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Original Article

Percutaneous radiofrequency ablation with internally cooled wet electrodes versus cluster electrodes for the treatment of single medium-sized hepatocellular carcinoma

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A B S T R A C T

Background: To compare the effectiveness and complications of radiofrequency ablation (RFA) using cluster electrodes or internally cooled wet (ICW) electrodes in patients with medium-sized hepatocellular carcinomas (HCCs).

Methods: Between February 2008 and September 2013, 40 patients (31 men and 9 women; mean age, 61.2 years) with a single medium-sized HCC (mean size, 3.5 ± 0.5 cm; range, 3.1–5.0 cm) underwent percutaneous RFA with cluster electrodes (n = 19) or ICW electrodes (n = 21). Technical success, technical effectiveness, ablation volume, major complications, and local tumor progression were compared.

Results: After the initial RFA, technical success was achieved in 84% of patients and 90% of patients treated by cluster electrodes and ICW electrodes, respectively (P = 0.654). At 1 month, technical effectiveness was achieved by cluster electrodes and ICW electrodes in 84% and 100% of patients, respectively (P = 0.098). During follow-up period (mean, 17.8 months; range, 0–67 months), the median local tumor progression rates were 21.3 months in the cluster group and 31.0 months in the ICW group. The 6-month, 1-, 2-, and 4-year local tumor progression rates were significantly lower after RFA with ICW electrodes (0%, 7%, 25%, and 57%, respectively) than after RFA with cluster electrodes (26%, 33%, 53%, and 68%, respectively; P = 0.036). Major complications occurred in 15.8% of patients treated with cluster electrodes and in 4.8% of patients treated with ICW electrodes (P = 0.331).

Conclusion: For the treatment of medium-sized HCCs, percutaneous RFA using ICW electrodes results in lower rate of local tumor progression and fewer serious complications, compared to cluster electrodes.

Keywords: Cluster electrode, Hepatocellular carcinoma, Internally cooled wet electrode, Radiofrequency ablation

Introduction

Percutaneous radiofrequency ablation (RFA) is a safe and effective treatment for local tumor control in patients with small (≤3 cm) or medium-sized (3.1–5.0 cm) hepatocellular carcinomas (HCCs).[1–5] However, local tumor progression, a common significant prognostic factor of RFA-treated HCC,[6] can be as high as 17–35% after mean follow-up periods of 16–25.7 months.[7–9] Furthermore, local tumor progression is more common in patients with large tumors.[10,11] For medium-sized HCCs, the complete ablation rates ranged from 53% to 74% according to previous studies on RFA.[11–13]

Thus, a sufficiently large ablation zone is necessary to achieve complete tumor destruction and lower local tumor recurrence rates, especially in patients with medium-sized HCC. To address the many challenges of enlarged ablation zones, several types of electrodes such as internally cooled needles,[14] perfused needles,[15] and expandable needles[13] have been developed; however, the total ablation volume that can be destroyed is limited. For example, to treat HCCs >3 cm in diameter, multiple overlapping ablations are often required to cover the entire tumor volume and the peripheral ablation margins.[16,17] However, this procedure is time consuming and technically challenging because gas bubbles that form disturb repositioning the electrode under ultrasound guidance, and thereby leads to incomplete ablation.

To avoid problems related to multiple overlapping ablations such as technical difficulties and a long procedural time, a cluster electrode is typically used to treat medium-sized HCCs.[18] A cluster electrode may nevertheless demonstrate a higher incidence of complications because of the greater difficulty of delicately manipulating the cluster electrode to avoid damaging structures such as the hepatic vessels. In addition, the consistently larger ablation zone of a cluster electrode may contribute to collateral thermal injury in adjacent organs.[19]

Internally cooled wet (ICW) electrodes combine the advantages of cooled and saline-perfused electrodes.[20] The ICW electrode

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simultaneously provides interstitial infusion of saline and intra-electrode cooling.[20] The original ICW electrode had two coaxial lumina, which thereby enabled the circulation of cooling water and interstitial infusion of saline through side holes. A modified ICW electrode was recently introduced with a simpler design that consists of only one lumen and two microholes on the active tip.[21–23] However, no comparative studies had assessed the differences between cluster and ICW electrodes in local therapeutic efficacy and safety. Therefore, we compared the effectiveness and complications of RFA using cluster and modified ICW electrodes for treating patients with medium-sized HCCs.

Method

Patient population

Our Institutional Review Board (Asan Medical Center, Korea) approved this retrospective review. Patients were included if they had a single HCC measuring 3.1–5.0 cm in diameter, no imaging evidence of vascular invasion, and no evidence of extrahepatic disease. Patients were excluded if they had multiple HCCs, vascular invasion, extrahepatic metastases, or coagulopathy (platelet count $<50 \times 10^3/\mu L$; international normalized ratio >1.5). Forty patients treated between February 2008 and September 2013 met the inclusion criteria. The criteria for the diagnosis of HCC were based on the guidelines of the American Association for the Study of Liver Diseases.[24] Nineteen patients underwent RFA with a cluster electrode and 21 patients underwent RFA with an ICW electrode. The radiologist who performed RFA chose the electrode based on preference or availability. (This study used three radiologists.)

RFA system

All RFA procedures were percutaneously performed under ultrasound guidance with the patient under conscious sedation (using midazolam hydrochloride) and local anesthesia (using lidocaine hydrochloride). During the procedure, vital signs and cardiac status were monitored by pulse oximetry and electrocardiography. We used an internally cooled electrode system during all procedures. Two types of electrodes were used with a 200-W radiofrequency generator: (1) a single 17-gauge straight ICW electrode (RF Medical, Seoul, Korea) with a 3-cm active tip used to treat 21 patients and (2) a cluster type electrode (ValleyLab, Burlington, MA, USA) with a 2.5-cm active tip used to treat 19 patients. The internal structure of the exposed tip of the ICW electrode and the conventional internally cooled electrode are identical, except the ICW electrode contains two 0.03-mm side holes. When using ICW electrodes with exposed 3-cm tips, 99% of chilled 0.9% isotonic saline was administered at a rate of 1 mL/min for cooling and 1% isotonic saline was infused at a rate of 1.2 mL/min.

All electrodes were placed via the transhepatic approach. The radiofrequency current was emitted for 12 minutes using a 200-W generator that was set to deliver maximum power using the automatic impedance control method. The overlapping ablation technique was used to treat 13 patients (average, 2.7 times; range, 2–4 times) in the ICW group and treat 10 patients (average, 2.9 times; range, 2–4 times) in the cluster group. Ablation time was subject to the operators' discretion, and based on tumor size, extent of echogenic clouds, and patient condition (e.g., vital signs, pain). The endpoint of ablation was complete ablation of the visible tumor and its margins, which were 0.5–1.0 cm into the normal liver parenchyma surrounding the tumor. In some patients, artificial ascites or pleural effusion was created to visualize the lesion or avoid thermal injury to the adjacent diaphragm. After ablation, we cauterized the electrode path during retraction of the electrode to minimize bleeding and tract seeding. Patients were discharged from the hospital the day after the procedure if immediate post-procedure computed tomography (CT) images or overnight clinical observation showed no complications.

Follow-up

Contrast-enhanced CT examinations were performed <2 hours or 1 day after RFA to evaluate the extent of the treated areas and assess possible complications such as bleeding and fluid collection. Unenhanced CT scans were initially obtained, followed by contrast-enhanced CT scans (contrast medium injection rate: 3.0 mL/s). The contrast-enhanced CT scans were obtained during the hepatic arterial phase (using bolus-tracking methods or 36-second delays), the portal venous phase (72-second delay), and the equilibrium phase (3-minute delay). Additional RFA was performed if residual nodular enhancement was observed near the ablated area. However, transarterial chemoembolization (TACE) was performed if a residual enhanced lesion was difficult to target using RFA. One month after the procedure, RFA efficacy was evaluated using contrast-enhanced CT. The 1-month CT examination consisted of a second CT study, and the imaging technique was identical to the first CT that was performed after RFA.

If the 1-month CT showed a completely ablated tumor and no new tumors were noted at other liver sites, subsequent follow-up contrast-enhanced CT scans were obtained every 2–3 months. All new tumors—whether in the ablated lesion or at other liver sites—present during the follow-up period were treated with RFA if the patient still met the criteria for such treatment; if not, the lesions were treated by TACE.

Evaluation of ablation volume

To assess the ablation volume, CT analysis was performed immediately after RFA or 1 day after RFA. Volumetric data were obtained from the portal phase images, and the margins of the ablated area were manually drawn slice-by-slice from top to bottom. We calculated the volume using the summation-of-area method.

Definition and evaluation of data

Data were analyzed on an intention-to-treat basis. Technical success was defined as treatment completion, based on the protocol, with complete coverage and adequate safety margins evident at the time of the procedure.[25] One month after RFA, technical effectiveness was defined as the complete ablation of the tumor on imaging. At 1 month after RFA, local tumor progression was defined as nodular or irregular enhancement at any follow-up assessment. Major complications were defined as any event that required additional treatment such as increased level of care, hospital stay beyond the observation status (including readmission after initial discharge), or permanent adverse sequelae such as substantial morbidity, disability, or death.[25] Tumors were categorized as non-subcapsular or subcapsular, and subcapsular tumors were defined as lesions with margins located <1 cm from the liver surface.[26] The rates of technical success, technical effectiveness, ablation volume, major complications, and local tumor progression were compared between the two groups.

Statistical analysis

The Mann–Whitney *U* test was used to compare pairs of independent continuous variables. Fisher's exact test was used to compare categorical variables. Local tumor progression rates were