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Percutaneous Liver Tumour Ablation: Image Guidance, Endpoint Assessment, and Quality Control

Robbert S. Puijk, MD[a,*], Alette H. Ruarus, MD[a], Hester J. Scheffer, MD, PhD[a], Laurien G.P.H. Vroomen, MD[a], Aukje A.J.M. van Tilborg, MD, PhD[a], Jan J.J. de Vries, MD[a], Ferco H. Berger, MD[b], Petrousjka M.P. van den Tol, MD, PhD[c], Martijn R. Meijerink, MD, PhD[a]

[a]*Department of Radiology and Nuclear Medicine, VU University Medical Center, Amsterdam, the Netherlands*
[b]*Department of Medical Imaging, Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada*
[c]*Department of Surgery, VU University Medical Center, Amsterdam, the Netherlands*

Abstract

Liver tumour ablation nowadays represents a routine treatment option for patients with primary and secondary liver tumours. Radiofrequency ablation and microwave ablation are the most widely adopted methods, although novel techniques, such as irreversible electroporation, are quickly working their way up. The percutaneous approach is rapidly gaining popularity because of its minimally invasive character, low complication rate, good efficacy rate, and repeatability. However, matched to partial hepatectomy and open ablations, the issue of ablation site recurrences remains unresolved and necessitates further improvement. For percutaneous liver tumour ablation, several real-time imaging modalities are available to improve tumour visibility, detect surrounding critical structures, guide applicators, monitor treatment effect, and, if necessary, adapt or repeat energy delivery. Known predictors for success are tumour size, location, lesion conspicuity, tumour-free margin, and operator experience. The implementation of reliable endpoints to assess treatment efficacy allows for completion-procedures, either within the same session or within a couple of weeks after the procedure. Although the effect on overall survival may be trivial, (local) progression-free survival will indisputably improve with the implementation of reliable endpoints. This article reviews the available needle navigation techniques, evaluates potential treatment endpoints, and proposes an algorithm for quality control after the procedure.

Resumé

De nos jours, l'ablation de tumeurs hépatiques primitives et secondaires est une option thérapeutique courante pour les patients qui en sont atteints. Les méthodes d'ablation par radiofréquence et par micro-ondes sont les plus répandues, mais des techniques novatrices, comme l'électroporation irréversible, gagnent rapidement du terrain. Il en va de même pour la méthode percutanée en raison de sa nature peu effractive, de son bon taux de réussite et de sa répétabilité. Cependant, lorsqu'elle est associée à l'hépatectomie partielle et à l'ablation par chirurgie ouverte, elle entraîne des problèmes de récurrence au site d'ablation encore non résolus et doit donc être améliorée. Dans le cas de l'ablation percutanée de tumeurs hépatiques, plusieurs modalités d'imagerie en temps réel permettent d'améliorer la visibilité de la tumeur, de détecter les structures critiques voisines, de guider les applicateurs, de surveiller les effets du traitement et, au besoin, de modifier ou de répéter la dose d'énergie. La taille et l'emplacement de la tumeur, la perceptibilité de la lésion, la marge saine et l'expérience de l'opérateur sont des indicateurs connus permettant de prédire la réussite d'une intervention. La mise en place d'indicateurs de résultats fiables pour évaluer l'efficacité du traitement rend les interventions complémentaires possibles, que ce soit pendant une même visite ou quelques semaines plus tard. Même si ces indicateurs ont peu d'incidence sur la survie générale, ils améliorent indiscutablement la survie sans progression (locale). Le présent article examine les techniques de navigation de l'aiguille, évalue les indicateurs de résultats potentiels du traitement et propose un algorithme de contrôle de la qualité à la suite de l'intervention.

Key Words: Image guidance; Microwave ablation; Percutaneous liver tumour ablation; Quality control; Radiofrequency ablation

* Address for correspondence: Robbert S. Puijk, MD, Department of Radiology and Nuclear Medicine, VU University Medical Center, De Boelelaan 1117, 1081 HV Amsterdam, the Netherlands.

E-mail address: r.puijk@vumc.nl (R. S. Puijk).

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With hepatocellular carcinoma (HCC) being the third leading cause of cancer deaths worldwide and colorectal cancer as the second most common cause of cancer-related mortality in developed countries, primary and secondary malignant liver tumours are very frequently encountered. About 40%−76% of colorectal cancer patients develop colorectal liver metastases (CRLMs) in the course of their disease [1,2]. Although gradually shifting, surgical resection is still considered the gold standard for curative intent treatment of hepatic malignancies. However, the majority of patients (80%−90%) [2,3] cannot undergo partial hepatectomy because of: 1) an impaired general health status; 2) a history of extensive abdominal surgery; 3) early or rapid disease progression; 4) the presence of lesions in an anatomical unfavorable location; or 5) an insufficient future liver remnant to resect all lesions [1,4−6]. Given the negligible ablation site recurrence rate for small (≤2 cm) HCCs, the well-known international Barcelona Clinic Liver Cancer staging system has replaced surgical resection with percutaneous ablation as primary treatment option [7−15]. Similarly, surgery for small (≤3 cm) CRLMs is currently being challenged in 2 large ongoing phase III trials from the Netherlands (the COLLISION [Colorectal Liver Metastases: Surgery vs Thermal Ablation] trial, low-risk patients; NCT03088150) and the United Kingdom (LAVA [Liver Resection Surgery vs Thermal Ablation for Colorectal Liver Metastases] trial, high-risk patients; ISRCTN52040363).

Over the past 2 decades thermal ablation techniques, such as radiofrequency ablation (RFA) and microwave ablation (MWA), have become auspicious treatment options for patients with hepatic malignancies due to their minimal invasiveness, good and still improving efficacy, potential for repeated ablations, and low costs [16−23]. Irreversible electroporation (IRE) is a novel, predominantly nonthermal, ablation technique that is increasingly investigated for liver tumours near major bile ducts and blood vessels.

Preprocedural staging and treatment planning is quintessential to assess treatment success. Similar to routine workup before partial hepatectomy, at minimum a contrast-enhanced computed tomography (CECT) is required. Routinely performing contrast-enhanced magnetic resonance imaging (MRI) with liver-specific contrast agents such as gadoxetate disodium (Primovist), plus high B-value MR diffusion-weighted imaging (DWI) has proven to reduce intrahepatic recurrence and, therefore, the need for repeat procedures [24]. The use of 2-[18F]-fluoro-2-deoxy-D-glucose (18F-FDG) positron emission tomography (PET) CT may also be indicated for CRLM patients to exclude extrahepatic disease and to differentiate between malignant and benign lesions. However, specificity is suboptimal for mucinous tumours and poor for patients treated with neoadjuvant chemotherapy [25].

Assessment of treatment response, during and shortly after the procedure, is crucial to determine treatment outcome and patient safety [26]. Conventional B-mode ultrasound (US) remains the gold standard for performing ablative procedures during laparotomy and, although lesion conspicuity remains a prerequisite, is still commonly used to guide percutaneous procedures [26]. CT and MRI are the most established techniques for percutaneous ablation because they enable acquisition of 3-dimensional images of the tumour in relation to the surrounding structures, the probes and the ablation zone [26,27]. Nowadays, image fusion, (electromagnetic or infrared) needle tracking, and robotics can provide even more accurate targeting [28].

Despite technological advances, the primary technique effectiveness (90%−95% for lesions ≤3 cm and <90% for lesions >3 cm in diameter) should still be considered inadequate and requires further improvements [27]. Technical success depends on several factors such as tumour size, molecular subtype (RAS wild type or mutation) [29], location, visibility, tumour-free margin, operator experience, and local availability of devoted equipment, such as (virtual) gantry tilt, computer-assisted fusion and navigation techniques, and open MR systems [21,23,30−32]. Sophisticated image-guiding techniques and parameters to evaluate treatment success directly after or within the first weeks after ablation (allowing for completion procedures) will likely improve outcome. Although the effect on overall survival may be trivial [33], local progression-free and disease-free survival will indisputably increase.

This article reviews currently available image-guiding techniques for percutaneous ablation of liver malignancies, provides an overview of methods to determine technical success, and suggests an algorithm for quality control.

Image-Guiding Techniques and Needle Navigation

In percutaneous ablation, adequate imaging is crucial for: 1) preprocedural planning; 2) intraprocedural targeting (needle guidance or catheter delivery); 3) intraprocedural monitoring (real-time imaging of tissue changes resulting from treatment); 4) intraprocedural modification (real-time ability to make adjustments); and 5) postprocedural assessment (measurement of treatment effectiveness and need for further intervention) [23,26]. Different imaging techniques can be used, solitarily or in combination, to successfully perform each of these steps (Table 1).

A successful procedure can be achieved by ablation that covers the complete tumour volume plus a certain tumour-free margin without harming nearby critical structures. Therefore, optimal imaging modalities should provide anatomical 3-dimensional (3D) images to depict the target, surrounding structures, and the interventional probes, as well as physiological information indicative for the ablated volume, such as alterations in echogenicity, signal attenuation, contrast enhancement, or metabolic activity. Although present-day imaging systems provide some of these characteristics, none provide all of them [23].

Transcutaneous Ultrasound

Conventional B-mode US is the most widely used real-time imaging technique, mainly because it is cheap, fast, easy to use, repeatable, and does not require ionizing