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**Hydrochloric acid enhanced radiofrequency ablation in the treatment of large** **hepatocellular carcinoma in the caudate lobe:** **Three cases of report**

Deng HX *et al*. HCl enhanced RFA treatment of large HCC

Han-Xia Deng, Jin-Hua Huang, Wan-Yee Lau, Fei Ai, Min-Shan Chen, Zhi-Mei Huang, Tian-Qi Zhang, Meng-Xuan Zuo

**Han-Xia Deng, Jin-Hua Huang, Fei Ai, Zhi-Mei Huang, Tian-Qi Zhang, Meng-Xuan Zuo,**Department of Minimally Invasive Interventional Therapy, Cancer Centre of Sun Yat-Sen University, 651 Dongfeng Road East, Guangzhou 510060, Guangdong Province, China

**Wan-Yee Lau, Min-Shan Chen,**Department of Hepatobiliary Surgery, Cancer Centre of Sun Yat-Sen University, 651 Dongfeng Road East, Guangzhou 510060, Guangdong Province, China

**Han-Xia Deng, Jin-Hua Huang, Fei Ai, Min-Shan Chen, Zhi-Mei Huang, Tian-Qi Zhang, Meng-Xuan Zuo,** State Key Laboratory of Oncology in Southern China, Guangzhou 510060, Guangdong Province, China

**Wan-Yee Lau,**Faculty of Medicine, The Chinese University of Hong Kong, Prince of Wales Hospital, Shatin, New Territories, Hong Kong, China

**Ying-Fang Fan,** Department of Hepatobiliary Surgery, Zhujiang Hospital, The Southern Medical University, Guangzhou 510280, Guangdong Province, China

**ORCID number:** Han-Xia Deng (0000-0002-1250-3444); Jin-Hua Huang (0000-0003-2960-6148); Wan-Yee Lau (0000-0002-9802-6537); Fei Ai (0000-0003-2336-6315); Min-Shan Chen (0000-0002-7442-4637); Zhi-Mei Huang ([0000-0002-4136-5896](http://orcid.org/0000-0002-4136-5896)); Tian-Qi Zhang (0000-0002-1528-5323); Meng-Xuan Zuo (0000-0003-3589-7316).

**Author contributions:** Huang JH made the study concept and designed the study; Huang JH, Deng HX and Ai F drafted the manuscript; Lau WY, Chen MS and Fan YF made critical revision of the manuscript for important intellectual content; Huang ZM and Zhang TQ made the technical support.

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**Corresponding author: Jin-Hua Huang, MD, Professor,** Minimally Invasive Interventional Radiology, Sun Yat-sen University Cancer Center, State Key Laboratory of Oncology in South China, Collaborative Innovation Center for Cancer Medicine, 651 Dongfeng Road East, Guangzhou 510000, Guangdong Province, China. [huangjh@sysucc.org.cn](file:///C:\Users\Liansheng%20Ma\Desktop\Liansheng%20Ma\WJCC%20Dispose\2019-01-03_Final_Acceptance_WJCC_WJD_WJGS_WJGE\42932\huangjh@sysucc.org.cn)

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**Abstract**

***BACKGROUND***

To report on the use of percutaneous hydrochloric acid (HCl) enhanced radiofrequency ablation (HRFA) in the treatment of large (maximum diameter ≥ 5 cm) hepatocellular carcinomas (HCC) in the caudate lobe.

***CASE SUMMARY***

Between August 2013 and June 2016, 3 patients with a large HCC (maximum diameter of 5.0, 5.7 and 8.1 cm) in the caudate lobe were treated by transarterial chemoembolization followed by computer tomography (CT) guided RFA using a monopolar perfusion RF electrode, which was enhanced by local infusion of 10% HCl at 0.2 mL/min (total volume from 3 mL to 12 mL). The output power of HRFA reached 100 W, and the average ablation time was 39 min (range, 15 to 60 min). Two patients each underwent one session of HRFA and one patient two sessions. After treatment, CT/MR showed all the 3 lesions were completely ablated. There was no major complication. 2 patients had asymptomatic bile duct dilatation. One patient died of tongue cancer 24 mo after ablation. Remaining 2 patients are alive and no area of enhancement is detected in the caudate lobe at 28, 60 mo after ablation, respectively.

***CONCLUSION***

Percutaneous CT-guided HRFA was safe and efficacious in treating large HCC in the caudate lobe.

**Key words:** Hydrochloric acid; Radiofrequency ablation; Hydrochloric acid enhanced radiofrequency ablation; Caudate lobe; Large hepatocellular carcinoma; Case report

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**Core tip:** Caudate lobe hepatocellular carcinoma (HCC) was considered high technical difficult by surgery and the outcome of interventional therapies, including transarterial chemoembolization and conventional radiofrequency ablation (RFA), according to previous studies was unsatisfied. Hydrochloric acid enhanced RFA, an innovative technique, can create ablation zone larger than 5 cm by a single perfusate electrode without major complication, which is promising to treat large caudate lobe HCC patient.

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**INTRODUCTION**

Hepatocellular carcinoma (HCC) arising from the caudate lobe is rare[1]. The caudate lobe is situated deep between the hepatic hilum and the inferior vena cava. Caudate lobectomy is considered to be technically difficult even for small tumors, with high risks of local recurrence and poor overall survival[2,3]. For large tumors in the caudate lobe, resection is challenging even in the hands of experienced liver surgeons[4,5]. Interventional therapies, including various intravascular and extravascular procedures, have been reported to treat caudate lobe HCC[6-14]. However, most of those focused on treating small HCC (maximum diameter < 5 cm). This is a retrospective study on 3 patients with HCC ≥ 5 cm in the caudate lobe treated with hydrochloric acid (HCl) enhanced radiofrequency ablation (HRFA).

**CASE PRESENTATION**

***Case 1***

A 61-year-old female was found to have a caudate lobe lesion (55 mm × 57 mm × 63 mm) on magnetic resonance imaging (MRI). The patient had a history of chronic hepatic B virus (HBV) infection, with Child-Pugh A liver function and negative serum alpha-fetoprotein (AFP) concentration (0.71 ng/mL). A biopsy confirmed HCC. Transarterial chemoembolization (TACE) using an emulsion of tetrahydropalmatine (THP) 50 mg, lobaplatin 50 mg and lipiodol 10 mL was performed in August 2013. One month later, computed tomography (CT) showed that the tumor had enlarged (72 mm × 75 mm × 81 mm), and was separated into the superior and inferior parts by a fibrous septum.

Since the tumor enlarged after TACE, patient was suggested ablation therapy. Conventional RFA was insufficient to ablate such a huge tumor. Thus, the patient received two sessions of HRFA in September and December 2013 respectively to ablate the superior and inferior parts of the tumor. HRFA was applied for 60 min in the first and 30 min in the second session. No discomfort during ablation and no complications such as fever, pain or hemorrhage after HRFA were observed.

One month after the first HRFA, a peripheral hyper-metabolic nodule was detected by PET-CT. Thus, the patient underwent two more sessions of COOL-TIP RFA in December 2013 and March 2014 respectively. After that, the hypermetabolic lesion was no longer visible. The last follow-up CT in July 2018 showed the tumor had decreased to an inactive fibrous tissue mass of about 2 cm in diameter. During the course of treatment and follow-up, there are no major complications. Minor complications was slightly asymptomatic dilated (total bilirubin concentration once elevated to 72 μmol/L 18 mo after HRFA and returned normal without any treatment) bile ducts. (Figure 1)

***Case 2***

A 69-year-old man was found on health checkup to have a caudate lobe tumor, 17 mm × 25 mm on PET-CT in June 2013. He had a history of chronic HBV infection. The AFP concentration was negative, and he had Child-Pugh A liver function. Biopsy confirmed the diagnosis of HCC. The patient received two sessions of TACE in August and November, 2013. CT in March 2014 showed that the lesion had enlarged to 47 mm × 57 mm, with poor lipiodol deposition. Besides, the patient has a history of tongue cancer and received radiotherapy 4 years ago.

In March 2014, HRFA through anterior approach was applied for 60 min. There was no acute adverse effect occurred peri-ablation and post-ablation period, and an MRI one month later showed no areas of enhancement.

Ten months after HRFA, in January 2015, MRI showed the margin of the lesion to be suspiciously enhanced by contrast. He underwent one session of COOL-TIP RFA. No visible active lesion was detected in the next MRI. The last MRI in December 2015 found no active lesion in the liver. Twenty-four months after HRFA, the patient died of recurrent tongue cancer. (Figure 2)

***Case 3***

A 73-year-old male presented with chest and abdomen pain in February 2016. CT showed a mass in the pancreatic neck and a low density lesion, 35 × 50 mm, in the caudate lobe. The patient had a history of chronic HBV infection, Child-Pugh A disease, negative serum AFP concentration. The PIVKA level was 20.266 AU/m. Exploratory laparotomy showed a primary tumor in caudate lobe and lesion in pancreatic neck was a spontaneous hematoma. Frozen section of an enlarged portal lymph node showed metastatic HCC. TACE was performed in April 2016, with emulsion of THP 30 mg, lobaplatin 30 mg and lipiodol 10 mL. CT after TACE showed good lipiodol deposition.

Three days later, HRFA applied for 15 min through anterior approach. No major complications occurred. One month later, the PIVKA concentration dropped to 2.566 AU/mL and no visible contrast enhanced areas on MRI. Follow-up at 28 mo after HRFA showed no signs of relapse or metastasis. (Figure 3)

All the summaries of the three patients were shown in Table 1.

**DISCUSSION**

Surgical resection of a caudate lobe tumor is technically challenging as the caudate lobe is situated deep between the hepatic hilum and the inferior vena cava[1]. In one report on 12 patients, the median operative time was 568 min, the median intraoperative blood loss was 550 mL, and 5 patients developed postoperative bile leak with problems in renal function[4]. Caudate lobectomy is commonly combined with major or extended hepatectomies with sacrifice of a large amount of non-tumorous liver parenchyma which increases the risk of postoperative liver failure.

Compared to surgery, interventional therapies such as TACE or RFA have a lower risk of treatment morbidities. In 1986, Takayasu *et al*[6] reported 5 patients who underwent transcatheter arterial infusion (TAI) or transcatheter arterial embolization (TAE) treating advanced-stage caudate lobe HCC. Unfortunately, 4 of these patients died at a mean of 5.5 mo. With advances in interventional technology and better understanding of arterial blood supply of caudate lobe HCC[8,15,16], the success rate of selective subsegmental TACE in treating caudate lobe HCC has been greatly improved. However, long-term survival after treatment remains a problem. Kim *et al*[9] performed selective TACE to treat 34 patients with caudate lobe HCCs with a diameter of less than 3 cm. The 5-year overall survival and progression-free rates were 72% and 21%, respectively. TACE cannot completely block the feeding arteries and gain a complete tumor necrosis, which causes recurrence[10]. For a large caudate lobe HCC, the results using TACE is even worse.

Percutaneous ablation therapies, including percutaneous ethanol injection (PEI), RFA and MWA, are well-established and widely-used treatments for HCC. In 2002, Shibata *et al*[11] first introduced PEI with or without TAE to treat 25 patients with caudate lobe HCC (average diameter, 27 mm). Peng *et al*[13] reported on 17 patients who underwent RFA treatment for caudate lobe HCC (average diameter 31 mm). However, most of these studies focused on treating small caudate lobe tumors. Nevertheless, incomplete ablation and recurrence still happened. Nishigaki *et al*[14] compared the recurrence rates in patients with caudate lobe HCC or HCC located in other liver segments. They found the caudate lobe patients had a higher risk of developing tumor recurrence. Caudate lobe HCCs are more difficult to be completely ablated than those in other liver segments due to the restricted approach through which a RFA electrode can be introduced, and the heat sink effect of inferior vena cava.

In the last decade, several new techniques, such as normal saline perfused radiofrequency ablation (NSRFA) and multi-electrodes applications had been developed aiming to create a large ablative zone[17]. Our previous experiments showed infusing diluted HCl instead of normal saline during RFA could enlarge the diameter of ablation zone from a mean (SD) of 3.52 cm (0.07) to 6.85 cm (0.32) at 30 W-30 min[18]. This is because the conductivity of HCl is about three times than saline, greatly increasing the conductivity around RF electrode[19]. In vivo experiments, HRFA also exhibited larger ablative zone with favorable safety[21-22]. Based on these studies, we have reported performing HRFA on a HCC patient with spontaneously ruptured HCC patient, which successfully controlled bleeding and achieved completely necrosis after ablation without any complication[19]. In a word, HRFA, a technique that can create a large ablation volume by using a monopolar electrode, is promising in treating large caudate lobe HCCs. In the present study, all three patients had unresectable large caudate lobe HCC. One patient underwent two sessions of HRFA and the other 2 patients underwent 1 session each. After HRFA and followed complementary COOL-TIP RFA, all the 3 caudate lobe tumors showed complete necrosis.

Among four sessions of HRFA, three were performed through anterior approach and the remaining one was through lateral approach (case 1, the 2nd session) in order to protect peripheral vessels and biliary system. HRFA also avoids repeated puncture because one session of HRFA is sufficient to achieve completely necrosis. Besides, the electrode in HRFA could be placed at the center of the lesion whereas in other RFA techniques, it must reach the tumor margin which would induce damage of structure nearby. There was no major complication and asymptomatic bile duct dilatation as minor complication occurred in patient 1 18 mo after HRFA. It’s hypothesized that the non-active lesion, which had shrunk from 7cm to less than 3 cm, stretched its peripheral liver tissue and induced bile duct dilatation.

**CONCLUSION**

HRFA can be an efficacious and safe choice for patients with a large caudate lobe HCC. However, further research are necessary to determine the appropriate role of HRFA in treating caudate lobe HCCs. Combination of HRFA with TACE or other systemic therapies is expected to further improve the prognosis of patients.

**REFERENCES**

1 **Kumon M.** Anatomy of the caudate lobe with special reference to portal vein and bile duct. *Acta Hepatol Jpn* 1985; **26**: 1193-9 [DOI: 10.2957/kanzo.26.1193]

2 **Tanaka S**, Shimada M, Shirabe K, Maehara S, Tsujita E, Taketomi A, Maehara Y. Surgical outcome of patients with hepatocellular carcinoma originating in the caudate lobe. *Am J Surg* 2005; **190**: 451-455 [PMID: 16105535 DOI: 10.1016/j.amjsurg.2004.12.005]

3 **Kumon M**. Anatomical Study of the Caudate Lobe with Special Reference to Portal Venous and Biliary Branches Using Corrosion Liver Casts and Clinical Application. *Liver Cancer* 2017; **6**: 161-170 [PMID: 28275582 DOI: 10.1159/000454682]

4 **Viganò L**, Costa G, Procopio F, Donadon M, Cimino M, Del Fabbro D, Gatti A, Torzilli G. Parenchyma-Sparing Liver Surgery for Large Segment 1 Tumors: Ultrasound-Guided Lateral and Superior Approaches as Safe Alternatives to Major Hepatectomy. *J Am Coll Surg* 2015; **221**: e65-e73 [PMID: 26272013 DOI: 10.1016/j.jamcollsurg.2015.07.008]

5 **Wang ZG**, Lau W, Fu SY, Liu H, Pan ZY, Yang Y, Zhang J, Wu MC, Zhou WP. Anterior hepatic parenchymal transection for complete caudate lobectomy to treat liver cancer situated in or involving the paracaval portion of the caudate lobe. *J Gastrointest Surg* 2015; **19**: 880-886 [PMID: 25759077 DOI: 10.1007/s11605-015-2793-4]

6 **Takayasu K**, Muramatsu Y, Shima Y, Goto H, Moriyama N, Yamada T, Makuuchi M, Kaneko A, Itabashi M, Shimamura Y. Clinical and radiologic features of hepatocellular carcinoma originating in the caudate lobe. *Cancer* 1986; **58**: 1557-1562 [PMID: 3017540]

7 **Terayama N**, Miyayama S, Tatsu H, Yamamoto T, Toya D, Tanaka N, Mitsui T, Miura S, Fujisawa M, Kifune K, Matsui O, Takashima T. Subsegmental transcatheter arterial embolization for hepatocellular carcinoma in the caudate lobe. *J Vasc Interv Radiol* 1998; **9**: 501-508 [PMID: 9618113]

8 **Woo S**, Kim HC, Chung JW, Jung HS, Hur S, Lee M, Jae HJ. Chemoembolization of extrahepatic collateral arteries for treatment of hepatocellular carcinoma in the caudate lobe of the liver. *Cardiovasc Intervent Radiol* 2015; **38**: 389-396 [PMID: 24934735 DOI: 10.1007/s00270-014-0929-7]

9 **Kim HC**, Chung JW, Jae HJ, Yoon JH, Lee JH, Kim YJ, Lee HS, Yoon CJ, Park JH. Caudate lobe hepatocellular carcinoma treated with selective chemoembolization. *Radiology* 2010; **257**: 278-287 [PMID: 20697120 DOI: 10.1148/radiol.10100105]

10 **Goldberg SN**, Ahmed M. Minimally invasive image-guided therapies for hepatocellular carcinoma. *J Clin Gastroenterol* 2002; **35**: S115-S129 [PMID: 12394215 DOI: 10.1097/00004836-200211002-00008]

11 **Shibata T**, Maetani Y, Ametani F, Kubo T, Itoh K, Konishi J. Efficacy of nonsurgical treatments for hepatocellular carcinoma in the caudate lobe. *Cardiovasc Intervent Radiol* 2002; **25**: 186-192 [PMID: 12058213 DOI: 10.1007/s00270-001-0111-x]

12 **Yamakado K**, Nakatsuka A, Akeboshi M, Takaki H, Takeda K. Percutaneous radiofrequency ablation for the treatment of liver neoplasms in the caudate lobe left of the vena cava: electrode placement through the left lobe of the liver under CT-fluoroscopic guidance. *Cardiovasc Intervent Radiol* 2005; **28**: 638-640 [PMID: 16132396 DOI: 10.1007/s00270-004-0104-7]

13 **Peng ZW**, Liang HH, Chen MS, Zhang YJ, Li JQ, Zhang YQ, Lau WY. Percutaneous radiofrequency ablation for the treatment of hepatocellular carcinoma in the caudate lobe. *Eur J Surg Oncol* 2008; **34**: 166-172 [PMID: 17851020 DOI: 10.1016/j.ejso.2007.08.004]

14 **Nishigaki Y**, Tomita E, Hayashi H, Suzuki Y, Iritani S, Kato T, Yamada T. Efficacy and safety of radiofrequency ablation for hepatocellular carcinoma in the caudate lobe of the liver. *Hepatol Res* 2013; **43**: 467-474 [PMID: 23072582 DOI: 10.1111/j.1872-034X.2012.01095.x]

15 **Yoon CJ**, Chung JW, Cho BH, Jae HJ, Kang SG, Kim HC, Choi YH, Jeon UB, Park JH. Hepatocellular carcinoma in the caudate lobe of the liver: angiographic analysis of tumor-feeding arteries according to subsegmental location. *J Vasc Interv Radiol* 2008; **19**: 1543-50; quiz 1550 [PMID: 18755606 DOI: 10.1016/j.jvir.2008.07.008]

16 **Miyayama S**, Yamashiro M, Yoshie Y, Nakashima Y, Ikeno H, Orito N, Yoshida M, Matsui O. Hepatocellular carcinoma in the caudate lobe of the liver: variations of its feeding branches on arteriography. *Jpn J Radiol* 2010; **28**: 555-562 [PMID: 20972854 DOI: 10.1007/s11604-010-0471-8]

17 **Kang TW**, Rhim H. Recent Advances in Tumor Ablation for Hepatocellular Carcinoma. *Liver Cancer* 2015; **4**: 176-187 [PMID: 26674766 DOI: 10.1159/000367740]

18 **Jiang XY**, Gu YK, Huang JH, Gao F, Zou RH, Zhang TQ. Ex Vivo Liver Experiment of Hydrochloric Acid-Infused and Saline-Infused Monopolar Radiofrequency Ablation: Better Outcomes in Temperature, Energy, and Coagulation. *Cardiovasc Intervent Radiol* 2016; **39**: 600-605 [PMID: 26486153 DOI: 10.1007/s00270-015-1218-9]

19 **Huang JH**, Morelli JN, Ai F, Zou RH, Gu YK, Gao F, Zhang TQ, Yao W, Jiang XY, Zhang YY. Hydrochloric acid-enhanced radiofrequency ablation for treating a large hepatocellular carcinoma with spontaneous rapture: a case report. *Chin J Cancer* 2017; **36**: 1 [PMID: 28061892 DOI: 10.1186/s40880-016-0161-8]

20 **Weijian F**, Zan L, Suhong H, Hongmei Z, Lei Z, Yanjie Z, Yi C, Ni J. Destructive effect of percutaneous hydrochloric acid injection therapy for liver cancer--a preliminary experimental and clinical study. *Gan To Kagaku Ryoho* 2006; **33**: 1852-1856 [PMID: 17212126]

21 **Yao W**, Gu YK, Wang J, Gao F, Liu WL, Huang JH. Safety evaluation of a potential ablation agent-hydrochloric acid in the rabbits' model. *Ann Palliat Med* 2014; **3**: 250-262 [PMID: 25841905 DOI: 10.3978/j.issn.2224-5820.2014.02.01]

22 **Zhang TQ**, Huang SM, Gu YK, Gao F, Huang ZM, Jiang XY, Liu DX, Huang JH. Safety and effect on ablation size of hydrochloric acid-perfused radiofrequency ablation in animal livers. *Int J Hyperthermia* 2018; **34**: 925-933 [PMID: 29457524 DOI: 10.1080/02656736.2018.1442588]

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**Figure 1 Arterial-phase computed tomography images showing a large caudate lobe tumor enhanced after transarterial chemoembolization in a 61-year-old woman with confirmed hepatocellular carcinoma.** A: The tumor with poor lipiodol deposition was predominantly composed by isodense tissue (black asterisk), representing the contrast enhanced active part of the tumor and the hypodense necrotic region without enhancement (white asterisk). The hyperdensity in the hepatic parenchyma represents lipiodol deposition after TACE; B: The caudate lobe and porta hepatis were involved (white arrows); C, D: Computed tomography images taken during the ablation show precise placement of the RF electrode into the active regions of the tumor, and the area of destruction can be seen easily; E: The coronal magnetic resonance image (MRI) shows an enhanced inferior residual tumor after the first session of HRFA (white asterisk); F: No active tissue was detected after the second session of HRFA; G: The latest coronal post-contrast T1-weighted image shows focal atrophy and fibrosis formation, resulting in an irregular, non-active region in the caudate lobe about 20 mm in diameter. The bile ducts were slightly dilated on the latest follow-up MRI.

**Figure 2 A well-defined active caudate lobe tumor adjacent to the right hepatic vein was found in a 69-year-old man with a history of tongue cancer.** After two sessions of TACE, A and B: The enhanced part was predominant and had poor Lipiodol deposition consistent with active tumor tissues; C and D: Post-contrast magnetic resonance imaging (MRI) images after HRFA therapy show a non-enhanced mass with hypointensity. The central irregular hyperintensity (black asterisk, C) was caused by the hemorrhagic content of the necrotic cavity, rather than by contrast enhancement. Relapse was not detected in the most recent MRI examination (data not shown).



**Figure 3 Preoperative computed tomography and magnetic resonance imaging images of a 73-year-old male show a large intrahepatic tumor in the caudate lobe (white asterisks, A, B), which was confirmed as hepatocellular carcinoma by histopathology.** A, B: **A large intrahepatic tumor in the caudate lobe was confirmed as hepatocellular carcinoma by histopathology.** A hyperintensity mass was noted in the pancreatic neck region on T1-weighted imaging (black asterisk, B). This was shown to be a hematoma on subsequent exploratory laparotomy; C: After TACE, CT images show that lipiodol deposition involved almost the entire area of the lesion in the caudate lobe; D: However, peripheral residual tumor medial to the necrotic cavity was demonstrated in a coronal post-contrast T1-weighted image (black asterisk). The non-enhancing soft tissue in the porta hepatis region inferior to the intrahepatic lesion and adjacent to the neck of pancreas (white arrows) is consistent with the shrunken hematoma after exploratory laparotomy (white asterisk). E: CT image shows the needle in the tumor during HRFA; F: On the post-contrast T1-weighted image after HRFA therapy a thin enhancing rim-like tissue inferior to the necrotic cavity (white arrows) is evident. The necrotic region does not show enhancement. No relapse is detected during follow-up MRI examinations. This enhancing rim probably represents reactive granulation tissues, rather than residual tumor.

**Table 1 The summary of all three patients**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Case 1 | Case 2 | Case 3 |
| Sex | Female | Male | Male |
| Age | 61 | 69 | 73 |
| Tumor Size | 75 × 81 | 47 × 57 | 35 × 50 |
| Sessions of HRFA | 2 | 1 | 1 |
| Complementary RFA | Yes | Yes | None |
| Survival | 60 | 48 | 28 |
| Complications | asymptomatic bile duct dilatation | None | None |
| Alive | Alive | Died of tongue cancer recurrence | Alive |

HRFA: Hydrochloric acid enhanced radiofrequency ablation.