Korean Journal of Radiology

KJR

Radiofrequency Ablation for Treating Liver Metastases from a Non-Colorectal Origin

Bo La Yun, MD[1], Jeong Min Lee, MD[1, 2], Ji Hyun Baek, MD[1], Se Hyung Kim, MD[1, 2], Jae Young Lee, MD[1, 2], Joon Koo Han, MD[1, 2], Byung Ihn Choi, MD[1, 2]

[1]Department of Radiology, Seoul National University Hospital, Seoul 110-744, Korea; [2]Department of Radiology and the Institute of Radiation Medicine, Seoul National University Hospital, Seoul 110-744, Korea

Objective: We wanted to assess the safety and efficacy of performing radiofrequency ablation (RFA) in patients with non-colorectal liver metastases.

Materials and Methods: In this retrospective study, 25 patients with 40 hepatic metastases (M:F = 17:8; mean age, 57 years; tumor size, 0.5-5.0 cm) from a non-colorectal origin (stomach, biliary, breast, pancreas, kidney and skin) were treated with RFA. The RFA procedures were performed using either an internally cooled electrode or a clustered electrode under ultrasound or CT guidance. Contrast-enhanced CT scans were obtained immediately after RFA and follow-up CT scans were performed within three months after ablation and subsequently at least every six months. The intrahepatic disease-free interval was estimated and the overall survival from the time of the initial RFA was analyzed using the Kaplan-Meier method.

Results: No intraprocedural deaths occurred, but four major complications developed, including abscesses (n = 3) and pneumothorax (n = 1). Technical effectiveness was determined on the initial follow-up images. During the follow-up period (range, 5.9-68.6 months; median time, 18.8 months) for 37 tumors in 22 patients where technical effectiveness was achieved, 12 lesions (32%, 12 of 37) showed local tumor progression and new intrahepatic metastases occurred in 13 patients (59%, 13 of 22). The median intrahepatic disease-free interval was 10.1 months. The 1-year, 3-year and 5-year overall survival rates after RFA were 86%, 39% and 19%, respectively.

Conclusion: RFA showed intermediate therapeutic effectiveness for the treatment of non-colorectal origin liver metastases.

Index terms: Liver; Interventional procedures; Radiofrequency ablation; Preliminary clinical study

Corresponding author: Jeong Min Lee, MD, Department of Radiology, Seoul National University Hospital, 101 Daehak-ro, Jongno-gu, Seoul 110-744, Korea.
• Tel: (822) 2072-3154 • Fax: (822) 743-6385
• E-mail: jmsh@snu.ac.kr

INTRODUCTION

Radiofrequency ablation (RFA) has recently received considerable attention as a minimally invasive treatment for tumor. The technique has been increasingly used for the treatment of hepatocellular carcinoma (HCC) and colorectal liver metastases. In patients with a solitary HCC and Child-Pugh class A cirrhosis, RFA had been shown to be associated with an excellent 5-year survival rate that is comparable to surgical resection (1-6). Furthermore, for

the patients with colorectal liver metastases, the 3-year and 5-year survival rates after RFA are in the range of 42-64% and 31-44%, respectively (7-12). Several studies have demonstrated that for patients with small solitary colorectal metastases, the survival rates after surgical resection and RF ablation might be comparable (13-15). Therefore, RFA has been increasingly used as an alternative modality to surgery for patients with small liver metastases from colorectal cancer and who have limited hepatic metastatic disease.

Some parts of eastern Asia, including Korea and Japan, have a very high incidence of gastric cancer (16, 17), and the patients suffering from tumor recurrence in the liver after primary cancer resection are common. Cholangiocarcinoma is the second most common primary liver cancer after HCC (18). Although many studies have demonstrated the therapeutic efficacy and survival of RFA for the treatment of liver metastases (19-33), there have been only limited studies on using RFA for treating liver metastases from non-colorectal cancers such as gastric cancers (19-21) and cholangiocarcinomas (22). The purpose of this study was to assess the safety and efficacy of curative intent RFA for the treatment of metachronous isolated liver metastases from non-colorectal cancers, including gastric cancers and cholangiocarcinomas.

MATERIALS AND METHODS

A review of our radiofrequency ablation (RFA) database identified that 74 treatment sessions for 58 patients were performed for the management of liver metastases from non-colorectal cancer between September 2002 and March 2008. We only included the procedures performed for a curative intent of hepatic metastases. The inclusion criteria included the following. 1) On the images obtained prior to the RFA procedure, the primary cancer was controlled, 2) inoperable hepatic metastases because of bilobar disease, comorbidity, a previous history of liver resection or the patient's refusal, 3) the patients had no detectable extrahepatic metastases, 4) the number of metachronous hepatic metastases was five or less, 5) the tumor size was 5cm or less, and 6) the patients had at least one follow-up image. We conducted a retrospective review of the imaging findings and medical records. The Institutional Review Board approved this retrospective study and the requirement for patient informed consent was waived.

Patients

Over a 6-year-period, we selected 28 RFA sessions in 25 patients (M:F = 17:8; age range, 36-83 years; mean age, 57 years) that were performed with a curative intent for hepatic metastases. The histological diagnosis of the primary cancers and the types of treatment for the primary cancers are listed in Table 1. The size of the treated tumors ranged from 0.5 cm to 5 cm in diameter (mean ± standard deviation [SD], 2.0 ± 1.0 cm). The total number of RFA treated tumors was 40 with a range of 1-4 per one treatment session (mean ± SD, 1.6 ± 0.8).

In our institution, the diagnostic work-up included a dynamic abdominal CT examination that was performed within one month before the RFA procedure. Laboratory tests such as a liver function test, a coagulation test and complete blood tests were also performed. All of the tumors were 5 cm or less in size. For RFA, the metastases should be less than 5 cm in diameter and the tumors should be located remote from large vessels, the bowel or diaphragm to minimize the risk of complications (34, 35). A platelet count of more than $50 \times 10^3/\mu L$ and an INR (international normalized ratio) of less than 1.5 were required before the procedure.

Radiofrequency Ablation Procedure

The patients underwent RFA treatment after 12 hours of fasting. For all the patients, RFA therapy was performed with conscious sedation and analgesia, which were achieved by means of intravenous administration of 1-2 mg of midazolam (Dormicum; Roche, Basel, Switzerland) and 50-100 g of fentanyl citrate (Fentanyl; Myengmun, Seoul, Korea). A nurse and the attending physician continuously monitored the vital signs during the procedure and for one hour following the procedure.

Percutaneous RFA was performed by one of the attending physicians with 3-10 years experience in RFA and these procedures were mostly done under sonographic guidance and monitoring, except for three metastases that were not visualized on a sonographic examination and so they were treated under CT guidance. RFA was performed using a 500-KHz monopolar RF generator (either a CC-1, Integra Radionics, Burlington, MA or a multi-channel RF generator, Taewoong, Koyang, Korea). A single cool tip electrode (Cool Tip Electrode; Valleylab, Boulder, CO) or a clustered electrode (Valleylab) was used based on the target tumor size. A single cool tip electrode was used for tumors smaller than 3 cm and a clustered electrode was used for tumors

Table 1. Patient Characteristics

No.	Age	Gender	Primary Cancer	Surgery	Initial Pathologic Stage	Pre-RFA Treatment	#1 Session	#2 Session	#3 Session	Post-RFA Treatment	Survival	Follow up Duration (months)
1	38	M	Stomach, AGC	Extended total gastrectomy	T2N1M0	0	2	4		RTx, CTx	No	46
2	66	F	Stomach, AGC	STG	T2N1M0	0	1			CTx	No	29
3	67	M	Stomach, AGC	STG	T2N2M0	CTx	1			0	No	11
4	80	F	Stomach, AGC	TG	T3N1M0	CTx	1			Follow-up loss	No	13
5	41	M	Stomach, AGC	TG	T3N3M0	CTx	3			CTx	No	14
6	70	M	Stomach, AGC	TG with R en Y	T2N3M0	CTx	1			CTx	No	15
7	51	M	Stomach, AGC	TG	T2N3M0	CTx	1			CTx	No	15
8	63	M	Stomach, AGC	STG	T2N3M0	CTx	1			CTx	No	14
9	73	M	Stomach, AGC	STG	T3N3M0	0	1			CTx	No	9
10	60	M	Stomach, AGC	TG,T-colon R & A, E-J, J-J colocolostomy	T2N0M0	CTx	1			CTx	Yes	39
11	83	M	Biliary, intrahepatic	Left lateral segmentectomy	T1N1M0	0	3			Follow-up loss	No	27
12	73	M	Biliary, intrahepatic	Left lobectomy, cholecystectomy	T1NxM0	CTx + TACE + tumorectomy	3			Follow-up loss	No	35
13	38	M	Biliary, intrahepatic	Extended left hemihepatectomy, caudate resection	T2N1M0	CTx	1	3		CTx	Yes	19
14	55	M	Biliary, intrahepatic	Right lobectomy	T1N0M0	0	1	1	1	CTx	Yes	30
15	53	M	Biliary, extrahepatic	PPPD	T3N1M0	CTx + RTx	2	1	2	0	No	14
16	59	M	Biliary, extrahepatic	PPPD	T2N1M0	0	1	1		CTx	Yes	69
17	51	M	Biliary, extrahepatic	PPPD	T1N0M0	0	1			CTx + tumorectomy	Yes	42
18	71	F	Biliary, GB	Cholecystectomy, right lobectomy	T3N1M0	RTx + CTx	3			Follow-up loss	No	9
19	45	F	Breast, IDC	Right MRM	T2N0M0	CTx	1			CTx	Yes	23
20	50	F	Breast, IDC	Bilateral mastectomy	T2N0M0	CTx	2			CTx	Yes	6
21	39	F	Breast, IDC	Right MRM	T3N1M0	CTx	1			CTx + RTx	Yes	42
22	36	F	Breast, IDC	Right quadrantectomy	T2N0M0	CTx + RT	1	1		CTx	Yes	28
23	51	M	Kidney, RCC	Left radical nephrectomy	T2N0M0	0	2			CTx	Yes	19
24	60	F	Pancreas, endocrine tumor	Whipple's operation	T3N0M0	CTx	3			0	Yes	7
25	60	M	Skin, malignant melanoma	Skin, subcutis, left tibia, excision	T3N0M0	IFN-α, RTx	1			Follow-up loss	Yes	7

Note.— AGC = advanced gastric cancer, CTx = chemotherapy, E-J = esophagojejunal anastomosis, GB =gallbladder, IDC = intraductal infiltrating carcinoma, J-J = jejunojejunal anastomosis, MRM = modified radical mastectomy, PPPD = pylorus-preserving pancreatoduodenectomy, R en Y = Roux-en Y, RCC = renal cell carcinoma, RFA = radiofrequency ablation, RTx = radiation therapy, STG = subtotal gastrectomy, T-colon R & A = transverse colon resection and anastomosis, TACE = transarterial chemoembolization, TG = total gastrectomy
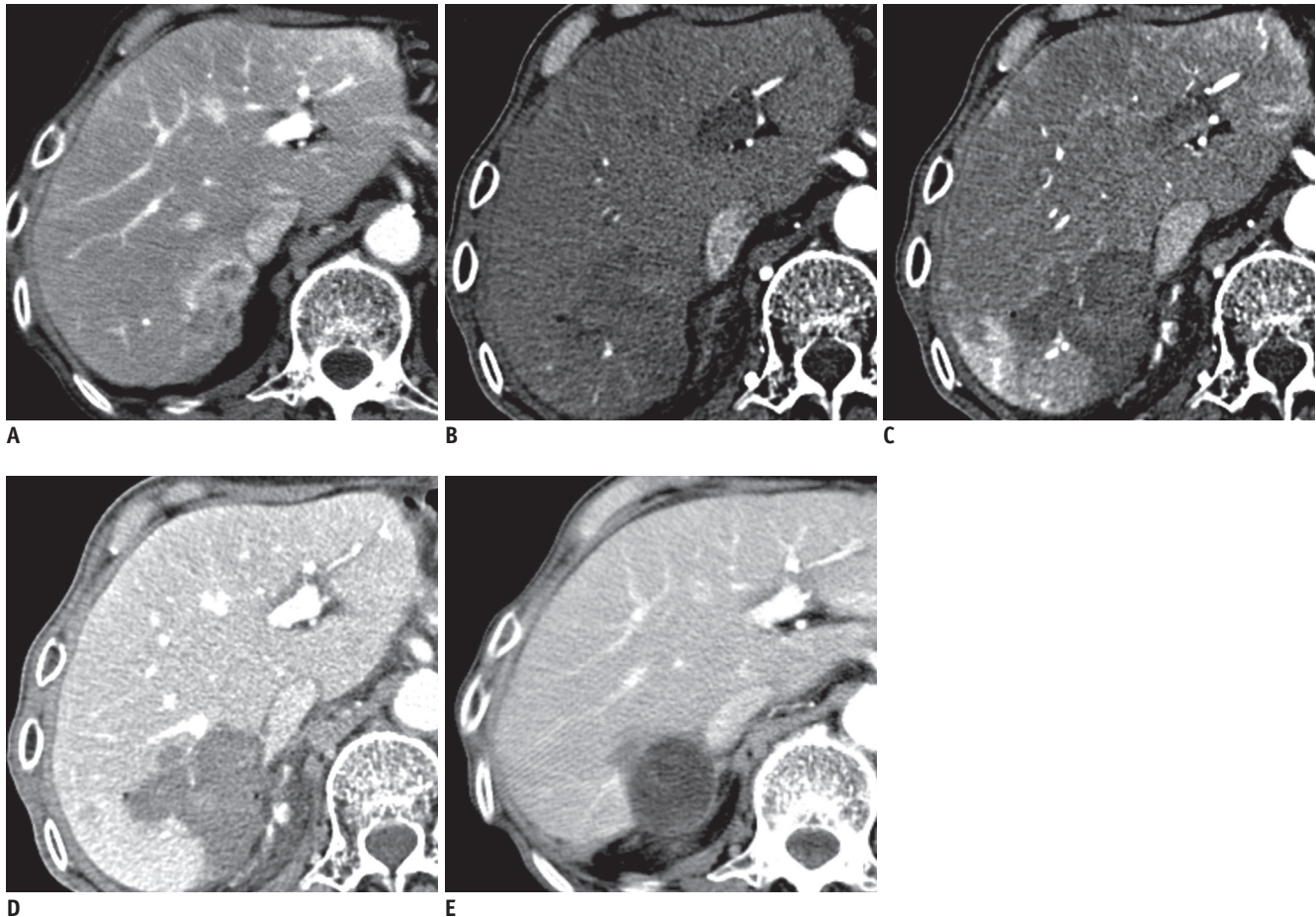
Fig. 1. Imaging findings are shown for approximately 3.6 cm sized gastric cancer liver metastasis that was completely ablated (technical success) without recurrence.
A-E. Pre-ablation contrast-enhanced CT in equilibrium phase **(A)** shows 3.6 cm sized peripheral enhancing mass located at segment 7. Immediate-ablation dynamic contrast-enhanced CT demonstrates complete necrosis of metastasis with lack of enhancement on early arterial **(B)**, late arterial **(C)** and portal venous **(D)** phase. After eight months, follow-up contrast-enhanced CT image **(E)** shows cystic change of ablated lesion without evidence of recurrence.

larger than 3 cm.

Radiofrequency was initially applied for 12 minutes and for subsequent ablations for 6 to 12 minutes. An impedance-controlled automated pulsed RF algorithm was used (upper limit, 80 ohms) with a maximum peak current of 1000-2000 mA and 50-200 W. A peristaltic pump (Watson-Marlow, Paris, France) was used for cooling of the electrode with saline solution (0°C) at a rate that was sufficient to maintain an electrode temperature below 20°C. Constant monitoring of the temperature at the tip of the needle was also performed. After ablation, the electrode was withdrawn with cauterizing the tract.

Treatment Assessment and Follow Up

Immediately after the completion of the radiofrequency ablation procedure, a three-phase dynamic enhanced CT

study (120 kVp, 200 mAs, 1.5 ml/body weight of nonionic contrast) was performed to evaluate the presence of residual tumor at the treated site and any immediate complications such as hemorrhage and bowel injury. A lack of enhancement of the ablated zone that covered the tumor area with no evidence of irregular peripheral enhancement was considered complete ablation of the macroscopic tumor and a technically successful RFA procedure (Fig. 1). Four metastases were seen as residual lesions on the immediate post-RFA enhanced CT images and additional RFA treatment was performed within 24 hours after the initial RFA procedure. After additional sonography-guided or CT-guided RFA, technically successful RFA was performed for all of the treated lesions.

Initial follow-up imaging was performed within three months. Standardized time interval imaging was obtained

at three and six months after the RFA procedure and then every six months. Nodular or irregular enhancement seen during the follow-up imaging was considered local tumor progression. Repeat treatment was performed to treat local tumor progression and/or new intrahepatic lesions in three patients who had fewer than five foci of intrahepatic tumor with no evidence of extrahepatic disease, as seen on imaging studies.

Statistical Analysis

The intrahepatic disease-free interval was defined as the interval between the initial treatment and the first appearance of a new lesion in the liver. Overall survival from the time of the initial RFA was also analyzed using the Kaplan-Meier method. MedCalc software (version 10.1.3.0; MedCalc Software, Mariakerke, Belgium) was used for all the statistical analyses.

RESULTS

Technical Effectiveness

Complete ablation of macroscopic tumors, as depicted on the initial follow-up CT images, and the technical effectiveness were confirmed for 22 of 25 (88%) patients after initial treatment. The technical effectiveness for 40 treated lesions was 88% (22 of 25) on a per patient basis and 93% (37 of 40 lesions) on a per tumor basis.

Intrahepatic Tumor Control

The liver CT imaging follow-up time was 19.2 months (range, 2.0-64.9 months; median time, 13.2 months). During the follow-up period, no viable tumors were detected in the liver in seven patients. Four of these seven patients were totally tumor free during the follow-up period, but three of the patients developed distant metastases. Among the 15 patients with intrahepatic tumor recurrence, nine patients also had an extrahepatic metastasis during the follow-up period. Among the 15 patients with intrahepatic tumor recurrence, seven patients had new metastases that were remote from the radiofrequency-treated lesions; two patients had local tumor progression and six patients had both new metastases and local tumor progression.

Local tumor Progression

Among the 40 lesions, three metastases were unsuccessfully treated. The patients with the 37 lesions that were effectively treated underwent follow-up. The

overall local tumor progression rate was 32% (12 of 37) for all of the totally treated lesions, including 25% (3 of 12) for stomach cancer, 43% (6 of 14) for biliary cancer, 60% (3 of 5) for breast cancer and 0% (0 of 3) for the other tumors (Fig. 2).

Intrahepatic Recurrence

The intrahepatic recurrence rate was 68% (15 of 22) for the primary treatment session, 66% (6 of 9) for stomach cancer, 83% (5 of 6) for biliary cancer and 75% (3 of 4) for breast cancer. Intrahepatic recurrence developed in the patients with renal cell carcinoma (RCC) liver metastases. The intrahepatic remote recurrence rate was 59% (13 of 22) for all of the treatment sessions, 83% (5 of 6) for biliary cancer, 44% (4 of 9) for stomach cancer and 75% (3 of 4)
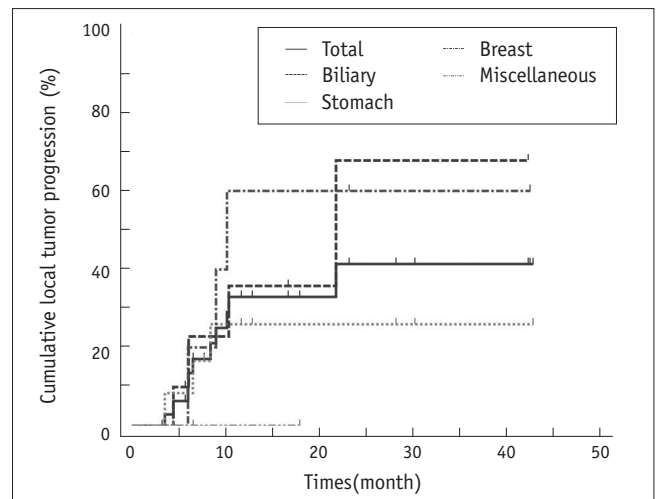

Fig. 2. Rates of local tumor progression after radiofrequency ablation.
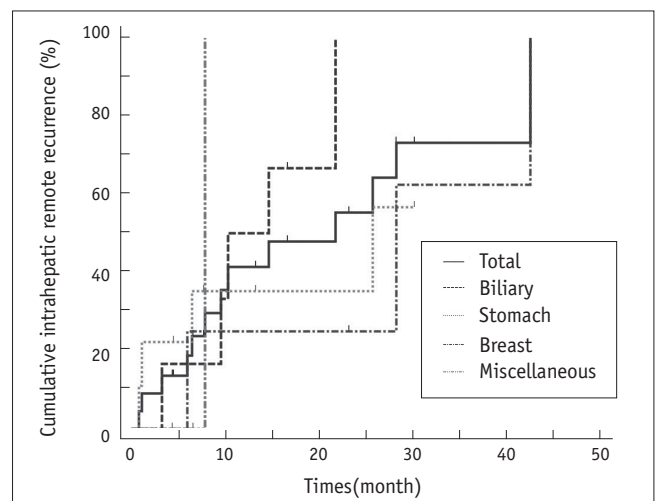

Fig. 3. Rates of intrahepatic remote recurrence after radiofrequency ablation.

for breast cancer (Fig. 3).

We calculated the time between RFA treatment and the follow-up imaging that showed a new intrahepatic lesion. The median intrahepatic disease-free interval was 10.1 months (Fig. 4). Repeated radiofrequency ablation was performed to treat local disease progression and new lesions for five patients. One biliary cancer patient underwent two curative intent RFA procedures and one palliative intent RFA procedure. One additional RFA session with a curative intent was performed on one breast cancer patient and one biliary cancer patent, respectively, and one additional RFA session with a palliative intent was performed on one stomach cancer patient and one biliary cancer patent, respectively.

Extrahepatic Tumor Recurrence

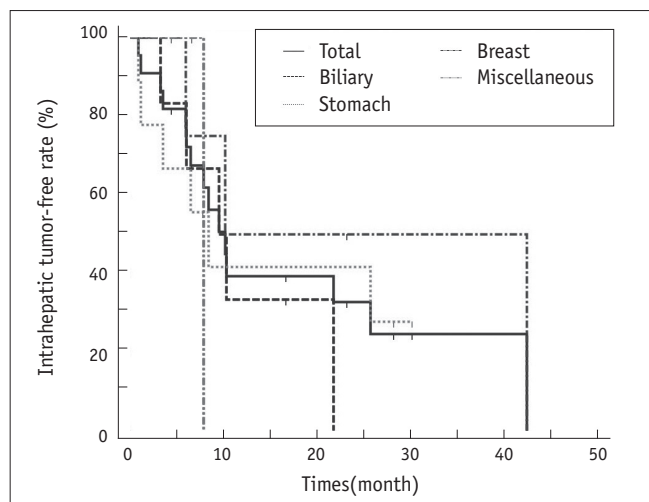The extrahepatic recurrence rate was 55% (12 of 22) for

Fig. 4. Intrahepatic tumor-free interval after radiofrequency ablation.
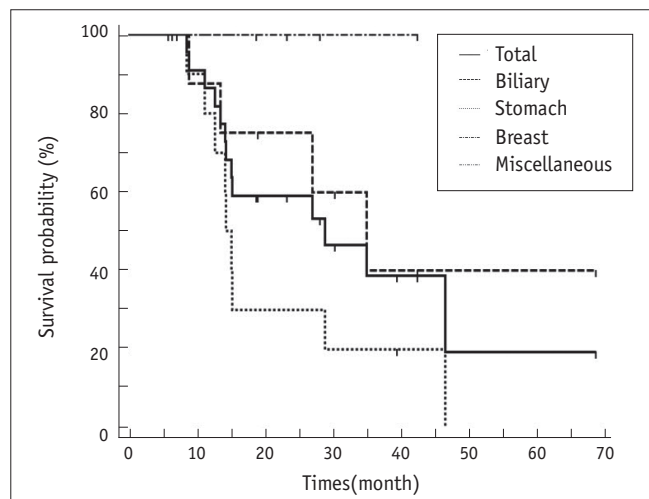

Fig. 5. Survival rate after radiofrequency ablation.

the primary treatment session, 56% (5 of 9) for stomach cancer, 67% (4 of 6) for biliary cancer and 25% (1 of 4) for breast cancer. Extrahepatic recurrence also developed in the RCC and malignant melanoma patients. Seventy five percent of these patients with extrahepatic recurrence combined with intrahepatic metastases. Three of them first presented with extrahepatic metastases. The mean time between RFA treatment and the follow-up imaging showing a new extrahepatic lesion was 13.7 months.

Survival after Radiofrequency Ablation

The mean follow-up was 23.3 months (range, 5.9-68.6 months; median time, 18.8 months; n = 25). Thirteen patients died during follow-up. The median overall survival after radiofrequency ablation was 28.8 months. The 1-year, 3-year and 5-year estimated survival rates after radiofrequency ablation were 86%, 39% and 19%, respectively (Fig. 5).

Complications

The side effects and complications after RFA are summarized in Table 2. No intraprocedural deaths occurred. Four major complications occurred. One patient who developed a large pneumothorax was treated with a chest-tube and three patients who developed liver abscesses were treated with percutaneous drainage. For the 25 patients, the total complication rate was 40% (10 of 25).

DISCUSSION

Our study provides the therapeutic results of percutaneous RFA for non-colorectal liver metastases, and the estimated survival rate for patients with non-colorectal liver

Table 2. Side Effects and Complications

Type of Complication	Number
Minor complications	
Subsegmental atelectasis with a small pleural effusion	1
Focal diaphragmatic injury	1
Focal lung parenchymal injury, intravenous thrombus at splenoportal junction	1
Biliary stricture	3
Major complications	
Large pneumothorax	1
Liver abscess	3

metastases was 86%, 39% and 19% for one year, three years and five years, respectively. These results are not as good as the results of the previous studies on RFA in patients with colorectal liver metastases, which showed the 1, 3 and 5-year estimated survival rates were 87-96%, 42-57% and 24-44%, respectively (7-12).

Although the results of RFA for patients with non-colorectal liver metastases were not as good as that for RFA in patients with colorectal liver metastases, our study results might have some clinical meaning. For example, surgical resection for a gastric liver metastasis is rarely performed, which is different from the treatment of colorectal liver metastases. Following curative resection of gastric cancer, the liver is the most common site of hematogenous metastases and approximately 15% of all recurrences were liver metastasis alone (36). However, the majority of liver metastases are combined with locoregional or peritoneal seeding, and even if a metastasis is confined in the liver, bilobar disease is common and so there is a very limited number of surgical candidates (36, 37).

The reported 5-year survival rate after hepatic resection of selected patients with resectable gastric liver metastases is approximately 30% (38-40). Considering this clinical situation, our estimated survival rate after RFA for one year, three years and five years was 78%, 22% and 0%, respectively, with a median survival of 15.1 months. The local tumor control rate of stomach cancer was excellent. However, as compared with other metastatic tumors, a relatively high rate of intrahepatic remote metastases and extrahepatic metastases was found. This recurrence pattern has also been reported in previous studies regarding surgical resection of gastric liver metastases (36, 41). Although our results are not as good as compared with the surgical results, a complementary role for RFA should be considered when remembering that all our patients were in an inoperable state (21, 22, 42). However, because of the high rate of remote recurrence of stomach cancer, RFA as a sole treatment is ethically unacceptable and systemic therapy should also be considered.

Surgical resection is the only potentially curative treatment for patients with biliary cancer. However, after curative resection, the five-year survival rate for patients with tumor-free margins is 20-40% and the operative mortality is approximately 10%. Even after curative resection, 31-50% of these patients have a recurrence in one year, and about half of the cancers recur in the remaining liver (43-45). The patients who have had prior

surgery have a lesser chance of curative resection. In addition, postoperative chemotherapy and radiation therapy were not significantly identified as being efficacious for treating biliary cancer (46, 47). Based on our results, half of the patients had complete tumor resection and half of the patients had palliative surgery and the latter received chemoradiation treatment. Because of bilobar disease or having undergone hepatectomy, the patients underwent RFA for the treatment of recurred cancer. The local tumor progression-free rates on a per lesion-basis were 64% and 32% for one year and two years, respectively, and the median intrahepatic disease free interval was 9.5 months. Considering the recurrence rate after surgery, there might be some role for RFA to control local tumor in patients with unresectable disease.

A small number of breast cancer patients were included in our series. None of the patients with breast cancer died during the follow-up period (range, 5-42 months; mean, 25 months; median, 25 months). New metastases were observed in three (75%) of four patients. It was not possible to compare our study with the previous studies. However, for the intrahepatic tumor control of the previous largest study, 58% of the patients developed tumors after a 4-44 month period (mean, 10 months) (25). In comparison, the estimated 10-month intrahepatic recurrence rate in our study is similar to the rate in a previous study (27). The median intrahepatic disease-free interval determined in our study (10.1 months) is similar with the 13-month median time to recurrence for surgical resection in a previous study (48). However, different patient selection and the prior disease status should be considered and our findings suggest the usefulness of RFA as an alternative procedure in place of surgery. As most of our patients received pre-RFA and/or post-RFA chemotherapy and other adjuvant therapy, the results of our study were, perhaps, partially due to the effects of the previous therapies. Maybe a synergistic effect of chemotherapy and RF ablation played a role in our study.

There are several limitations of our study. First, this was a retrospective study and some heterogeneity existed for the patient characteristics and their tumors. Second, the study population was not sufficiently large to demonstrate the clinical value of RFA. Despite these limitations, our study results are important to provide the preliminary findings to evaluate the short-term efficacy of RFA for treating non-colorectal liver metastases. A randomized controlled prospective trial will be needed to prove the clinical role of RFA. Third, we did not always apply RFA for the treatment

of recurred tumors after the initial RFA and we were not able to determine the potential maximum role of RFA to treat non-colorectal liver metastases.

In summary, RFA showed relatively less therapeutic effectiveness for the treatment of non-colorectal origin liver metastases as compared with colorectal liver metastases. However, the therapeutic results of RFA were not disappointing as compared with the therapeutic results of surgical resection for liver metastases from the same patient population with non-colorectal primary cancer. In addition, the low morbidity and mortality rates and the improved selectivity of candidates for RFA suggest the possible broad application of RFA treatment for liver metastases. A prospective randomized trial that will compare systemic treatment alone and systemic treatment with RFA for liver metastases is needed.

REFERENCES

1. Fong Y, Sun RL, Jarnagin W, Blumgart LH. An analysis of 412 cases of hepatocellular carcinoma at a Western center. *Ann Surg* 1999;229:790-799; discussion 799-800

2. Llovet JM, Fuster J, Bruix J. Intention-to-treat analysis of surgical treatment for early hepatocellular carcinoma: resection versus transplantation. *Hepatology* 1999;30:1434-1440

3. Poon RT, Fan ST, Lo CM, Liu CL, Wong J. Long-term survival and pattern of recurrence after resection of small hepatocellular carcinoma in patients with preserved liver function: implications for a strategy of salvage transplantation. *Ann Surg* 2002;235:373-382

4. Lencioni R, Cioni D, Crocetti L, Franchini C, Pina CD, Lera J, et al. Early-stage hepatocellular carcinoma in patients with cirrhosis: long-term results of percutaneous image-guided radiofrequency ablation. *Radiology* 2005;234:961-967

5. Choi D, Lim HK, Rhim H, Kim YS, Lee WJ, Paik SW, et al. Percutaneous radiofrequency ablation for early-stage hepatocellular carcinoma as a first-line treatment: long-term results and prognostic factors in a large single-institution series. *Eur Radiol* 2007;17:684-692

6. Fukuda S, Itamoto T, Nakahara H, Kohashi T, Ohdan H, Hino H, et al. Clinicopathologic features and prognostic factors of resected solitary small-sized hepatocellular carcinoma. *Hepatogastroenterology* 2005;52:1163-1167

7. Solbiati L, Livraghi T, Goldberg SN, Ierace T, Meloni F, Dellanoce M, et al. Percutaneous radio-frequency ablation of hepatic metastases from colorectal cancer: long-term results in 117 patients. *Radiology* 2001;221:159-166

8. Iannitti DA, Dupuy DE, Mayo-Smith WW, Murphy B. Hepatic radiofrequency ablation. *Arch Surg* 2002;137:422-426; discussion 427

9. Machi J, Oishi AJ, Sumida K, Sakamoto K, Furumoto NL, Oishi

RH, et al. Long-term outcome of radiofrequency ablation for unresectable liver metastases from colorectal cancer: evaluation of prognostic factors and effectiveness in first- and second-line management. *Cancer J* 2006;12:318-326

10. Abitabile P, Hartl U, Lange J, Maurer CA. Radiofrequency ablation permits an effective treatment for colorectal liver metastasis. *Eur J Surg Oncol* 2007;33:67-71

11. Sorensen SM, Mortensen FV, Nielsen DT. Radiofrequency ablation of colorectal liver metastases: long-term survival. *Acta Radiol* 2007;48:253-258

12. Gillams AR, Lees WR. Five-year survival in 309 patients with colorectal liver metastases treated with radiofrequency ablation. *Eur Radiol* 2009;19:1206-1213

13. Hur H, Ko YT, Min BS, Kim KS, Choi JS, Sohn SK, et al. Comparative study of resection and radiofrequency ablation in the treatment of solitary colorectal liver metastases. *Am J Surg* 2009;197:728-736

14. Oshowo A, Gillams A, Harrison E, Lees WR, Taylor I. Comparison of resection and radiofrequency ablation for treatment of solitary colorectal liver metastases. *Br J Surg* 2003;90:1240-1243

15. Veltri A, Sacchetto P, Tosetti I, Pagano E, Fava C, Gandini G. Radiofrequency ablation of colorectal liver metastases: small size favorably predicts technique effectiveness and survival. *Cardiovasc Intervent Radiol* 2008;31:948-956

16. Ahn YO. Cancer in Korea: present features. *Jpn J Clin Oncol* 2002;32 Suppl:S32-36

17. Shin HR. Global activity of cancer registries and cancer control and cancer incidence statistics in Korea. *J Prev Med Public Health* 2008;41:84-91

18. Khan SA, Taylor-Robinson SD, Toledano MB, Beck A, Elliott P, Thomas HC. Changing international trends in mortality rates for liver, biliary and pancreatic tumours. *J Hepatol* 2002;37:806-813

19. Kim HO, Hwang SI, Hong HP, Yoo CH. Radiofrequency ablation for metachronous hepatic metastases from gastric cancer. *Surg Laparosc Endosc Percutan Tech* 2009;19:208-212

20. An JY, Kim JY, Choi MG, Noh JH, Choi D, Sohn TS, et al. Radiofrequency ablation for hepatic metastasis from gastric adenocarcinoma. *Yonsei Med J* 2008;49:1046-1051

21. Carditello A, Scisca C, Stilo F, Parisi A, Basile M. The possible role of radiofrequency as complementary treatment of locally advanced gastric cancer. *Ann Ital Chir* 2005;76:39-41

22. Kim JH, Won HJ, Shin YM, Kim PN, Lee SG, Hwang S. Radiofrequency ablation for recurrent intrahepatic cholangiocarcinoma after curative resection. *Eur J Radiol* 2010 [Epub ahead of print]

23. Carrafiello G, Lagana D, Cotta E, Mangini M, Fontana F, Bandiera F, et al. Radiofrequency ablation of intrahepatic cholangiocarcinoma: preliminary experience. *Cardiovasc Intervent Radiol* 2010;33:835-839

24. Sofocleous CT, Nascimento RG, Gonen M, Theodoulou M, Covey AM, Brody LA, et al. Radiofrequency ablation in the management of liver metastases from breast cancer. *AJR Am J Roentgenol* 2007;189:883-889

25. Livraghi T, Goldberg SN, Solbiati L, Meloni F, Ierace T, Gazelle GS. Percutaneous radio-frequency ablation of liver metastases from breast cancer: initial experience in 24 patients. *Radiology* 2001;220:145-149

26. Lawes D, Chopada A, Gillams A, Lees W, Taylor I. Radiofrequency ablation (RFA) as a cytoreductive strategy for hepatic metastasis from breast cancer. *Ann R Coll Surg Engl* 2006;88:639-642

27. Gunabushanam G, Sharma S, Thulkar S, Srivastava DN, Rath GK, Julka PK, et al. Radiofrequency ablation of liver metastases from breast cancer: results in 14 patients. *J Vasc Interv Radiol* 2007;18:67-72

28. Rath GK, Julka PK, Thulkar S, Sharma DN, Bahl A, Bhatnagar S. Radiofrequency ablation of hepatic metastasis: results of treatment in forty patients. *J Cancer Res Ther* 2008;4:14-17

29. Penka I, Kaplan Z, Sefr R, Sirotek L, Eber Z, Ondrak M. Use of radiofrequency ablation in the treatment of malignant liver lesions. *Hepatogastroenterology* 2008;55:562-567

30. Mazzaglia PJ, Berber E, Milas M, Siperstein AE. Laparoscopic radiofrequency ablation of neuroendocrine liver metastases: a 10-year experience evaluating predictors of survival. *Surgery* 2007;142:10-19

31. Fan WJ, Wu PH, Zhang L, Huang JH, Zhang FJ, Gu YK, et al. Radiofrequency ablation as a treatment for hilar cholangiocarcinoma. *World J Gastroenterol* 2008;14:4540-4545

32. Gervais DA, Arellano RS, Mueller PR. Percutaneous radiofrequency ablation of ovarian cancer metastasis to the liver: indications, outcomes, and role in patient management. *AJR Am J Roentgenol* 2006;187:746-750

33. Yokoyama T, Egami K, Miyamoto M, Watanabe H, Hasegawa H, Iida S, et al. Percutaneous and laparoscopic approaches of radiofrequency ablation treatment for liver cancer. *J Hepatobiliary Pancreat Surg* 2003;10:425-427

34. Kim SW, Rhim H, Park M, Kim H, Kim YS, Choi D, et al. Percutaneous radiofrequency ablation of hepatocellular carcinomas adjacent to the gallbladder with internally cooled electrodes: assessment of safety and therapeutic efficacy. *Korean J Radiol* 2009;10:366-376

35. Kang TW, Rhim H, Kim EY, Kim YS, Choi D, Lee WJ, et al. Percutaneous radiofrequency ablation for the hepatocellular carcinoma abutting the diaphragm: assessment of safety and therapeutic efficacy. *Korean J Radiol* 2009;10:34-42

36. Yoo CH, Noh SH, Shin DW, Choi SH, Min JS. Recurrence following curative resection for gastric carcinoma. *Br J Surg* 2000;87:236-242

37. Kwok CM, Wu CW, Lo SS, Shen KH, Hsieh MC, Lui WY. Survival of gastric cancer with concomitant liver metastases. *Hepatogastroenterology* 2004;51:1527-1530

38. Okano K, Maeba T, Ishimura K, Karasawa Y, Goda F, Wakabayashi H, et al. Hepatic resection for metastatic tumors from gastric cancer. *Ann Surg* 2002;235:86-91

39. Sakamoto Y, Ohyama S, Yamamoto J, Yamada K, Seki M, Ohta K, et al. Surgical resection of liver metastases of gastric cancer: an analysis of a 17-year experience with 22 patients. *Surgery* 2003;133:507-511

40. Koga R, Yamamoto J, Ohyama S, Saiura A, Seki M, Seto Y, et al. Liver resection for metastatic gastric cancer: experience with 42 patients including eight long-term survivors. *Jpn J Clin Oncol* 2007;37:836-842

41. D'Angelica M, Gonen M, Brennan MF, Turnbull AD, Bains M, Karpeh MS. Patterns of initial recurrence in completely resected gastric adenocarcinoma. *Ann Surg* 2004;240:808-816

42. Yamakado K, Nakatsuka A, Takaki H, Mori Y, Tonouchi H, Kusunoki M, et al. Prospective study of arterial infusion chemotherapy followed by radiofrequency ablation for the treatment of liver metastasis of gastric cancer. *J Vasc Interv Radiol* 2005;16:1747-1751

43. Hasegawa S, Ikai I, Fujii H, Hatano E, Shimahara Y. Surgical resection of hilar cholangiocarcinoma: analysis of survival and postoperative complications. *World J Surg* 2007;31:1256-1263

44. Valverde A, Bonhomme N, Farges O, Sauvanet A, Flejou JF, Belghiti J. Resection of intrahepatic cholangiocarcinoma: a Western experience. *J Hepatobiliary Pancreat Surg* 1999;6:122-127

45. El Rassi ZE, Partensky C, Scoazec JY, Henry L, Lombard-Bohas C, Maddern G. Peripheral cholangiocarcinoma: presentation, diagnosis, pathology and management. *Eur J Surg Oncol* 1999;25:375-380

46. McMasters KM, Tuttle TM, Leach SD, Rich T, Cleary KR, Evans DB, et al. Neoadjuvant chemoradiation for extrahepatic cholangiocarcinoma. *Am J Surg* 1997;174:605-608; discussion 608-609

47. Khan SA, Thomas HC, Davidson BR, Taylor-Robinson SD. Cholangiocarcinoma. *Lancet* 2005;366:1303-1314

48. Vlastos G, Smith DL, Singletary SE, Mirza NQ, Tuttle TM, Popat RJ, et al. Long-term survival after an aggressive surgical approach in patients with breast cancer hepatic metastases. *Ann Surg Oncol* 2004;11:869-874