Individualized Ablation of Hepatocellular Carcinoma: Tailored Approaches across the Phenotype Spectrum

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Abstract

Ablation is now recommended by international guidelines for the definitive treatment of hepatocellular carcinoma (HCC). Extensive clinical studies have demonstrated outcomes comparable to surgical resection with shorter hospital stays, decreased costs, and improved quality of life. Successful ablation requires complete treatment of both tumor and margin while preserving critical adjacent structures. HCC exhibits highly variable presentations in both anatomic involvement and biology which have significant implications on choice of ablative therapy. There are now abundant ablation modalities and adjunctive techniques which can be used to individualize ablation and maximize curative results. This article provides a patient-centered summary of approaches to HCC ablation in the context of patient performance, hepatic reserve, tumor phenotype and biology, intra- and extrahepatic anatomy, and ablation technology.

Keywords
► hepatocellular carcinoma
► locoregional therapy
► ablation

Ablation is now endorsed by international professional societal guidelines, including those of the American Association for the Study of Liver Disease[1] and the European Association for the Study of the Liver,[2] and it has been incorporated within the Barcelona Clinic Liver Cancer group schema,[3] for the definitive treatment of hepatocellular carcinoma (HCC). Randomized controlled trials have demonstrated no difference in overall survival (OS) or recurrence-free survival (RFS) between ablation and surgical resection for small tumors[4,5] with the added benefits of comparatively shorter hospital stays,[6] reduced 30-day admissions,[6] decreased cost,[7] and improved quality of life.[8] Recurrence rates after resection can be as high as 75% 5 years after surgery[9–11] and 8% within the first year of transplantation.[12] These patients may not be candidates for additional surgery but may benefit from ablation of low-volume intrahepatic recurrence.

High-quality ablation requires appropriate patient selection and must consider overall oncologic intent, staging the extent of disease, and estimation of liver reserve after therapy. All treatments should maximize pathologic necrosis of the targeted lesion and the at-risk tissue while preserving critical intra- and extrahepatic anatomy. Many curative stage tumors presenting in unfavorable anatomic locations for thermal ablation may be relegated to palliative therapies such as transarterial chemoembolization (TACE) or systemic therapy. These "orphaned" tumors are generally underrecognized in the literature due to a lack of intention-to-treat data in most ablation studies. Emerging ablation modalities and adjunctive techniques offer an opportunity to individualize the therapeutic approach based on tumor presentation. These choices may be particularly beneficial in patients who are not conventional candidates for thermal ablation. This article provides a tailored approach to definitive HCC ablation in the context of patient health and hepatic reserve, tumor phenotype and biology, intra- and extrahepatic anatomy, and ablation technology.

Patient Health and Hepatic Substrate

Given the frequent concomitant hazard of liver disease, ablation must be performed in patients with an adequate

life expectancy to benefit from treatment. Performance status is commonly assessed with the Eastern Cooperative Oncology Group (ECOG) or Karnofsky scales. Multiple studies have demonstrated that the ECOG is inversely proportional with survival rates in patients treated with radiofrequency ablation (RFA),[13] stereotactic body radiation therapy (SBRT),[14] radioembolization (TARE),[15] and TACE.[16] Appropriate ablation candidates typically have an ECOG score ≤ 1 in which patients demonstrate minimal physical restriction.[17] Higher ECOG scores (≥2) may be acceptable when patients are treated as part of a liver transplantation effort, but are subject to increased toxicity. Furthermore, less toxic therapies may be considered in patients with limited natural life expectancy, at the expense of efficacy, in select circumstances.[18]

Patients undergoing ablative therapy should have adequate volume and functional capacity to tolerate devitalization of the lesion and margin. The total liver function which sustains the patient, or hepatic substrate, is frequently a subjective impression based on summation of factors but can be quantified to some degree using clinical calculators. The albumin-bilirubin grade, Child–Pugh score, and Model for End Stage Liver Disease (MELD) score have all demonstrated useful correlations with survival after locoregional therapy.[16,19–23] Prognostic models which take into consideration both patient and tumor factors have been recently developed for ablation and may help with clinical decision making.[24] Ultimately, these instruments should be used to better define the risks of a treatment plan to both the patient and care team.

In addition to objective signs of liver function, the operator should be aware of more inconspicuous factors that may increase the probability of adverse events such as prior external beam radiotherapy, previous systemic therapy, or extrahepatic comorbidities such as diabetes.[25] Bacterial colonization of bile ducts after previous enterobiliary manipulation has been associated with higher rates of abscess formation after thermal ablation.[26] With proper preprocedural investigation, many of the complications associated with these factors can be avoided.

Endpoints of High-Quality Ablation

The intraprocedural objective of high-quality ablation is complete coverage of the lesion and margin with preservation of critical structures. Ablation margins for the treatment of HCC were initially adopted from the surgical literature, which ranged from 5 to 10 mm, and have since been validated with multiple studies.[27,28] While some authors support a margin of 3 mm for ablation candidacy,[29] margins of less than 5 mm have shown higher rates of local tumor progression (LTP)[30–32] and distant intrahepatic recurrence.[33] Similarly, margins greater than 5 mm have demonstrated decreased rates of LTP, out-of-field progression, and RFS for solitary HCC ≤ 5 cm.[34,35] Margins should be based on imaging predictors of poor biology, such as microvascular invasion (MVI), as resection data have demonstrated margins less than 1 cm in the setting of MVI result in a twofold increase in both recurrence and mortality.[36,37] Most studies evaluating HCC treatment margins do not stratify recommendations based on tumor biology and this is a shortcoming of most guidelines.

Interestingly, there are data to suggest that suboptimal ablation has the ability to promote unfavorable biology and encourage nodal recurrence after transplantation.[38,39] Animal models have demonstrated that more aggressive HCC phenotypes develop through sublethal heat induced activation of extracellular matrix collagen I[40] and induction of an epithelial–mesenchymal transition,[41] while metastatic potential may increase through thermal promotion of vascular endothelial growth factor pathways.[42] Achieving a complete pathologic response prior to transplantation has shown superior posttransplant 5-year recurrence-free survival rates compared with incomplete responses.[43] Overall, the combined surgical and locoregional experience suggests that a 5mm margin is appropriate for lesions that are well-defined, demonstrate favorable biology, and measure less than 3cm and margins of 1cm or greater may be required for larger or more aggressive tumors (►Fig. 1).

Given the potential for harm associated with suboptimal treatment, ablation programs should invest in continuous medical education and quality control efforts to approximate
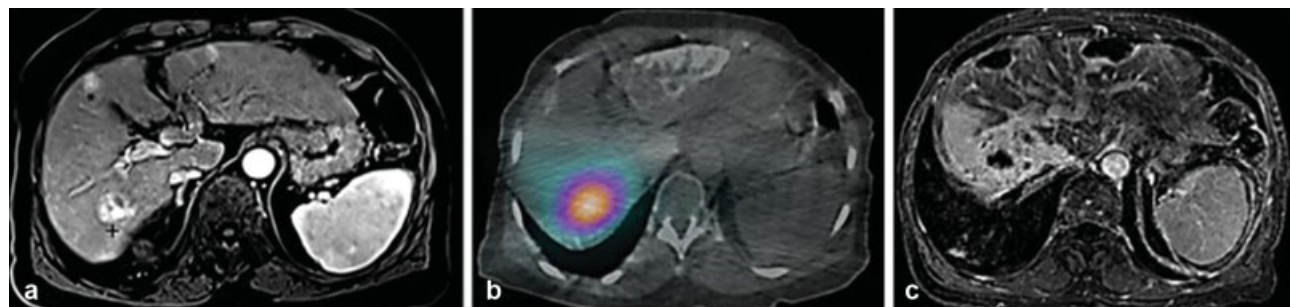

Fig. 1 (a) Contrast-enhanced magnetic resonance imaging (MRI) demonstrates two well-rounded, hypervascular, non–aggressive-appearing hepatocellular carcinomas (HCCs) anteriorly (*) in addition to a large posterior HCC (+) with aggressive features including non-smooth margins, irregular rim-like arterial enhancement, and capsular disruption. The posterior lesion required larger ablation margins to cover the tumor, at-risk margin, and adjacent satellite nodules. (b) Bremsstrahlung single-photon emission computed tomography/computed tomography after ablative radioembolization of the posterior lesion demonstrates activity within the targeted angiosomes covering the entire tumor, satellite lesions, and at least a 1-cm at-risk margin. (c) Contrast-enhanced MRI 3 months after treatment demonstrates a complete response to all three HCCs. There are microwave ablation cavities replacing the anterior low-risk lesions with at least a 5- to 10-mm margin and evolving ablative radioembolization changes to the large posterior aggressive HCC with at least a 1-cm ablative margin. There was no change in baseline liver function after treatment.

the results of experienced high-volume centers. To assist in the advancement of ablation outcomes, interventional radiology is now a separate medical specialty where residents are given specific training in interventional oncology as part of their board certification.

Tumor Biology

HCC biology is remarkably heterogeneous and is driven by a complex interplay between molecular subgrouping, genetic alterations, and other oncologic pathways.[44] Transcriptome-based imaging research suggests that T stage alone may insufficiently predict tumor biology.[45] Imaging predictors of aggressive biology include irregular peripheral morphology and peritumoral enhancement, pseudocapsule disruption, satellite formation, and peritumoral hypointensity on hepatobiliary phase imaging.[46,47] Lower apparent diffusion coefficient values, obtained with b-value 0 to 500 second/ mm^2, may indicate MVI in small HCCs ≤ 2 cm.[48] Poorly differentiated HCC tends to present with arterial phase hypointensity and T2 sequence hyperintensity per magnetic resonance imaging.[46] More established predictors related to aggressive biology include size,[49] biliary[50] and portal system involvement,[51,52] and a doubling time less than 2 months.[53] The presence of fat is associated with lower rates of MVI.[54] Developments in radiomic and texture analysis have demonstrated clinical applicability in HCC and may have a future role in tumor characterization.[55,56]

Although α-fetoprotein (AFP) is the most practical and widely adopted tumor marker for HCC in clinical practice, it has well known limitations in both sensitivity and specificity where up to 40% of patients are nonproducers.[57,58] AFP levels as low as 20 ng/mL have been associated with MVI, poor differentiation, and tumor recurrence compared with non–AFP-producing tumors,[59] while levels greater than 1,000 may compromise transplant candidacy.[60] Elevations in carbohydrate antigen 19–9 in addition to AFP suggest the diagnosis of the biphenotypic hepatocholangiocarcinoma (HCC-CCA).[61] HCC-CCA tumors are more aggressive, have imaging features anywhere along the HCC or cholangiocarcinoma spectrum, and survival is similar to or worse than

intrahepatic cholangiocarcinoma, even in the posttransplant setting.[61–63]

Immunologic ratios such as the serum neutrophil-to-lymphocyte ratio and platelet-to-lymphocyte ratio have been associated with lower OS and RFS after RFA of HCC within Milan criteria.[64] Des-gamma-carboxyprothrombin has been used to predict survival and recurrence after RFA[65] and the hepatitis B viral load has been shown to correlate with local recurrence after RFA.[66] Less commonly used biomarkers include AFP-L3, glypican-3, cytokeratin 19, Golgi protein 73, Midkine, osteopontin, squamous cell carcinoma antigen, annexin A2, and lens culinaris agglutinin.[67,68] Sampling of circulating microRNAs and cell-free DNA in conjunction with clinical presentation may increase the accuracy of HCC diagnosis.[67] The discovery of biomarkers remains an active area of HCC research where future applications may include early treatment reallocation and incorporation into societal guidelines.

Ablation Modality

Thermal

Thermal ablation continues to have the largest published experience of all ablation technologies and RFA carries international recommendations for definitive treatment of HCC ≤ 3 cm with favorable anatomy.[3] These outcomes have been confirmed with post-RFA explant analysis demonstrating HCC complete pathologic necrosis rates ranging from 55 to 100%.[69,70] Microwave ablation (MWA) has theoretical advantages over RFA by offering increased power, the ability to perform larger ablations, less susceptibility to tissue charring, potentially overcoming the heat sink effect, and decreasing procedure time. While a meta-analysis demonstrated superior tumor control in favor of MWA over RFA, a subsequent randomized controlled trial did not identify a difference in outcomes between the two.[71,72]

Cryoablation is of use in high-risk anatomy due to its ability to actively monitor intraprocedural ice formation (►Fig. 2). While animal models demonstrate the −20°C isotherm is 1 mm from the edge of the visualized ice ball,[73] lethal isotherms are highly variable in clinical

Fig. 2 (a) T2-weighted magnetic resonance imaging (MRI) demonstrates a 1.6-cm hepatocellular carcinoma (HCC) with poor arterial conduit and nearby biliary dilatation in which irreversible electroporation could not be performed due to adjacent parallel transjugular intrahepatic portosystemic shunts (TIPS) (*). (b) Two cryoablation probes were placed through the cranial and caudal aspect of the mass with adequate intraprocedural ice formation encompassing the HCC and margin. (c) T2-weighted MRI image along the same plane demonstrates scaring of the treated region without residual disease. There was no evidence of injury to the bile ducts or the TIPS.

practice. Cryoablation can generate larger ablations than RFA with reports of improved outcomes for HCC greater than 3 cm,[74] although larger cryoablations have been loosely associated with rare posttreatment systemic inflammatory reactions termed "cryoreaction" and "cryoshock."[75] Cryoablation may be limited by longer procedure times and a conceptual increased susceptibility to the heat sink effect. Laser ablation, which has the unique property of delivering energy via 21-gauge needles, has shown comparable results to RFA for small HCC, but has limited availability and few centers have developed expertise compared with other thermal modalities.[76]

Nonthermal

Controlled tissue destruction can be achieved via other technologies that do not rely on the alteration of tissue temperature for efficacy. Irreversible electroporation (IRE) generates tumor lethality via the induction of nanoscale

cellular lipid bilayer perforations that result in eventual apoptosis rather than coagulative necrosis. This provides a theoretical advantage with high-risk anatomy via the preservation of extracellular matrix in adjacent tissues and being independent of heat-related effects (►Fig. 3). The disadvantages of IRE include the requirement for general anesthesia and meticulous parallel probe placement. IRE has demonstrated promising results with complete response rates between 77 and 92% for HCCs in challenging locations not amenable to thermal modalities.[77] A recent explant correlation study demonstrated 83% of IRE-treated lesions had complete pathologic necrosis.[78]

Chemical

Percutaneous ethanol injection (PEI) was one of the initially adopted locoregional modalities for HCC. It relies on the caustic properties of ethanol which generate ablative effects via protein denaturation, cellular dehydration, and vascular

Fig. 3 (a) Contrast-enhanced magnetic resonance imaging (MRI) demonstrates a well-rounded hilar hepatocellular carcinoma adjacent to the central bile ducts and the portal vein which could not be safely and effectively treated with thermal ablation. (b) Radioembolization could not be utilized due to an inadequate microvascular conduit, watershed arterial supply, and nontarget preferential flow. The lesion was stained with lipiodol to improve visualization for subsequent irreversible electroporation (IRE). (c) Intraprocedural noncontrast computed tomography demonstrates placement of four parallel IRE probes bracketing the lesion. (d) Noncontrast MRI 3 months after treatment demonstrates complete response with hemorrhage in the center of the lesion and an adequate margin of ablated tissue. Contrast-enhanced images (not shown) demonstrated no evidence of enhancement and there were no complications.

thrombosis. Ethanol can be safely injected next to critical structures such as bile ducts and bowel. While it is useful in treating small tumors adjacent to high-risk structures, outcomes are inferior with larger tumors and adequate chemical diffusion within a lesion can be highly variable.[79–81] Reported rates of PEI complete pathologic necrosis range from 30%[82] to 64.3%[83] in tumors generally smaller than 3 cm.

Chemical ablation can also be performed via transarterial infusion of ethanol (TAE) with wedged embolization in a 1:2 or 1:3 (alcohol:lipiodol) ratio via the complete saturation of arterioles, sinusoids, peribiliary plexus, and portal venules. Candidacy for TAE relies upon the presence of a favorable arterial supply as a therapeutic conduit. A large study evaluating TAE for both small and large HCCs showed a complete response rate of 69.1% with a median time to progression (TTP) of 9.1 months, and a progression-free survival (PFS) of 8.4 months.[84] Compared with TACE, TAE has demonstrated improved TTP and PFS (34.6 vs. 26.1 and 14.8 vs. 9.3 months, respectively) and increased complete response rates at 3, 6, and 12 months.[85] A meta-analysis of 19 RCTs demonstrated TACE with PEI had higher local tumor control and survival rates than PEI alone.[86] As such, the addition of ethanol therapy to thermal ablation could improve outcomes where anatomic constraints would have prevented solitary treatment with either modality.[87]

Radiation

Radioembolization has demonstrated its ability to serve as an ablative therapy in segmental administrations where uniform dose exceeds 190 Gy, commonly referred to as radiation segmentectomy.[88] There are single-center, long-term, five-year survival data that have shown comparability of radiation segmentectomy to established curative standards.[89] Radioembolization can safely ablate large volumes (►Fig. 4), including neoadjuvant lobar treatments, in challenging locations while having minimal toxicity on adjacent structures.[90,91] Radioembolization relies on suitable arterial tumor conduit and adequate margin within the targeted angiosome. Systemic therapies which alter tumor vascularity (e.g., bevacizumab or sorafenib) may affect treatment outcomes. Modulation of suboptimal angiosomes using reversible intra-arterial occlusion has been reported.[92] Hepatic

explant evaluation has demonstrated more than 50% complete pathologic necrosis (>90% in all treated patients) in solitary tumors ≤ 5 cm treated with radioembolization which were not amenable to RFA.[15]

When percutaneous or transarterial ablative therapy is not an option, SBRT with either photon or proton radiation has shown 1-year local control rates of 90.9% and a PFS of 82.7, 58.3, and 36.4% at 1, 3, and 5 years for HCC ≤ 5 cm,[93] respectively. Complete pathologic necrosis rates range from 13%[94] to 28%[95] for tumors up to 4.5 cm in patients undergoing bridge to transplantation.

High-Intensity Focused Ultrasound

High-intensity focused ultrasound (HIFU) is an emerging modality that generates high-energy external compression waves as a means of tissue ablation. Compared with RFA, HIFU has demonstrated similar complete response rates for small recurrent HCC with a mean size of 1.7 to 1.8 cm without a significant difference in disease-free survival or OS.[96] It has also demonstrated similar complete response rates (87.2 vs. 94.4%) and comparable 1- and 3-year OS for tumors less than 3 cm compared with RFA.[97] Utilization has been limited due to long procedure times and the limitations of acoustic windows to access targeted tumors.

Anatomical Considerations

Intrahepatic Anatomy

The anatomic presentation of HCC has major implications in its ability to undergo successful ablation. Due to the extreme effects of thermal-induced coagulative necrosis, tumors located near the central portal triad have demonstrated higher rates of incomplete coverage after thermal ablation,[98,99] an increased risk of intrasegmental recurrence,[100] higher rates of biliary injury,[101] and increased mortality.[102] While experienced users may have the ability to engage centrally located tumors in addition to using adjunctive techniques such as bile duct cooling,[103] effective treatment can still be performed by utilizing nonthermal modalities such as PEI, IRE,[104–106] and radioembolization. Cryoablation has demonstrated reduced damage to central bile ducts in some reports, but caution should still be exerted.[107]
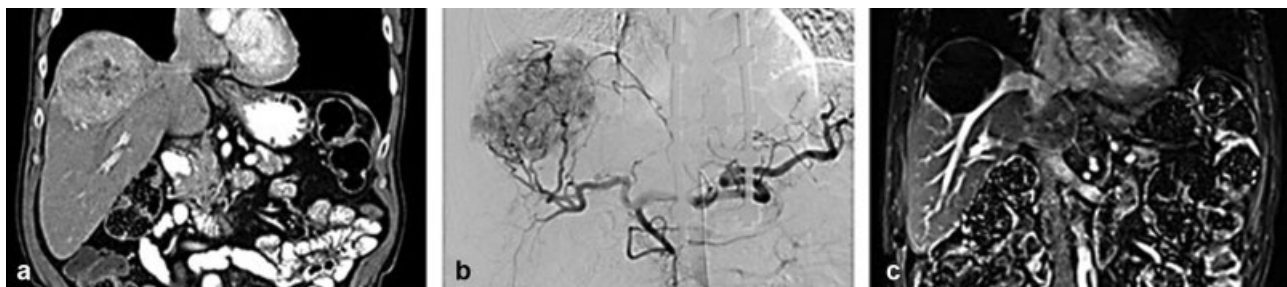

Fig. 4 (a) Contrast-enhanced computed tomography demonstrates a systemic therapy refractory 10 cm hepatocellular carcinoma at the dome of the liver in a patient who was not a surgical candidate due to a spine metastasis. Treatment of such a large tumor with thermal ablation would have been potentially challenging and toxic in a patient with stage IV disease. (b) Mapping angiography demonstrated a favorable arterial conduit and the patient was subsequently treated with segmental ablative radioembolization. (c) Dynamic contrast-enhanced subtraction magnetic resonance imaging 1 year after treatment continues to demonstrate a modified Response Evaluation Criteria in Solid Tumors complete response of the targeted tumor. There was no change in baseline liver function after ablation.

Operators may choose to treat lesions with MWA over a conceptual benefit in the setting of increased heat sink near major vessels.[108] Transarterial approaches may be limited in the setting of watershed territories which tend to overlap near the hepatic hilum and paracaval regions.

Tumors in subcapsular location are also at risk for suboptimal outcomes including progression[99,109] and tract seeding.[110] Although uncommon, tract seeding occurs approximately from ≤1.5%[110,111] to 12.5%,[112] and has been associated with concurrent biopsy of the lesion.[110,111] The risk of tract seeding may be decreased by utilizing techniques such as "no touch" tangential probe placement, tract cauterization, minimizing probe repositioning, and avoiding biopsy when possible.[113] Subcapsular tumors can occasionally pose a challenge to transarterial therapies by their tendency to recruit extrahepatic arterial supply and having poor capacitance in their capsular arterial conduit.

Percutaneous ablation of HCC adjacent to the diaphragm and heart also has an increased risk of technical failure and may be accompanied by shoulder pain, transient lung injury, and temporary cardiac and hemodynamic complications.[114,115] Utilizing adjunctive techniques such as hydrodissection, inducing pneumoperitoneum, gantry angulation, and real-time probe placement with ultrasound can help mitigate complications and safely reach these hazardous locations.

Many times, a patient will be allocated to a given approach which provides the best ability to visualize the lesion during ablation. In the event of inadequate lesion visualization, preablation intra-arterial lipiodol staining, either the lesion or abutting parenchyma creating a "photo negative" of the tumor, fiducial placement, or the intraprocedural addition of a contrast agent can be performed to increase target conspicuity. Image fusion techniques that incorporate separate modalities or generate real-time biologic feedback of ablation and cavity formation are now available and can be useful in select patients, although careful preoperative alignment is critical as this technology may be susceptible to misregistration.[116]

In addition to the aforementioned strategies, TEA and radioembolization are extremely versatile and can be safely used near critical intrahepatic anatomy, subcapsular and other difficult to reach locations, or in transplant patients where tract seeding precludes transplantation. Ablative radioembolization is particularly useful for tumors which may require the ablation of larger margins. While thermal techniques can also achieve large volume ablation, the instantaneous destruction of significant parenchymal volumes may be more prone to complications compared with gradual devitalization over 1 to 3 months via ablative radioembolization.

Extrahepatic Anatomy

The presence of critical extrahepatic anatomy in close proximity to a thermal ablation target, such as the kidney, bowel, diaphragm, lung, and gallbladder, can be managed with displacement techniques such as hydrodissection with saline, dextrose when colligative property benefits are required, carbon dioxide, balloons or stiff wires, and blunt tip needles. When using general anesthesia, alteration of lung volumes can be of benefit. Repositioning the patient

either decubitus or prone may occasionally provide adequate internal rearrangement to permit ablation. The operator should also modulate the power of each probe as needed and aim the tip of the probe in the direction they want to minimize energy deposition. Although the presence of native ascites is often drained prior to intervention, it has not demonstrated an increased risk of complication after RFA.[117]

When a critical structure cannot be sufficiently displaced, the use of thermocouples can serve as an intraoperative surveillance. The risk to extrahepatic anatomy can also be minimized by combining modalities and techniques such as MWA and PEI.[87] Radioembolization can be performed near bowel and bile ducts with reduced risk over thermal ablation but requires adequate conduit.[118] Additional assistance can be provided laparoscopically or if there is safe approach for external beam radiation therapy.

Individualizing Ablation Approaches

A thoughtful approach to patient selection for ablation is critical in optimizing outcomes. Treatment intent (i.e., neoadjuvant, definitive, or palliative) is essential in determining risk tolerance and the optimal therapeutic approach. The decision to offer therapy is made in the context of the anticipated life expectancy pending a successful result. For example, the chosen approach for a patient with a MELD score of 20 will vary based on whether they are candidates for transplantation. Likewise, the decision to treat a given tumor stage in a patient with limited comorbidities may be entirely different when applied to a patient with severe chronic systemic illness.

Parenchymal preservation as a function of underlying hepatic substrate must be considered when an ablation modality is chosen. For example, a patient who has recurrence after a right trisegmentectomy, where the hazard of liver failure may be comparable to the risk of an undertreated margin, would benefit from a tissue-sparing approach.

The diverse biologic presentations of HCC have significant influence on treatment approach. Ablation modalities are therefore chosen relative to their ability to generate margin for a given phenotype. For example, an ill-defined 4-cm HCC with non-smooth margins, irregular peritumoral enhancement, a discontinuous capsule, and an AFP above 500 needs to be treated aggressively with a modality that can predictably ablate large volumes such as MWA, radioembolization, or a combination therapy. Alternatively, a lower risk HCC that is well defined, slow growing, and ≤ 3 cm can be targeted with any thermal-based modality the operator is most experienced with.

The location and architectural makeup of a tumor exerts tremendous influence on treatment approach based on its visualization, proximity to critical structures, the quality of its vascular conduit, and accessibility. A central lesion in a watershed territory may be treated with thermal ablation whereas an exophytic lesion near bowel with a single vascular pedicle may be a good candidate for radioembolization. Similarly, adjacent extrahepatic structures (such the stomach, bowel, gallbladder, heart, lung, diaphragm, and kidney) exert equal influence on treatment approach. A 1.5-cm segment three HCC herniating into the stomach would

Modality	Size		Biology		Anatomy		Vascular Conduit		Liver Volume	
	≤3cm	> 3cm	Favorable	Aggressive	Favorable	Challenging	Adequate	Poor	Expendable	Not Expendable
RFA							N/A	N/A		
MWA							N/A	N/A		
Cryoablation							N/A	N/A		
IRE							N/A	N/A		
PEI							N/A	N/A		
TEA										
RE										
SBRT							N/A	N/A		

Legend:
- Generally Recommended
- Experienced Operators
- Consider Alternative
- Generally Not Recommended

Fig. 5 Example score card for ablation modality considerations in the context of hepatocellular carcinoma size, biology, intra- and extrahepatic anatomy, vascular conduit, and liver volume. These guidelines are meant to stimulate thoughtful ablation, but operators should use techniques with which they are most experienced in accordance with institutional practice. Green: generally recommended; blue: experienced operators; yellow: consider alternative; red: generally not recommended.

require adjunctive displacement for most thermal modalities but may be easily treated with PEI.

Although a well-rounded and versatile interventional oncology program is best, institutional and operator experience can greatly affect the success of any given locoregional therapy.[99,119,120] There is also emerging data to support that centers with expertise in more therapeutic modalities are associated with improved outcomes for patients with HCC.[121]

Conclusion

Ablative therapy for HCC is now a mature treatment that is regarded as standard of care in selected settings. Judicious patient selection and comprehensive assessment of tumor presentation are indispensable to successful curative outcomes (►Fig. 5). The strategies proposed in this article provide an approach to high-quality, individualized, HCC ablation.

Conflict of Interest
Beau Toskich, MD is an advisor for BTG, Johnson & Johnson, Boston Scientific, and AstraZeneca.t

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