Microwave ablation versus hepatic resection in management of hepatocellular carcinoma

Mohammed Hussien[a], Sahar Hassany[b], Mohamed El Kassas[d], Ahmed M. Ali[c], Ehab F. A. Moustafa[b], Osman A. H. Osman[b]

[a]Department of Hepatology, Gastroenterology and Infectious Disease, Faculty of Medicine, Kafrelsheikh University, Kafrelsheikh, Egypt [b]Department of Tropical Medicine and Gastroenterology, [c]Department of General Surgery, Faculty of Medicine, Assiut University, Assiut, [d]Department of Endemic Medicine, Faculty of Medicine, Helwan University, Cairo, Egypt

Correspondence to Mohammed Hussien, MD, Department of Hepatology, Gastroenterology and Infectious Disease, Faculty of Medicine, Kafrelsheikh University, Kafrelsheikh, Egypt
Postal Code: 33511;
Tel: +01 004 039 954;
E-mail: mohammed_hessien@med.kfs.edu.eg

Received 14 March 2018
Accepted 27 April 2018

Journal of Current Medical Research and Practice
September-December 2019, 4:261–267

Background
Management of early hepatocellular carcinoma (HCC) in cirrhotic patients is still a challenge. Hepatic resection remains the best curative treatment, but more complications with a risk of HCC recurrence in cirrhotic patients make it less favorable. Few studies have recently started to evaluate microwave ablation (MWA) as a method of HCC eradication in cirrhotic patient and compare it by other ablative methods. The aim of this study was to evaluate patient with HCC before and after both MWA and hepatic resection.

Patients and methods
A prospective study was performed in Assiut University Hospital in collaboration with National Hepatology and Tropical Medicine Research Institute in Cairo. We recruited 40 patients; all of them had radiology-proved HCC with lesion up to 5 cm and amenable for MWA or surgical resection.

Results
There is a statistically significant difference between Child score after hepatic resection in comparison with the mean Child score for patients who underwent MWA (before ablation was 6.1 ± 0.7 and after ablation was 6.1 ± 1.0, but was 5.5 ± 0.6 and was 7.2 ± 1.4 after hepatic resection). There is marked decrease of α-fetoprotein after hepatic resection (as the mean level before resection was 172.73 and after liver resection was 10.95). Fewer complications were recorded after MWA in comparison with that after hepatic resection.

Conclusion
Hepatic resection is superior to MWA in HCC eradication as no residual activity. MWA is better than hepatic resection in maintaining the Child score, as it was more affected in patients who underwent hepatic resection than those who underwent MWA.

Keywords:
child Score post microwave ablation and hepatic resection, Hepatic resection, management of early HCC, Microwave Ablation

J Curr Med Res Pract 4:261–267

2357-0121

Introduction

Hepatocellular carcinoma (HCC) is the most common primary neoplasm of the liver with a significant cause of morbidity and mortality and carries an unfavorable prognosis with aggressive behavior and a high recurrence rate [1]. It is the third leading cause of cancer deaths worldwide, with more than 500 000 people affected. The incidence of HCC is highest in Asia and Africa, where the endemic high prevalence of hepatitis B and hepatitis C strongly predisposes to the development of chronic liver disease and subsequent development of HCC [2]. Egypt is confronted with a huge number of hepatitis C virus (HCV) infections, which distinguishes it from the rest of North Africa. It has the highest prevalence of HCV in the world, and up to 90% of HCC cases in the Egyptian population were owing to HCV. So, HCC represents an important public health problem in Egypt and is the third among male cancers [3]. The mainstay of screening and diagnosis of HCC is liver imaging, which classify into the following: routine noninvasive studies such as ultrasound (US), computed tomography (CT), and MRI, and more specialized invasive techniques including CT during hepatic arteriography and CT arterial portography [4]. Hepatic resection is the treatment of choice for early HCC in noncirrhotic patients and offers the best curative rate with a 5-year survival of 41–74%. The resectability of the tumor is dependent on the tumor size, location, underlying liver function, and whether or not the remaining liver volume will allow for resection without increasing post resection morbidity and mortality. However, unfortunately this option is feasible in only 5% of the cases in western countries [5]. Microwaves offer several advantages over other ablation therapy, including faster heating over a larger volume, less susceptibility

to 'heat sinks' or local perfusion compared with Radiofrequency (RF), and the ability to create much larger ablation zones. Few studies have recently started to evaluate microwave ablation (MWA) as a method of HCC eradication in cirrhotic patient and compare it with other ablative methods [6–10]. The aim of this study was to evaluate patient with HCC before and after both MWA and hepatic resection in short-term evaluation. This study is considered as the first study in Egypt to evaluate MWA versus hepatic resection in management of HCC by assessment of the patients before intervention and after intervention in short-term follow-up.

Patients and methods

This is a prospective study performed between December 2014 and August 2016 in Assuit University Hospital for the patients candidate for hepatic resection and National Institute of Tropical Medicine and Hepatology in Cairo for the patients candidate for MWA.

A total of 46 patients with liver cirrhosis and HCC who fulfilled the inclusion criteria were enrolled in the study and MWA was done for 20 cases and hepatic resection for 20 patients (according to the multidisciplinary team decision). Of the 46 patients, follow-up was done for 40 cases only because four cases were missed on follow-up and two cases refused to continue in the study. So 40 (nine females and 31 males) cases were enrolled and followed up and statistical analysis was done for them. A total of 32 cases were diagnosed by typical arterial enhancement of the tumor followed by a washout pattern in the images in the portal venous phase or the equilibrium phase on dynamic spiral CT imaging and only eight needed further confirmation by dynamic MRI with diffusion.

The patient selection for microwave or hepatic resection was carried out by a multidisciplinary team which consists of hepatologists, interventional radiologists, transplant surgeons, oncologists and residents.

Inclusion criteria of the patients were radiology-proved cases of HCC, and the patients with lesion up to 5 cm and amenable for MWA or surgical resection, with the Child score A and early B (score not > 7).

Exclusion criteria of the patients were advanced HCC or with focal lesion not amenable for resection or MWA, patients who refused follow-up and evaluation, failure to obtain consent, pregnant patients to avoid potential risks to the patient and/or fetus, and patients with implanted electronic devices such as implantable pacemakers that may be adversely affected by microwave power output.

All included patients were subjected to full history taking and full clinical examination, including complete blood count, liver function tests, urea and creatinine, international normalization ratio (INR), prothrombin time and concentration, hepatitis B surface antigen, HCV antibody, serum α-fetoprotein (AFP), abdominal ultrasonography, abdominal CT, and dynamic MRI with diffusion when needed.

Microwave ablation technique

Patients were treated under sedation with intravenous administration of fentanyl and propofol, in spontaneous breathing with oxygen mask support.

The technique uses microwave energy that induces an ultra-high speed, 915 or 2.450 MHz (2.45 GHz), alternating electric field, which causes water molecule rotation and the creation of heat. This results in thermal coagulation and localized tissue necrosis. In MWA, we use a single microwave antenna connected to a generator inserted directly into the tumor or tissue to be ablated; energy from the antenna generates friction and heat.

The size and the shape of the hyperechoic zone caused by gas microbubbles appearing in the ablated zone during MWA procedure were monitored by US to assess the completeness of therapy.

Treatment was stopped when the entire target was completely hyperechoic and the determined time and power according to the size of the lesion reached.

Hepatic resection

Hepatic resection was done on the basis of the segmental anatomy of the liver, which can be delineated using intraoperative ultrasound during operation. The delineation of a proper transaction plane is important not only for adequate tumor-free margin in resection of liver tumors but also to avoid inadvertent injuries to major intrahepatic vessels or bile duct pedicles.

Follow-up after the intervention

Evaluation criteria in hepatocellular carcinoma 4 weeks after the initiation of therapy

Reassessment of the patient includes complete clinical examination, including complete blood count, liver function tests, urea and creatinine, INR and serum AFP level. Abdominal ultrasound and triphasic CT examination of the abdomen were done to evaluate WHO performance status, Child score, and BCLC classification.

Ethics and consents

The survey was approved by the faculty's ethics committee and permission was obtained from all departments who assured that confidentiality would be maintained and ethical principles would be followed. Before initiation of the study, a background about the study and its reason was explained to the patients, the targeted population was encouraged to participate without any undue pressure, and written informed consent was obtained.

Statistical analyses

Statistical package for the social sciences (SPSS) software (SPSS Inc., Chicago, Illinois, USA) version 16 for Windows 7 (Microsoft Corp., Redmond, Washington, USA) was used for analysis.

Wilcoxon's test and paired Student's *t*-test were used to compare paired data, whereas χ^2-test, Fisher's exact test and Mann–Whitney *U*-test were used to compare unpaired data.

Results

During the period of the study, a total of 40 patients previously diagnosed as having HCC by characteristic radiologic findings, such as typical arterial enhancement of the tumor followed by a washout pattern in the images in the portal venous phase or the equilibrium phase on dynamic spiral CT imaging or contrast-enhanced MRI were enrolled in the study. So 40 (nine females and 31 males) cases were enrolled and followed up and statistical analysis was done for them. The mean age was 58.1 ± 7.7 years for patients who underwent MWA and 57.8 ± 4.3 years for patient who underwent hepatic resection (Table 1). The descriptions data of the patients according to their age, sex and type of hepatitis infection are shown in Table 1.

Patients underwent MWA had a mean Child score of 6.1 ± 0.7 and after ablation 6.1 ± 1.0, but was 5.5 ± 0.6 before hepatic resection and 7.2 ± 1.4 after resection (Table 2).

Table 3 shows the mean HCC size in patients who underwent MWA was 3.15 ± 1.15 and was 3.82 ± 0.84 cm in patients who underwent hepatic resection. Overall, 75% of patients underwent MWA were in right lobe and 80% for those underwent hepatic resection.

There is a high statistically significant difference in hemoglobin level in patients who underwent hepatic resection at *P* value 0.000 but not in patients who underwent MWA, as shown in Table 4. Serum albumin was 3.34 ± 0.63 g/dl after MWA and 2.83 ± 0.75 g/dl after hepatic resection (Fig. 1). INR was 1.25 ± 0.23 after MWA and was 1.22 ± 0.19 after hepatic resection. Changes in prothrombin concentration after both microwave and hepatic

Table 1 Demographic data of the studied patients

	Microwave (*n*=20) [*n* (%)]	Hepatic resection (*n*=20) [*n* (%)]	*P*
Age			
Mean±SD	58.1±7.7	57.8±4.3	0.880
24-34 years	1 (5.0)	0	0.323
46-65 years	16 (80.0)	19 (95.0)	
66-85 years	3 (15.0)	1 (5.0)	
Sex			
Male	13 (65.0)	18 (90.0)	0.058
Female	7 (35.0)	2 (10.0)	
Hepatitis markers			
HBs Ag	1 (5.0)	1 (5.0)	1.000
HCV Ab	19 (95.0)	19 (95.0)	

HBs Ag, hepatitis B surface antigen; HCV Ab, hepatitis C virus antibody.

Table 2 Child scoring before and after both microwave ablation and hepatic resection

	Child score before intervention [*n* (%)]	Child score after intervention [*n* (%)]	*P*
Microwave (*n*=20)			
Mean±SD	6.1±0.7	6.1±1.0	0.789
5	4 (20.0)	6 (30.0)	
6	10 (50.0)	8 (40.0)	
7	6 (30.0)	3 (15.0)	
8	0	3 (15.0)	
Hepatic resection (*n*=20)			
Mean±SD	6.1±1.0	7.2±1.4	0.000*
5	11 (55.0)	3 (15.0)	
6	8 (40.0)	3 (15.0)	
7	1 (5.0)	6 (30.0)	
8	0	4 (20.0)	
9	0	3 (15.0)	
10	0	1 (5.0)	

**P*<0.05, statistically significant difference.

Table 3 Description of hepatocellular carcinoma

	Microwave [*n* (%)]	Hepatic resection [*n* (%)]	*P*
Size	3.15±1.15	3.82±0.84	0.043*
Site			
Right	15 (75.0)	16 (80.0)	0.705
Left	5 (25.0)	4 (20.0)	
Segment			
II	1 (5.0)	0	0.705
III	3 (15.0)	3 (15.0)	
IV	0	4 (20.0)	
IVb	1 (5.0)	1 (5.0)	
V	3 (15.0)	4 (20.0)	
VI	5 (25.0)	4 (20.0)	
VII	3 (15.0)	2 (10.0)	
VIII	4 (20.0)	2 (10.0)	

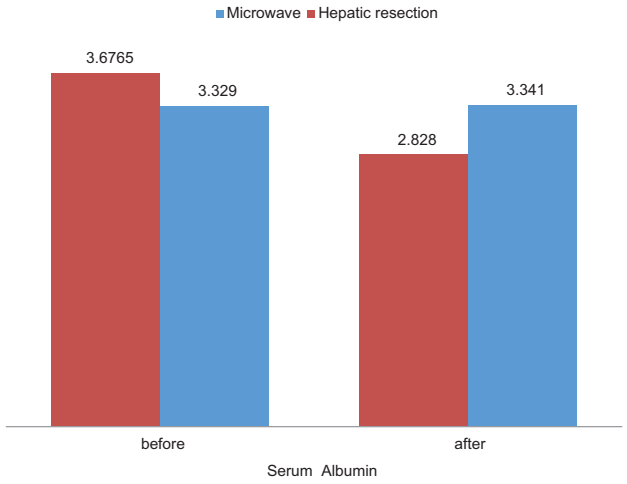
**P*<0.05, statistically significant difference.

resection in comparison with preintervention level are shown in Fig. 2. The AFP level after MWA was 130 ± 268.84 and was 10 ± 6.73 after hepatic resection, as shown in Fig. 3.

There is a statistically significant difference in total protein before and after hepatic resection, with *P* value 0.030, and also in serum albumin, with *P* value 0.025 and direct bilirubin, with *P* value 0.014 but not in MWA (Table 5). The difference in albumin level preintervention and postintervention is shown in Fig. 1.

Complications that occurred after 4 weeks of follow-up after MWA and hepatic resection are categorized as occurrence of recurrence in one case of 40 cases (in the patients who underwent hepatic resection), residual activity in two cases of the 40 cases (only in patients who underwent MWA), appearance of new lesion in six cases of the 40 cases (five cases in patients who underwent MWA and one case in patients who underwent hepatic resection), hepatic encephalopathy in two cases (in the patients who underwent hepatic resection), plural effusion in five cases (three cases in patients who underwent MWA and two cases in patients underwent hepatic resection), ascites in14 cases of the 40 cases (four cases in patients underwent MWA and 10 cases in patients who underwent hepatic resection), and skin laceration in one case (only in a patients who underwent MWA) (Fig. 4).

Figure 1

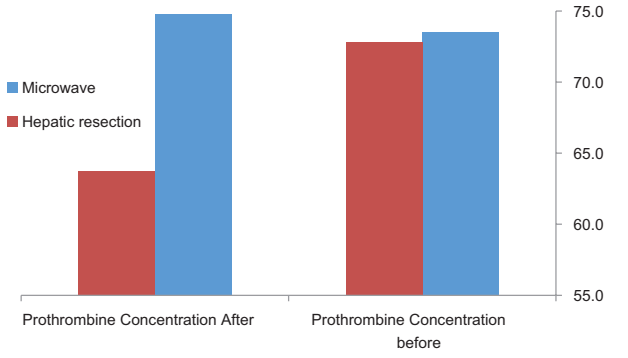


Variation in level of albumin after both microwave and hepatic resection in comparison to preintervention level.

Discussion

The choice of appropriate decision to treatment of early HCC in cirrhotic patients is still challenge.

Figure 2



Changes in prothrombin concentration after both microwave and hepatic resection in comparison to preintervention level.

Table 4 Comparison between blood picture values in the studied patients underwent both microwave and hepatic resection

	Microwave			Hepatic resection		
	Before	After	*P*	Before	After	*P*
WBC (10^9/l)	4.88±1.56	5.16±1.51	0.147	6.63±2.91	12.71±9.03	0.005**
RBC (cells/µl)	4.09±0.59	4.35±0.45	0.271	5.29±1.99	4.98±4.34	0.003**
HB (g/dl)	11.67±1.89	12.44±1.4	0.058	14.31±1.21	11.81±1.72	0.000**
PLT (10^3/µl)	118.8±28.79	125.05±44.46	0.136	158.75±71.9	159.1±67.32	0.779

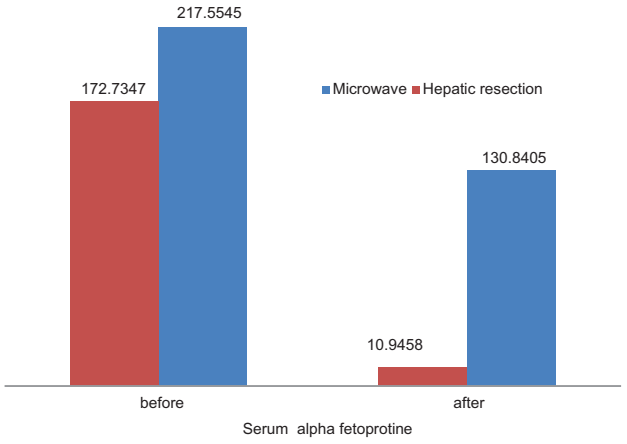
***P*<0.05, statistically significant difference. WBC: White blood cells, HB: Hemoglobin, PLT: Platelets

Table 5 Comparison between liver function values in the studied patient underwent both microwave and hepatic resection

	Microwave			Hepatic resection		
	Before	After	*P*	Before	After	*P*
Total BIL (mg/dl)	1.29±0.56	1.13±0.48	0.110	1.1±0.7	2.05±3.25	0.131
Direct BIL (mg/dl)	0.57±0.41	0.52±0.37	0.437	0.5±0.32	1.41±2.96	0.014*
Total protein (g/l)	67.33±4.41	57.13±26.67	0.896	70.75±11.98	58.48±15.25	0.030*
Albumin (g/dl)	3.33±0.49	3.34±0.63	0.837	3.68±0.41	2.83±0.75	0.033*
SGPT (IU/l)	45.59±23.16	63.74±34.87	0.073	57.58±33.44	169.81±303.69	0.191
SGOT (IU/l)	50.7±29.86	70.9±37.07	0.042*	68.67±58.42	116.01±162.99	0.422
GGT (IU/l)	85.5±91.22	121±124.45	0.180	225.33±138.01	133.36±86.05	0.182
ALP (IU/l)	138.8±53.2	265.6±129.43	0.017*	103.08±40.41	112.82±62.29	0.754

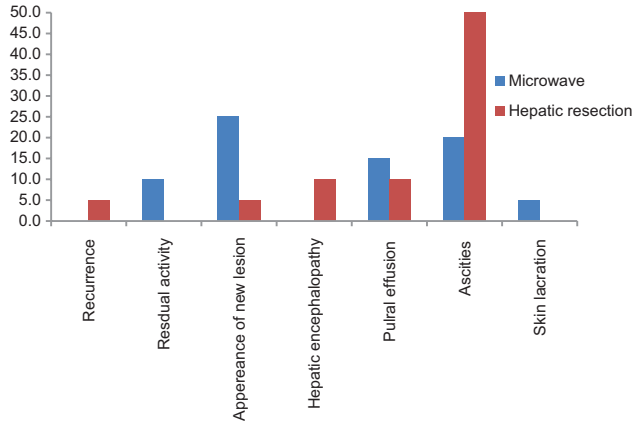
**P*<0.05, statistically significant difference. BIL: Bilirubin, SGPT: Serum glutamic pyruvic transaminase, SGOT: Serum Glutamic-Oxaloacetic Transaminase, ALP: Alkaline phosphatase.

Figure 3



Changes in the level of α-fetoprotein before and after intervention.

Figure 4



Complications postmicrowave ablation and hepatic resection.

Hepatic resection remains the best curative treatment but, the pre-existing liver damage and possible tumor multifocality in addition to portal hypertension and reduced functional capacity of the cirrhotic liver significantly increase the perioperative risk and increase postoperative decompensation, with the risk of development of another HCC in the cirrhotic liver again. The MWA offers several advantages, including faster heating over a larger volume, less susceptibility to 'heat sinks' or local perfusion compared with RF, and permits the simultaneous treatment of multiple lesions with multiple electrodes that can produce larger ablation volumes [11].

Our study showed that the patients who underwent MWA had a mean Child score of before ablation 6.1 ± 0.7 and after ablation 6.1 ± 1.0, but was before hepatic resection 5.5 ± 0.6 and 7.2 ± 1.4 after resection. This is concordant with Kauffmann and his colleagues who also showed that postoperative liver cell failure remains the most dreadful complication, [12] and it is the major source of morbidity and mortality after hepatic resection and the precise evaluation of liver condition is one of the key point to select patients undergoing liver resection in the intent to reduce postoperative morbidity and mortality [13].

We noticed that 90% of the patients with HCC were males and only 10% were females and this is concordant with Yu *et al.* [14] who mentioned that HCC is more prevalent in men than in women, which may be at least in part explained by the differences in exposure to risk factors. However, sex hormones and other X-linked genetic factors may also be important. It has been speculated that estrogens and androgens could modulate hepatocarcinogenesis and explain the higher incidence of HCC in men [15]. The prevalence of HCV in Egypt is much more increased [16]. This study showed that most of HCC cases attributed to HCV, as 95% of HCC had HCV antibody and only 5% had hepatitis B surface antigen positive. Schütte and his group also showed that the rise in the incidence of HCC was directly related to the increase in the prevalence of HCV infection [17].

This study detected that there is decrease in the level of albumin in comparison with its preresection level and increase in the total leukocytic count in spite of this, there is no difference in serum albumin level or leukocytic count after MWA (as the serum albumin was 3.34 ± 0.63 g/dl after MWA and 2.83 ± 0.75 g/dl after hepatic resection, and the mean white blood count level was 5.16 ± 1.51 10^9/l after MWA and 12.71 ± 9.03 10^9/l after hepatic resection). Haridas *et al.* [18], Neumayer *et al.* [19], and Gibbs *et al.* [20] showed that hypoalbuminemia is a well-known marker of liver cell failure, has been associated with higher incidences of sepsis and postoperative infection after hepatic resection.

In our study the mean prothrombin concentration was 74.79 ± 16.15% after MWA and was 63.7 ± 16.47% after hepatic resection and this was concordant with De Pietri *et al.* [21] and Bezeaud *et al.* [22] who noted that a postoperative derangement in conventional markers of coagulation such as INR, prothrombin time, prothrombin concentration and platelet count are common after liver resection, but our results are discordant regarding platelets level as there is no difference between the level before and after hepatic resection and also no difference between MWA or hepatic resection as *P* value is 0.157. This difference from other study may be owing to the extent of hepatic resection which may be affecting the thrombopoietin synthesis.

This study showed that there is high statistical significant difference between the level of AFP before

and after hepatic resection (as the mean level before resection was 172.73 ng/dl and after liver resection is 10.95 ng/dl). Moreover, there is statistically significant difference in the AFP level between patients who underwent hepatic resection and those underwent MWA as *P* value is 0.035, although that there is no statistical difference in the levels before both interventions as *P* value is 0.602. Toro *et al.* [23] also mentioned that the AFP level is useful in the diagnosis of recurrence and predicting prognosis in patients with HCC who have undergone hepatic resection or other loco regional therapy as it markedly decreased after complete eradication of HCC.

In our study we noticed that the mean time needed for complete ablation to HCC less than 5 cm was 80.5 s and the mean power was 58 W. Poggi *et al.* [24] mentioned that MWA is a very fast procedure, but the time of energy application differed according to the diameter of the nodules. A mean time of ablation of only 63 s was sufficient to obtain an adequate ablation.

In our study, there was 10% recurrence rate after hepatic resection after 1 month. We suggested that early recurrence may be owing to micro metastases in the remaining liver parenchyma rather than inadequate surgical resection. Regimbeau *et al.* [25], Belghiti *et al.* [26], Fong *et al.* [27], Farges *et al.* [28], Poon *et al.* [29], Imamura *et al.* [30] confirmed that the rate of recurrence following resection of HCC is ~80% at 5 years.

We noticed that residual activity occurred only in patients who underwent MWA (in 10% of cases), Liang *et al.* [31] mentioned that incomplete ablation after microwave occurred in 5.9% of cases.

Appearance of new lesion occurred in 25% of cases that underwent MWA in this study. Liang *et al.* [31] showed that new lesion occurred in the same segment but apart from the original sites in 9%. New lesion was found in different segments of the liver in 12%. Appearance of new lesion occur in 5% of cases who underwent hepatic resection. This difference between MWA and hepatic resection may be attributed to the superiority of hepatic resection in radical removal of the tumor which decreases the incidence of micro metastases.

Results from our study recorded fewer complications than that recorded by other studies, as we found that ascites occurred in 20%, plural effusion in 15%, and skin lacerations in 5% of patients underwent MWA. Liang *et al.* [32] noted that complications associated with MWA were generally related to the antenna application and include abscesses, bleeding, bile duct injury, burns, thoracic complications and bowel injury.

We noticed that patients who underwent hepatic resection had minor complications than that recoded by other studies. We categorized complications after hepatic resection as recurrence in 5% (but no residual activity had been detected at all), appearance of new lesion only in 5% of patients, hepatic encephalopathy in 10% of patients, pleural effusion in 10% patients, and ascites in 50% of patients. Jin *et al.* [33] mentioned that complications after of hepatic resection include venous catheter-related infection, pleural effusion, incisional infection, pulmonary atelectasis or infection, ascites, sub phrenic infection, urinary tract infection, intraperitoneal hemorrhage, bile leakage, gastrointestinal tract bleeding, biliary tract hemorrhage, coagulation disorders, and hepatic failure. Huang *et al.* [34] and Sato *et al.* [35] mentioned that the bleeding is the most feared technical complication and may be grounds for urgent reoperation, Liver failure poses a significant hazard to patients with underlying liver cirrhosis and complications after MWA are less common than those after hepatectomy. The amount of intraoperative blood loss was smaller and the length of hospital stay was shorter. This may demonstrate low invasiveness of MWA. We concluded that hepatic resection is superior to MWA in HCC eradication. Child score is more affected in patients who underwent hepatic resection than those underwent MWA. However, postprocedure complications more common in resection.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

References

1 Zekri AR, Bahnassy AA, Shaarawy SM, Mansour OA, Maduar MA, Khaled HM, *et al.* Hepatitis C virus genotyping in relation to neu-oncoprotein overexpression and the development of hepatocellular carcinoma. J Med Microbiol 2002; 49:89–95.

2 Llovet JM, Fuster J, Bruix J. The Barcelona approach: diagnosis, staging, and treatment of hepatocellular carcinoma. Liver Transpl 2004; 10(2 Suppl 1):S115–20.

3 Goldman R, Ressom HW, Abdel-Hamid M, Goldman L, Wang A, Varghese RS, *et al.* Candidate markers for the detection of hepatocellular carcinoma in low-molecular weight fraction of serum. Carcinogenesis 2007; 28:2149–53.

4 Bruix J, Sherman M; Practice Guidelines Committee, American Association for the Study of Liver Diseases. Management of hepatocellular carcinoma. Hepatology 2005; 42:1208–1236.

5 Vivarelli M, Risaliti A. Liver transplantation for hepatocellular carcinoma on cirrhosis: strategies to avoid tumor recurrence. World J Gastroenterol 2011; 17:4741–6.

6 Brace CL. Microwave tissue ablation: biophysics, technology, and applications. Crit Rev Biomed Eng 2010; 38:65–78.

7 Oshima F, Yamakado K, Nakatsuka A, Takaki H, Makita M, Takeda K. Simultaneous microwave ablation using multiple antennas in explanted bovine livers: relationship between ablative zone and antenna. Radiat Med 2008; 26:408–414.

8 Lubner MG, Brace CL, Hinshaw JL, Lee FT Jr. Microwave tumor ablation: mechanism of action, clinical results, and devices. J Vasc Interv Radiol 2010; 21(Suppl 8):S192–S203.

9 Knavel EM, Hinshaw JL, Lubner MG, Andreano A, Warner TF, Lee FT Jr, *et al*. High-powered gas-cooled microwave ablation: shaft cooling creates an effective stick function without altering the ablation zone. Am J Roentgenol 2012; 198:W260–W265.

10 Li X, Zhang L, Fan W, Zhao M, Wang L, Tang T, *et al*. Comparison of microwave ablation and multipolar radiofrequency ablation, both using a pair of internally cooled interstitial applicators: results in *ex vivo* porcine livers. Int J Hyperthermia 2011; 27:240–248.

11 Dong BW, Liang P, Yu XL, Zeng XQ, Wang PJ, Su L, *et al*. Sonographically guided microwave coagulation treatment of liver cancer: an experimental and clinical study. Am J Roentgenol 1998; 171:449–454.

12 Kauffmann R, Fong Y. Post-hepatectomy liver failure. Hepatobiliary Surg Nutr 2014; 3:238–46.

13 Llovet JM, Sala M, Castells L, Suarez Y, Vilana R, Bianchi L, *et al*. Randomized controlled trial of interferon treatment for advanced hepatocellular carcinoma. Hepatology 2000; 31:54–58.

14 Yu MW, Chang HC, Chang SC, Liaw YF, Lin SM, Liu CJ, *et al*. Role of reproductive factors in hepatocellular carcinoma: impact on hepatitis B and C-related risk. Hepatology 2003; 38:1393–1400.

15 Yu MC, Tong MJ, Govindarajan S, Henderson BE. Nonviral risk factors for hepatocellular carcinoma in a low-risk population, the non-Asians of Los Angeles County, California. J Natl Cancer Inst 1991; 83:1820–1826.

16 Shiina S, Tateishi R, Imamura M, Teratani T, Koike Y, Sato S, *et al*. Percutaneous ethanol injection for hepatocellular carcinoma: 20-year outcome and prognostic factors. Liver Int 2012 ;32:1434–42.

17 Bosch FX, Ribes J, Borràs J. Epidemiology of primary liver cancer. Semin Liver Dis 1999; 19:271–285.

18 Haridas M, Malangoni MA. Predictive factors for surgical site infection in general surgery. Surgery 2008; 144:496–501.

19 Neumayer L, Hosokawa P, Itani K, El-Tamer M, Henderson WG, Khuri SF. Multivariable predictors of postoperative surgical site infection after general and vascular surgery: results from the patient safety in surgery study. J Am Coll Surg 2007; 204:1178–1187.

20 Gibbs J, Cull W, Henderson W, Daley J, Hur K, Khuri SF. Preoperative serum albumin level as a predictor of operative mortality and morbidity: results from the National VA Surgical Risk Study. Arch Surg 1999; 134:36–42.

21 De Pietri L, Montalti R, Begliomini B, Scaglioni G, Marconi G, Reggiani A, *et al*. Thromboelastographic changes in liver and pancreatic cancer surgery: hypercoagulability, hypocoagulability or normocoagulability? Eur J Anaesthesiol 2010; 27:608–616.

22 Bezeaud A, Denninger MH, Dondero F, Saada V, Venisse L, Huisse MG, *et al*. Hypercoagulability after partial liver resection. Thromb Haemost 2007; 98:1252–1256.

23 Toro A, Ardiri A, Mannino M, Arcerito MC, Mannino G, Palermo F, *et al*. Effect of pre- and post-treatment α-fetoprotein levels and tumor size on survival of patients with hepatocellular carcinoma treated by resection, transarterial chemoembolization or radiofrequency ablation: a retrospective study. BMC Surg 2014; 14:40.

24 Poggi G, Montagna B, Dl Cesare P, Riva G, Bernardo G, Mazzucco M, *et al*. Microwave ablation of hepatocellular carcinoma using a new percutaneous device: preliminary results. Anticancer Res 2013; 33:1221–1228.

25 Regimbeau JM, Abdalla EK, Vauthey JN, Lauwers GY, Durand F, Nagorney DM, *et al*. Risk factors for early death due to recurrence after liver resection for hepatocellular carcinoma: results of a multicenter study. J Surg Oncol 2004; 85:36–41.

26 Belghiti J, Panis Y, Farges O, Benhamou JP, Fekete F. Intrahepatic recurrence after resection of hepatocellular carcinoma complicating cirrhosis. Ann Surg 1991; 214:114–117.

27 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.

28 Farges O, Regimbeau JM, Belghiti J. Aggressive management of recurrence following surgical resection of hepatocellular carcinoma. Hepatogastroenterology 1998; 45(Suppl 3):1275–1280.

29 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.

30 Imamura H, Matsuyama Y, Tanaka E, Ohkubo T, Hasegawa K, Miyagawa S, *et al*. Risk factors contributing to early and late phase intrahepatic recurrence of hepatocellular carcinoma after hepatectomy. J Hepatol 2003; 38:200–207.

31 Liang P, Dong B, Yu X, Yu D, Wang Y, Feng L, *et al*. Prognostic factors for survival in patients with hepatocellular carcinoma after percutaneous microwave ablation. Radiology 2005; 235:299–307.

32 Liang P, Wang Y. Microwave ablation of hepatocellular carcinoma. Oncology 2015; V.7(25).

33 Jin S, Fu Q, Wuyun G, Wuyun T. Management of post-hepatectomy complications. World J Gastroenterol 2013; 19:7983–7991.

34 Huang ZQ, Xu LN, Yang T, Zhang WZ, Huang XQ, Cai SW, *et al*. Hepatic resection: an analysis of the impact of operative and perioperative factors on morbidity and mortality rates in 2008 consecutive hepatectomy cases. Chin Med J (Engl) 2009; 122:2268–2277.

35 Sato M, Tateishi R, Yasunaga H, Horiguchi H, Yoshida H, Matsuda S, *et al*. Mortality and morbidity of hepatectomy, radiofrequency ablation, and embolization for hepatocellular carcinoma: a national survey of 54,145 patients. J Gastroenterol 2012; 47:1125–1133.