P, et al. Model for end-stage liver disease and Child-Turcotte-Pugh score as predictors of pretransplantation disease severity, posttransplantation outcome, and resource utilization in United Network for Organ Sharing status 2A patients. *Liver Transpl* 2002;8:278-84.
 50. Cucchetti A, Ercolani G, Vivarelli M, Cescon M, Ravaioli M, La Barba G, et al. Impact of model for end-stage liver disease (MELD) score on prognosis after hepatectomy for hepatocellular carcinoma on cirrhosis. *Liver Transpl* 2006;12:966-71.
 51. McCormack L, Petrowsky H, Jochum W, Furrer K, Clavien PA. Hepatic steatosis is a risk factor for postoperative complications after major hepatectomy: a matched case-control study. *Ann Surg* 2007;245:923-30.
 52. Nicoll A. Surgical risk in patients with cirrhosis. *J Gastroenterol Hepatol* 2012;27: 1569-75.
 53. Kudo M. Management of Hepatocellular Carcinoma in Japan: Current Trends. *Liver Cancer* 2020;9:1-5.
 54. Fan ST, Lai EC, Lo CM, Ng IO, Wong J. Hospital mortality of major hepatectomy for hepatocellular carcinoma associated with cirrhosis. *Arch Surg* 1995;130:198-203.
 55. Fan ST. Liver functional reserve estimation: state of the art and relevance for local treatments: the Eastern perspective. *J Hepatobiliary Pancreat Sci* 2010;17:380-4.
 56. Lam CM, Fan ST, Lo CM, Wong J. Major hepatectomy for hepatocellular carcinoma in patients with an unsatisfactory indocyanine green clearance test. *Br J Surg* 1999;86:1012-7.
 57. Yamazaki S, Takayama T. Surgical treatment of hepatocellular carcinoma: evidence-based outcomes. *World J Gastroenterol* 2008;14:685-92.
 58. Kim SU, Ahn SH, Park JY, Kim DY, Chon CY, Choi JS, et al. Prediction of postoperative hepatic insufficiency by liver stiffness measurement (FibroScan((R))) before curative resection of hepatocellular carcinoma: a pilot study. *Hepatol Int* 2008;2:471-7.
 59. Siu-Ting Lau R, Ip P, Lai-Hung Wong G, Wai-Sun Wong V, Jun-Yee Lo E, Kam-Cheung Wong K, et al. Liver stiffness measurement predicts short-term and long-term outcomes in patients with hepatocellular carcinoma after curative liver resection. *Surgeon* 2022;20:78-84.
 60. Singh S, Venkatesh SK, Loomba R, Wang Z, Sirlin C, Chen J, et al. Magnetic resonance elastography for staging liver fibrosis in non-alcoholic fatty liver disease: a diagnostic accuracy systematic review and individual participant data pooled analysis. *Eur Radiol* 2016;26:1431-40.
 61. Liang Y, Li D. Magnetic resonance elastography in staging liver fibrosis in non-alcoholic fatty liver disease: a pooled analysis of the diagnostic accuracy. *BMC Gastroenterol* 2020;20:89.
 62. Meier V, Ramadori G. Clinical staging of hepatocellular carcinoma. *Dig Dis* 2009;27:131-41.
 63. Kinoshita A, Onoda H, Fushiya N, Koike K, Nishino H, Tajiri H. Staging systems for hepatocellular carcinoma: current status and future perspectives. *World J Hepatol* 2015;7:406-24.
 64. Kim IG, Hu XG, Wang HJ, Kim BW, Hong SY, Shen XY. The 7th/8th American Joint Committee on Cancer and the Modified Union for International Cancer Control Staging System for Hepatocellular Carcinoma. *Yonsei Med J* 2019;60:140-7.
 65. Kudo M, Kitano M, Sakurai T, Nishida N. General Rules for the Clinical and Pathological Study of Primary Liver Cancer. Nationwide Follow-Up Survey and Clinical Practice Guidelines: The Outstanding Achievements of the Liver

- Cancer Study Group of Japan. Dig Dis 2015;33:765-70.
66. Ueno S, Tanabe G, Nuruki K, Hamanoue M, Komorizono Y, Oketani M, et al. Prognostic performance of the new classification of primary liver cancer of Japan (4th edition) for patients with hepatocellular carcinoma: a validation analysis. *Hepatol Res* 2002;24:395-403.
 67. Edge SB, Compton CC. The American Joint Committee on Cancer: the 7th edition of the AJCC cancer staging manual and the future of TNM. *Ann Surg Oncol* 2010;17:1471-4.
 68. Abdel-Rahman O. Assessment of the discriminating value of the 8th AJCC stage grouping for hepatocellular carcinoma. *HPB (Oxford)* 2018;20:41-8.
 69. Llovet JM, Brú C, Bruix J. Prognosis of hepatocellular carcinoma: the BCLC staging classification. *Semin Liver Dis* 1999;19:329-38.
 70. Llovet JM, Di Bisceglie AM, Bruix J, Kramer BS, Lencioni R, Zhu AX, et al. Design and endpoints of clinical trials in hepatocellular carcinoma. *J Natl Cancer Inst* 2008;100:698-711.
 71. Marrero JA, Kudo M, Bronowicki JP. The challenge of prognosis and staging for hepatocellular carcinoma. *Oncologist* 2010;15 Suppl 4:23-33.
 72. Zheng J, Kuk D, Gönen M, Balachandran VP, Kingham TP, Allen PJ, et al. Actual 10-year survivors after resection of hepatocellular carcinoma. *Ann Surg Oncol* 2017;24:1358-66.
 73. Ben Lassoued A, Nivaggioni V, Gabert J. Minimal residual disease testing in hematologic malignancies and solid cancer. *Expert Rev Mol Diagn* 2014;14:699-712.
 74. Rossi G, Ignatiadis M. Promises and pitfalls of using liquid biopsy for precision medicine. *Cancer Res* 2019;79:2798-804.
 75. Yang P, Si A, Yang J, Cheng Z, Wang K, Li J, et al. A wide-margin liver resection improves long-term outcomes for patients with HBV-related hepatocellular carcinoma with microvascular invasion. *Surgery* 2019;165:721-30.
 76. Rahbari NN, Garden OJ, Padbury R, Brooke-Smith M, Crawford M, Adam R, et al. Posthepatectomy liver failure: a definition and grading by the International Study Group of Liver Surgery (ISGLS). *Surgery* 2011;149:713-24.
 77. Hu W, Pang X, Guo W, Wu L, Zhang B. Relationship of different surgical margins with recurrence-free survival in patients with hepatocellular carcinoma. *Int J Clin Exp Pathol* 2015;8:3404-9.
 78. Zou H, Zhu CZ, Wang C, Wang ZS, Ma X, Han B, et al. Recurrence of Barcelona clinic liver cancer stage a hepatocellular carcinoma after hepatectomy. *Am J Med Sci* 2017;354:262-7.
 79. Lazzara C, Navarra G, Lazzara S, Barbera A, Saitta C, Raimondo G, et al. Does the margin width influence recurrence rate in liver surgery for hepatocellular carcinoma smaller than 5 cm? *Eur Rev Med Pharmacol Sci* 2017;21:523-9.
 80. Belghiti J, Guevara OA, Noun R, Saldinger PF, Kianmanesh R. Liver hanging maneuver: a safe approach to right hepatectomy without liver mobilization. *J Am Coll Surg* 2001;193:109-11.
 81. Hao S, Fan P, Chen S, Tu C, Wan C. Anterior approach to improve the long-term outcome in patients with large-size hepatocellular carcinoma having liver resection. *J Surg Oncol* 2016;114:872-8.
 82. Wang CC, Jawade K, Yap AQ, Concejero AM, Lin CY, Chen CL. Resection of large hepatocellular carcinoma using the combination of liver hanging maneuver and anterior approach. *World J Surg* 2010;34:1874-8.
 83. Chan KM, Wang YC, Wu TH, Lee CF, Wu TJ, Chou HS, et al. The Preference for anterior approach major hepatectomy: experience over 3 decades and a propensity score-matching analysis in right hepatectomy for hepatocellular carcinoma. *Medicine (Baltimore)* 2015;94:e1385.
 84. Wu TJ, Wang F, Lin YS, Chan KM, Yu MC, Lee WC. Right hepatectomy by the anterior method with liver hanging versus conventional approach for large hepatocellular carcinomas. *Br J Surg* 2010;97:1070-8.
 85. Liu CL, Fan ST, Cheung ST, Lo CM, Ng IO, Wong J. Anterior approach versus conventional approach right hepatic resection for large hepatocellular carcinoma: a prospective randomized controlled study. *Ann Surg* 2006;244:194-203.
 86. Sakon M, Nagano H, Nakamori S, Dono K, Umeshita K, Murakami T, et al. Intrahepatic recurrences of hepatocellular carcinoma after hepatectomy: analysis based on tumor hemodynamics. *Arch Surg* 2002;137:94-9.
 87. Regimbeau JM, Kianmanesh R, Farges O, Dondero F, Sauvanet A, Belghiti J. Extent of liver resection influences the outcome in patients with cirrhosis and small hepatocellular carcinoma. *Surgery* 2002;131:311-7.
 88. Moggia E, Rouse B, Simillis C, Li T, Vaughan J, Davidson BR, et al. Methods to decrease blood loss during liver resection: a network meta-analysis. *Cochrane Database Syst Rev* 2016;10:CD010683.
 89. Zerillo J, Agarwal P, Poeran J, Zubizarreta N, Poultides G, Schwartz M, et al. Perioperative management in hepatic resections: comparative effectiveness of neuraxial anesthesia and disparity of care patterns. *Anesth Analg* 2018;127:855-63.
 90. Belghiti J, Noun R, Malafosse R, Jagot P, Sauvanet A, Pierangeli F, et al. Continuous versus intermittent portal triad clamping for liver resection: a controlled study. *Ann Surg* 1999;229:369-75.
 91. Petrowsky H, McCormack L, Trujillo M, Selzner M, Jochum W, Clavien PA. A prospective, randomized, controlled trial comparing intermittent portal triad clamping versus ischemic preconditioning with continuous clamping for major liver resection. *Ann Surg* 2006;244:921-30.
 92. van den Broek MA, Bloemen JG, Dello SA, van de Poll MC, Olde Damink SW, Dejong CH. Randomized controlled trial analyzing the effect of 15 or 30 min intermittent Pringle maneuver on hepatocellular damage during liver surgery. *J Hepatol* 2011;55:337-45.
 93. Lim C, Osseis M, Lahat E, Azoulay D, Salloum C. Extracorporeal pringle

- maneuver during laparoscopic and robotic hepatectomy: detailed technique and first comparison with intracorporeal maneuver. *J Am Coll Surg* 2018;226:e19-25.
94. Ryckx A, Christiaens C, Clarysse M, Vansteenkiste F, Steelant PJ, Sergeant G, et al. Central venous pressure drop after hypovolemic phlebotomy is a strong independent predictor of intraoperative blood loss during liver resection. *Ann Surg Oncol* 2017;24:1367-75.
 95. Johnson M, Mannar R, Wu AV. Correlation between blood loss and inferior vena caval pressure during liver resection. *Br J Surg* 1998;85:188-90.
 96. Rahbari NN, Koch M, Zimmermann JB, Elbers H, Bruckner T, Contin P, et al. Infrahepatic inferior vena cava clamping for reduction of central venous pressure and blood loss during hepatic resection: a randomized controlled trial. *Ann Surg* 2011;253:1102-10.
 97. Makuuchi M, Hasegawa H, Yamazaki S. Ultrasonically guided subsegmentectomy. *Surg Gynecol Obstet* 1985;161:346-50.
 98. Imamura H, Shimada R, Kubota M, Matsuyama Y, Nakayama A, Miyagawa S, et al. Preoperative portal vein embolization: an audit of 84 patients. *Hepatology* 1999;29:1099-105.
 99. Makuuchi M, Thai BL, Takayasu K, Takayama T, Kosuge T, Gunvén P, et al. Preoperative portal embolization to increase safety of major hepatectomy for hilar bile duct carcinoma: a preliminary report. *Surgery* 1990;107:521-7.
 100. Nagino M, Kamiya J, Nishio H, Ebata T, Arai T, Nimura Y. Two hundred forty consecutive portal vein embolizations before extended hepatectomy for biliary cancer: surgical outcome and long-term follow-up. *Ann Surg* 2006;243:364-72.
 101. Ribero D, Abdalla EK, Madoff DC, Donadon M, Loyer EM, Vauthey JN. Portal vein embolization before major hepatectomy and its effects on regeneration, resectability and outcome. *Br J Surg* 2007;94:1386-94.
 102. Yamakado K, Takeda K, Matsumura K, Nakatsuka A, Hirano T, Kato N, et al. Regeneration of the un-embolized liver parenchyma following portal vein embolization. *J Hepatol* 1997;27:871-80.
 103. de Santibañes E, Clavien PA. Playing Play-Doh to prevent postoperative liver failure: the "ALPPS" approach. *Ann Surg* 2012;255:415-7.
 104. Schnitzbauer AA, Lang SA, Goessmann H, Nadalin S, Baumgart J, Farkas SA, et al. Right portal vein ligation combined with in situ splitting induces rapid left lateral liver lobe hypertrophy enabling 2-staged extended right hepatic resection in small-for-size settings. *Ann Surg* 2012;255:405-14.
 105. Linecker M, Björnsson B, Stavrou GA, Oldhafer KJ, Lurje G, Neumann U, et al. Risk adjustment in ALPPS is associated with a dramatic decrease in early mortality and morbidity. *Ann Surg* 2017;266:779-86.
 106. Cescon M, Vetrone G, Grazi GL, Ramacciato G, Ercolani G, Ravaioli M, et al. Trends in perioperative outcome after hepatic resection: analysis of 1500 consecutive unselected cases over 20 years. *Ann Surg* 2009;249:995-1002.
 107. Bryant R, Laurent A, Tayar C, Cherqui D. Laparoscopic liver resection- understanding its role in current practice: the Henri Mondor Hospital experience. *Ann Surg* 2009;250:103-11.
 108. Belli G, Limongelli P, Fantini C, D'Agostino A, Cioffi L, Belli A, et al. Laparoscopic and open treatment of hepatocellular carcinoma in patients with cirrhosis. *Br J Surg* 2009;96:1041-8.
 109. Guro H, Cho JY, Han HS, Yoon YS, Choi Y, Periyasamy M. Current status of laparoscopic liver resection for hepatocellular carcinoma. *Clin Mol Hepatol* 2016;22:212-8.
 110. Wakabayashi G, Cherqui D, Geller DA, Buell JF, Kaneko H, Han HS, et al. Recommendations for laparoscopic liver resection: a report from the second international consensus conference held in Morioka. *Ann Surg* 2015;261:619-29.
 111. Xiang L, Xiao L, Li J, Chen J, Fan Y, Zheng S. Safety and feasibility of laparoscopic hepatectomy for hepatocellular carcinoma in the posterosuperior liver segments. *World J Surg* 2015;39:1202-9.
 112. Teo JY, Kam JH, Chan CY, Goh BK, Wong JS, Lee VT, et al. Laparoscopic liver resection for posterosuperior and anterolateral lesions-a comparison experience in an Asian centre. *Hepatobiliary Surg Nutr* 2015;4:379-90.
 113. Jia C, Li H, Wen N, Chen J, Wei Y, Li B. Laparoscopic liver resection: a review of current indications and surgical techniques. *Hepatobiliary Surg Nutr* 2018;7:277-88.
 114. Lee MK, Gao F, Strasberg SM. Perceived complexity of various liver resections: results of a survey of experts with development of a complexity score and classification. *J Am Coll Surg* 2015;220:64-9.
 115. Thornblade LW, Shi X, Ruiz A, Flum DR, Park JO. Comparative effectiveness of minimally invasive surgery and conventional approaches for major or challenging hepatectomy. *J Am Coll Surg* 2017;224:851-61.
 116. Gil E, Kwon CH, Kim JM, Choi GS, Heo JS, Cho W, et al. Laparoscopic liver resection of hepatocellular carcinoma with a tumor size larger than 5cm: review of 45 cases in a tertiary institution. *J Laparoendosc Adv Surg Tech A* 2017;27:799-803.
 117. Ai JH, Li JW, Chen J, Bie P, Wang SG, Zheng SG. Feasibility and safety of laparoscopic liver resection for hepatocellular carcinoma with a tumor size of 5-10 cm. *PLoS One* 2013;8:e72328.
 118. Levi Sandri GB, Spoletoni G, Vennarecci G, Francione E, Abu Hilal M, Ettorre GM. Laparoscopic liver resection for large HCC: short- and long-term outcomes in relation to tumor size. *Surg Endosc* 2018;32:4772-9.
 119. Zhang KJ, Liang L, Diao YK, Xie YM, Wang DD, Xu FQ, et al. Short- and long-term outcomes of laparoscopic versus open liver resection for large hepatocellular carcinoma: a propensity score study. *Surg Today* 2023;53:322-31.
 120. Kabir T, Syn NL, Guo Y, Lim KI, Goh BK. Laparoscopic liver resection for huge (≥ 10 cm) hepatocellular carcinoma: a

- coarsened exact-matched single-surgeon study. *Surg Oncol* 2021;37:101569.
121. Cauchy F, Fuks D, Nomi T, Schwarz L, Barbier L, Dokmak S, et al. Risk factors and consequences of conversion in laparoscopic major liver resection. *Br J Surg* 2015;102:785-95.
 122. Kasai M, Cipriani F, Gayet B, Aldrighetti L, Ratti F, Sarmiento JM, et al. Laparoscopic versus open major hepatectomy: a systematic review and meta-analysis of individual patient data. *Surgery* 2018;163: 985-95.
 123. Dagher I, O'Rourke N, Geller DA, Cherqui D, Belli G, Gamblin TC, et al. Laparoscopic major hepatectomy: an evolution in standard of care. *Ann Surg* 2009;250:856-60.
 124. Sijberden JP, Hoogteijling TJ, Aghayan D, Ratti F, Tan EK, Morrison-Jones V, et al. Robotic versus laparoscopic liver resection in various settings: an international multicenter propensity score matched study of 10,075 patients. *Ann Surg* 2024; 280:108-17.
 125. Ji WB, Wang HG, Zhao ZM, Duan WD, Lu F, Dong JH. Robotic-assisted laparoscopic anatomic hepatectomy in China: initial experience. *Ann Surg* 2011;253:342-8.
 126. Sucandy I, Luberice K, Lippert T, Castro M, Krill E, Ross S, et al. Robotic major hepatectomy: an institutional experience and clinical outcomes. *Ann Surg Oncol* 2020;27:4970-9.
 127. Mao B, Zhu S, Li D, Xiao J, Wang B, Yan Y. Comparison of safety and effectiveness between robotic and laparoscopic major hepatectomy: a systematic review and meta-analysis. *Int J Surg* 2023;109:4333-46.
 128. Liu R, Abu Hilal M, Wakabayashi G, Han HS, Palanivelu C, Boggi U, et al. International experts consensus guidelines on robotic liver resection in 2023. *World J Gastroenterol* 2023;29:4815-30.
 129. Giulianotti PC, Sbrana F, Bianco FM, Addeo P. Robot-assisted laparoscopic extended right hepatectomy with biliary reconstruction. *J Laparoendosc Adv Surg Tech A* 2010;20:159-63.
 130. Jang EJ, Kim KW. Feasibility assessment of robotic major hepatectomy and bile duct resection in Klatskin type IIIB tumor with concomitant gallbladder cancer. *Ann Surg Oncol* 2024;31:7898-9.
 131. Christodoulou M, Pattilachan T, Ross SB, Larocca S, Sucandy I. Robotic left hepatectomy with en bloc biliary resection and Roux-en-Y hepaticojejunostomy: a technique of portal venous tangential vascular reconstruction. *Ann Surg Oncol* 2024;31:4905-7.
 132. Soyama A, Hamada T, Adachi T, Eguchi S. Current status and future perspectives of robotic liver surgery. *Hepatol Res* 2024;54:786-94.
 133. Ban D, Tanabe M, Ito H, Otsuka Y, Nitta H, Abe Y, et al. A novel difficulty scoring system for laparoscopic liver resection. *J Hepatobiliary Pancreat Sci* 2014;21:745-53.
 134. Wakabayashi G. What has changed after the Morioka consensus conference 2014 on laparoscopic liver resection? *Hepatobiliary Surg Nutr* 2016;5:281-9.
 135. Hasegawa Y, Wakabayashi G, Nitta H, Takahara T, Katagiri H, Umemura A, et al. A novel model for prediction of pure laparoscopic liver resection surgical difficulty. *Surg Endosc* 2017;31:5356-63.
 136. Kawaguchi Y, Fuks D, Kokudo N, Gayet B. Difficulty of laparoscopic liver resection: proposal for a new classification. *Ann Surg* 2018;267:13-7.
 137. Halls MC, Berardi G, Cipriani F, Barkhatov L, Lainas P, Harris S, et al. Development and validation of a difficulty score to predict intraoperative complications during laparoscopic liver resection. *Br J Surg* 2018;105:1182-91.
 138. Linn YL, Wu AG, Han HS, Liu R, Chen KH, Fuks D, et al. Systematic review and meta-analysis of difficulty scoring systems for laparoscopic and robotic liver resections. *J Hepatobiliary Pancreat Sci* 2023;30:36-59.
 139. Sucandy I, Dugan MM, Ross SB, Syblis C, Crespo K, Kenary PY, et al. Tampa Difficulty Score: a novel scoring system for difficulty of robotic hepatectomy. *J Gastrointest Surg* 2024;28:685-93.
 140. Ricker AB, Davis JM, Motz BM, Watson M, Beckman M, Driedger M, et al. External validation of the Japanese difficulty score for laparoscopic hepatectomy in patients undergoing robotic-assisted hepatectomy. *Surg Endosc* 2023;37:7288-94.
 141. Sung H, Siegel RL, Torre LA, Pearson-Stuttard J, Islami F, Fedewa SA, et al. Global patterns in excess body weight and the associated cancer burden. *CA Cancer J Clin* 2019;69:88-112.
 142. Bazurro S, Ball L, Pelosi P. Perioperative management of obese patient. *Curr Opin Crit Care* 2018;24:560-7.
 143. Chacon MM, Cheruku SR, Neuburger PJ, Lester L, Shillcutt SK. Perioperative care of the obese cardiac surgical patient. *J Cardiothorac Vasc Anesth* 2018;32:1911-21.
 144. Lang LH, Parekh K, Tsui BY, Maze M. Perioperative management of the obese surgical patient. *Br Med Bull* 2017;124:135-55.
 145. Behrns KE, Tsiotos GG, DeSouza NF, Krishna MK, Ludwig J, Nagorney DM. Hepatic steatosis as a potential risk factor for major hepatic resection. *J Gastrointest Surg* 1998;2:292-8.
 146. Villagomez D, Shah M, Marti F, Orozco G, Davenport D, Gupta M, et al. Hepatic steatosis is associated with an increased risk of postoperative infections and perioperative transfusion requirements in patients undergoing hepatectomy. *World J Surg* 2021;45:3654-9.
 147. Plassmeier L, Hankir MK, Seyfried F. Impact of excess body weight on postsurgical complications. *Visc Med* 2021;37:287-97.
 148. Berton M, Bettonte S, Stader F, Battegay M, Marzolini C. Repository describing the anatomical, physiological, and biological changes in an obese population to inform physiologically based pharmacokinetic models. *Clin Pharmacokinet* 2022;61:1251-70.
 149. Shah NM, Kaltsakas G. Respiratory complications of obesity: from early changes to respiratory failure. *Breathe (Sheff)* 2023;19:220263.
 150. Liu YW, Yong CC, Lin CC, Wang CC, Chen CL, Cheng YF, et al. Liver resection in elderly patients with hepatocellular carcinoma: age does matter. *Updates Surg* 2021;73:1371-80.

151. Esquiroz Lizauro I, Zambom-Ferraresi F, Zambom-Ferraresi F, Ollo-Martínez I, De la Casa-Marín A, Martínez-Velilla N, et al. Postoperative physical rehabilitation in the elderly patient after emergency surgery. Influence on functional, cognitive and quality of life recovery: study protocol for a randomized clinical trial. *Trials* 2024;25:584.
152. Ahmed FA, Khan SA, Hafeez MS, Jehan FS, Aziz H. Outcomes in elderly patients undergoing hepatic resection compared to ablative therapy for hepatocellular carcinoma. *J Surg Oncol* 2023;128:803-11.
153. Khan SA, Ahmed FA, Hafeez MS, Feng LR, Seth A, Kwon YK, et al. Outcomes in elderly patients undergoing hepatic resection compared to liver transplant for hepatocellular carcinoma. *J Surg Oncol* 2023;128:1320-8.
154. Verhoeff K, Glinka J, Quan D, Skaro A, Tang ES. Laparoscopic versus open hepatic resection in patients ≥ 75 years old: a NSQIP analysis evaluating 2674 patients. *J Surg Oncol* 2024;130:1006-13.
155. Cao S, Zheng T, Wang H, Niu Z, Chen D, Zhang J, et al. Enhanced recovery after surgery in elderly gastric cancer patients undergoing laparoscopic total gastrectomy. *J Surg Res* 2021;257:579-86.
156. You K, Han H. Application of ERAS in older patients with gastric cancer. *Medicine (Baltimore)* 2024;103:e38409.
157. Kanno H, Hashimoto K, Sakai H, Ogata T, Fukutomi S, Akashi M, et al. Safety and feasibility of liver resection including major hepatectomy for geriatric patients with hepatocellular carcinoma: a retrospective observational study. *BMC Cancer* 2024;24:765.
158. Kim KI, Park KH, Koo KH, Han HS, Kim CH. Comprehensive geriatric assessment can predict postoperative morbidity and mortality in elderly patients undergoing elective surgery. *Arch Gerontol Geriatr* 2013;56:507-12.
159. Kim SW, Han HS, Jung HW, Kim KI, Hwang DW, Kang SB, et al. Multidimensional frailty score for the prediction of post-operative mortality risk. *JAMA Surg* 2014;149:633-40.
160. Lee B, Cho JY, Han HS, Yoon YS, Lee HW, Lee JS, et al. A scoring system to predict the risk of major complications after laparoscopic liver resection in elderly patients with hepatocellular carcinoma. *Surg Endosc* 2022;36:7756-63.
161. Sabaté S, Mases A, Guilerá N, Canet J, Castillo J, Orrego C, et al. Incidence and predictors of major perioperative adverse cardiac and cerebrovascular events in non-cardiac surgery. *Br J Anaesth* 2011;107:879-90.
162. Tran TB, Worhunsky DJ, Spain DA, Dua MM, Visser BC, Norton JA, et al. The significance of underlying cardiac comorbidity on major adverse cardiac events after major liver resection. *HPB (Oxford)* 2016;18:742-7.
163. Johnson PJ. Non-surgical treatment of hepatocellular carcinoma. *HPB (Oxford)* 2005;7:50-5.
164. Yip WM, Hung HG, Lok KH, Li KF, Li KK, Szeto ML. Outcome of inoperable hepatocellular carcinoma patients receiving transarterial chemoembolisation: a real-life retrospective analysis in a Hong Kong regional hospital. *Hong Kong Med J* 2009;15:339-45.
165. Mahendran S, Thiagalingam A, Hillis G, Halliwell R, Pleass HC, Chow CK. Cardiovascular risk management in the peri-operative setting. *Med J Aust* 2023;219:30-9.
166. Liu XY, Zhao ZQ, Cheng YX, Tao W, Yuan C, Zhang B, et al. Does chronic kidney disease really affect the complications and prognosis after liver resection for hepatocellular carcinoma?: a meta-analysis. *Front Surg* 2022;9:870946.
167. Harrison TG, Hemmelgarn BR, Farragher JF, O'Rielly C, Donald M, James M, et al. Perioperative management for people with chronic kidney disease receiving dialysis undergoing major surgery: a protocol for a scoping review. *BMJ Open* 2020;10:e038725.
168. Nasr R, Chilimuri S. Preoperative evaluation in patients with end-stage renal disease and chronic kidney disease. *Health Serv Insights* 2017;10:1178632917713020.
169. Harrison TG, Hemmelgarn BR, Farragher JF, O'Rielly C, Donald M, James MT, et al. Perioperative management for people with kidney failure receiving dialysis: a scoping review. *Semin Dial* 2023;36:57-66.
170. Shirata C, Hasegawa K, Kokudo T, Yamashita S, Yamamoto S, Arita J, et al. Liver resection for hepatocellular carcinoma in patients with renal dysfunction. *World J Surg* 2018;42:4054-62.
171. Hatzaras I, Bischof DA, Fahy B, Cosgrove D, Pawlik TM. Treatment options and surveillance strategies after therapy for hepatocellular carcinoma. *Ann Surg Oncol* 2014;21:758-66.
172. Brown ZJ, Tsilimigras DI, Ruff SM, Mohseni A, Kamel IR, Cloyd JM, et al. Management of hepatocellular carcinoma: a review. *JAMA Surg* 2023;158:410-20.
173. Pinna AD, Yang T, Mazzaferro V, De Carlis L, Zhou J, Roayaie S, et al. Liver transplantation and hepatic resection can achieve cure for hepatocellular carcinoma. *Ann Surg* 2018;268:868-75.
174. Tabrizian P, Jibara G, Shrager B, Schwartz M, Roayaie S. Recurrence of hepatocellular cancer after resection: patterns, treatments, and prognosis. *Ann Surg* 2015;261:947-55.
175. Singal AG, Llovet JM, Yarchoan M, Mehta N, Heimbach JK, Dawson LA, et al. AASLD Practice Guidance on prevention, diagnosis, and treatment of hepatocellular carcinoma. *Hepatology* 2023;78:1922-65.
176. European Association for the Study of the Liver. EASL clinical practice guidelines: management of hepatocellular carcinoma. *J Hepatol* 2018;69:182-236.
177. Hasegawa K, Takemura N, Yamashita T, Watadani T, Kaibori M, Kubo S, et al. Clinical practice guidelines for hepatocellular carcinoma: the Japan Society of Hepatology 2021 version (5th JSH-HCC Guidelines). *Hepatol Res* 2023;53:383-90.
178. Kanwal F, Singal AG. Surveillance for hepatocellular carcinoma: current best practice and future direction. *Gastroenterology* 2019;157:54-64.
179. Su TH, Wu CH, Liu TH, Ho CM, Liu CJ. Clinical practice guidelines and real-life practice in hepatocellular carcinoma: a Taiwan perspective. *Clin Mol Hepatol*

- 2023;29:230-41.
- 180.Mirdad RS, Madison Hyer J, Diaz A, Tsilimigras DI, Azap RA, Paro A, et al. Postoperative imaging surveillance for hepatocellular carcinoma: How much is enough? *J Surg Oncol* 2021;123:1568-77.
- 181.Nguyen T, Vennatt J, Downs L, Surabhi V, Stanietzky N. Advanced imaging of hepatocellular carcinoma: a review of current and novel techniques. *J Gastrointest Cancer* 2024;55:1469-84.
- 182.Adeniji N, Dhanasekaran R. Current and emerging tools for hepatocellular carcinoma surveillance. *Hepatol Commun* 2021;5:1972-86.
- 183.Willatt J, Ruma JA, Azar SF, Dasika NL, Syed F. Imaging of hepatocellular carcinoma and image guided therapies: how we do it. *Cancer Imaging* 2017;17:9.
- 184.Park HJ, Kim SY. Imaging modalities for hepatocellular carcinoma surveillance: expanding horizons beyond ultrasound. *J Liver Cancer* 2020;20:99-105.
- 185.Min JH, Kim YK, Choi SY, Kang TW, Jeong WK, Kim K, et al. Detection of recurrent hepatocellular carcinoma after surgical resection: non-contrast liver MR imaging with diffusion-weighted imaging versus gadoxetic acid-enhanced MR imaging. *Br J Radiol* 2018;91:20180177.
- 186.Lee DD, Sapisochin G, Mehta N, Gorgen A, Musto KR, Hajda H, et al. Surveillance for HCC after liver transplantation: increased monitoring may yield aggressive treatment options and improved postrecurrence survival. *Transplantation* 2020;104:2105-12.
- 187.Cha DI, Kim JM, Jeong WK, Yi NJ, Choi GS, Rhu J, et al. Recurrence-free survival after liver transplantation versus surgical resection for hepatocellular carcinoma: role of high-risk MRI features. *Transplantation* 2024;108:215-24.
- 188.Miki A, Sakuma Y, Watanabe J, Endo K, Sasanuma H, Teratani T, et al. Remnant liver function is associated with long-term survival in patients with hepatocellular carcinoma undergoing hepatectomy. *Sci Rep* 2023;13:15637.
- 189.Xu X, Wang MD, Xu JH, Fan ZQ, Diao YK, Chen Z, et al. Adjuvant immunotherapy improves recurrence-free and overall survival following surgical resection for intermediate/advanced hepatocellular carcinoma a multicenter propensity matching analysis. *Front Immunol* 2023;14:1322233.
- 190.Yilma M, Houhong Xu R, Saxena V, Muzzin M, Tucker LY, Lee J, et al. Survival outcomes among patients with hepatocellular carcinoma in a large integrated US health system. *JAMA Netw Open* 2024;7:e2435066.
- 191.Yu S, Jo HS, Yu YD, Choi YJ, Kim DS. Clinical outcome of surgical resection for multifocal T2-T3 hepatocellular carcinoma up to 3 nodules: a comparative analysis with a single nodule. *J Liver Cancer* 2023;23:377-88.
- 192.Angeli-Pahim I, Chambers A, Duarte S, Zarrinpar A. Current trends in surgical management of hepatocellular carcinoma. *Cancers (Basel)* 2023;15:5378.