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# Hepatic resection versus microwave ablation for the treatment of early hepatocellular carcinoma: a comparative analysis of treatment outcomes and survival predictors

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**Abstract**

**Introduction:** Liver resection and local ablation are the two primary curative treatments for early-stage hepatocellular carcinoma (HCC). Microwave ablation (MWA) shows promising performance in terms of early tumor response, recurrence, and survival. This study aims to determine whether MWA would be comparable to liver resection in treating early-stage HCC.

**Methods:** This study included patients with hepatitis C-related HCC attending the multidisciplinary HCC clinic, Kasr Al-Ainy Hospital (March 2018 to September 2020). We included adults with early-stage HCC (BCLC stages 0-A). We studied patients and tumor characteristics, HCC treatment response, recurrence, and overall survival.

**Results:** Thirty-one patients were treated with liver resection and 41 patients were treated with MWA, including 4 patients who received intraoperative MWA. By the end of the study, 21 patients (28.77%) died. Patients who underwent MWA were younger compared to the hepatectomy group with lower baseline AFP (21 (6.7–54) versus 77 (31.3–136.0), respectively, (*P* value 0.024) and tumor size (2.78 (0.87) cm versus 3.77 (0.97) cm, respectively, (*P* value < 0.001). We found no differences between the studied groups in terms of treatment response, post-treatment decompensation, recurrence, or overall survival. One-year survival probability in the MWA and resection groups was 75.5% and 76.3% respectively. Post-procedure hepatic decompensation was the only independent predictor of lower survival by multivariate logistic regression analysis (OR 37.74, 95%CI 6.251–227.87, *P* value < 0.001) after adjusting for age, AFP, and tumor size.

**Conclusion:** Liver resection and MWA showed similar satisfactory results in the treatment of early-stage HCC, in terms of treatment response, recurrence, and overall survival.

**Keywords:** Hepatocellular carcinoma, Liver resection, Microwave ablation, Survival, Recurrence

## Introduction

Hepatocellular carcinoma (HCC) is the sixth and fourth most common cancer worldwide and in Egypt, respectively [1]. Africa shows a high incidence of the disease which is attributed to chronic HBV and HCV being endemic there [2]. Similarly, Egypt shows a high incidence of the disease, however, owing to the availability

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of multiple tertiary treatment centers and adopting a strict surveillance program, many patients are diagnosed early compared to other African countries allowing for employment of curative treatment modalities including surgical resection, transplantation or locoregional ablation [3].

Multiple treatment modalities exist for HCC whether curative or palliative. Hepatic resection is considered the first-line treatment for patients with solitary tumors confined to the liver without radiographic evidence of invasion of the vasculature and preserved liver functions. However, just a small proportion of patients have the opportunity to be candidates because of disease progression, anatomical location, and patient refusal to undergo surgery [4].

Locoregional ablation offers an alternative option for those patients not fit for surgery. One of the ablative methods used is microwave ablation (MWA) which offers several advantages over other ablative techniques, including faster heating over a larger volume, less susceptibility to 'heat sinks' or local perfusion compared with radiofrequency ablation (RFA), and the ability to perform simultaneous treatment of multiple lesions with multiple electrodes that can produce larger ablation volumes [5].

The current study aims to compare treatment response and outcome regarding clinical decompensation, recurrence, and overall survival between patients with early-stage HCC treated with surgical resection and those treated with microwave ablation.

## Patients and methods

### Study design and ethics statement

This is a prospective randomized study to compare microwave ablation (MWA) to liver resection in treating early-stage HCC. The protocol conformed to the ethical guidelines of the 1975 Declaration of Helsinki and its later amendments. An opt-out approach was used to obtain informed consent from the patients, and personal information was protected during data collection.

### Patients

Seventy-two Egyptian patients attending the Hepatocellular Carcinoma Multidisciplinary clinic in Kasr Alainy Hospital, Cairo University, were enrolled in this study during the period from March 2018 to September 2020. Patients were divided into two groups where Group 1 included 31 patients who were treated through liver resection while group 2 included 41 patients who got their tumor ablated by microwave therapy. Choice of treatment modality was made through the HCC multidisciplinary team of Kasr Alainy Hospital according to the location of the lesions, fitness for surgery as well as the liver status and portal pressure.

Exclusion criteria were as follows:

i) Decompensated liver disease (Child–Pugh score > 7)
ii) Advanced tumor stage (vascular invasion and/or extrahepatic spread)
iii) Patients who refused to sign the consent
iv) Pregnancy
v) ECOG performance status > 2

### Data collection

Hepatocellular carcinoma was diagnosed based on imaging modalities, such as dynamic computed tomography (CT) and/or dynamic magnetic resonance imaging (MRI).

The following items of categorical data were collected at the time of HCC diagnosis:

i) Demographics, namely age, sex, body mass index, and chronic medical illnesses
ii) Assessment of liver functions through serum levels of aspartate aminotransferase (AST), alanine aminotransferase (ALT), albumin, total bilirubin, and prothrombin activity
iii) Other laboratory investigations include complete blood picture, urea & creatinine, and viral markers (HCV Ab, HBsAg, HBcAb)
iv) Tumor factors, namely size and number of HCCs, clinical staging according to BCLC staging system, and alpha-fetoprotein levels.

The performance status was assessed using the Eastern Cooperative Oncology Group (ECOG) performance status scale [a scale of 0 (fully active, able to carry on all pre-disease performance without restriction) to 5 (dead)] [6].

### Treatment applied

#### *Group 1: liver resection*

Preoperative assessment: with the aforementioned clinical and laboratory investigations.

Anesthetic assessment: of the fitness for surgery.

A written informed consent was obtained from all patients prior to surgery.

Surgical set up:

- All the hepatic resection procedures were undertaken by experienced hepatobiliary surgeons through an inverted L-shaped incision in the right upper quadrant of the abdomen.
- Hepatic mobilization was performed first.
- Liver resection was then carried out on the basis of the segmental anatomy of the liver after delineation of the proper hepatic transection plane using

intraoperative ultrasound. Planning the parenchymal transection first was important, not only to help achieve an adequate tumor-free margin, but also to avoid injury of major intrahepatic vessels or bile duct pedicles.

- Tissue dissection was carried out using the monopolar diathermy, the ultracision Harmonic scalpel and/or the Ligasure electrothermal bipolar vessel sealing device (Covidien–Valleylab, Boulder, CO, USA).
- Intraoperative incidents were recorded, e.g., intraoperative bleeding, any other surgical or anesthetic complications.

#### *Group 2: microwave ablation*

- The procedures were performed under ultrasound guidance using a Hitashi EUB-5500 machine with a 3.5–5-MHz probe. We used an HS AMICA microwave machine (HS Hospital service S.P.A. Roma, Italy), so-called AMICA GEM machine. It operated at a frequency of 2450 MHz, and 14-gauge (150 mm and 200 mm) cooled shift electrodes (AMICA-probes) were used to deliver the microwave energy into the liver tissue [7].
- A single microwave antenna, connected to a generator, was inserted directly into the tumor or tissue to be ablated.
- High-frequency microwaves emitted by the antenna agitate water molecules, create friction, and therefore generate heat, thus resulting in coagulative tissue necrosis.
- The size and the shape of the hyperechoic zone caused by gas microbubbles appearing in the ablated zone during the 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 were reached.

### Follow-up

All patients were followed up till the end of the study, with a minimum follow-up period of 6 months. They were assessed early after the procedure (hepatic resection or microwave ablation) for complications and liver decompensation where follow up of liver functions was carried on days 0, 3, and 7 post-procedure, as well as one month after the procedure by assessment of serum ALT, total bilirubin, and INR. Assessment of serum AFP was done 3 months post-procedure in all patients during their regular follow-up visits. Triphasic CT was performed 4 weeks post-treatment and every 6 months during the follow-up period to exclude recurrence. The treatment response was assessed in all patients based on the modified Response Evaluation Criteria in Solid Tumors (mRECIST) criteria [8].

### Overall survival

The overall survival was calculated from the date of the patients' first visits to the multidisciplinary HCC clinic till the patients' death or the end of the study. Survival curves were plotted by the Kaplan–Meier method and compared using the log-rank test. Independent prognostic factors were estimated by the Cox proportional hazards in univariate and multivariate regression models [9].

### Statistical analysis

Data were coded and entered using the statistical package for Social Sciences (SPSS) version 26 (IBM Corp., Armonk, NY, USA). Data were summarized using mean, standard deviation, median, minimum, and maximum in quantitative data; and using frequency (count) and relative frequency (percentage) for categorical data. Comparisons between quantitative variables were done using the non-parametric Mann–Whitney *U* test [10]. For comparing categorical data, Chi-square $\left(\chi 2\right)$ test was performed. Fisher's exact test was used instead when the expected frequency was less than 5 [11]. *P* values less than 0.05 were considered statistically significant.

## Results

Patients' characteristics were summarized in Table 1. There was no significant difference regarding demographics among both groups. However, age was significantly lower in patients who underwent liver resection (mean = 57.81 ± 9.42 years), *P* value = 0.029; whereas, the number of patients with a history of the previous ablation was significantly higher in the group of patients who underwent microwave ablation ($n = 27$, 65.9%); *P* value < 0.001. Laboratory features as well were not significantly different among both groups except for baseline AFP which was significantly higher in patients who underwent microwave ablation while on the other hand, post-treatment AFP level was significantly higher in those who had a liver resection.

The majority of the study population was categorized as Child–Pugh class A ($N = 65$) with only 7 patients with Child–Pugh class B7 and there was no significant difference among both groups in their Child scores. Similarly, all patients were staged as very early (0) or early (A) according to the BCLC staging system with no difference between both groups. In the liver resection group, tumor burden was heavier where the mean focal lesions size was significantly higher compared to the microwave group (*P*

**Table 1** Demographic, laboratory, and imaging data of studied population

| | | Total (*N*=72) | Hepatectomy group (*N*=31) | Microwave group (*N*=41) | *P* value |
|---|---|---|---|---|---|
| **Demographic data (Count/%)** | | | | | |
| **Age** | | 60.24 (8.07) | 57.81 | 62.07 | **0.029** |
| **Gender** (male/female) | | 49 (68.1%)/23 (31.9%) | 23 (74.2%)/8 (25.8%) | 26 (63.4%)/15 (36.6%) | 0.331 |
| **BMI (mean/SD)** | | 29.08 (3.86) | 29.23 (3.98) | 28.97 (3.81) | 0.741 |
| **Smoking** | | 19 (26.4%) | 9 (29%) | 10 (24.4%) | 0.658 |
| **Diabetes mellitus** | | 23 (31.9%) | 10 (32.2%) | 13 (31.7%) | 0.960 |
| **Previous DAAs therapy** | | 17 (23.6%) | 8 (25.8%) | 9 (22%) | 0.703 |
| **Laboratory data (mean/SD)** | | | | | |
| **Hemoglobin** | | 14.32 (11.45) | 16.02 (17.34) | 13.03 (1.78) | 0.759 |
| **Leucocytic count** | | 6.48 (2.04) | 6.24 (1.65) | 6.67 (2.29) | 0.698 |
| **Platelets** | | 163.89 (45.94) | 175.68 (38.73) | 154.98 (49.31) | 0.070 |
| **Total bilirubin** | | 1.02 (0.49) | 0.90 (0.39) | 1.11 (0.53) | 0.151 |
| **ALT** | | 63.74 (52.5) | 55.68 (45.08) | 69.83 (57.27) | 0.209 |
| **AST** | | 59.17 (45.65) | 49.81 (28.42) | 66.24 (54.53) | 0.381 |
| **Albumin** | | 3.54 (0.52) | 3.49 (0.5) | 3.58 (0.54) | 0.698 |
| **Creatinine** | | 0.90 (0.26) | 0.89 (0.31) | 0.91 (0.22) | 0.939 |
| **INR** | | 1.40 (1.18) | 1.50 (1.77) | 1.33 (0.33) | 0.101 |
| **AFP (baseline) (median/IQR)** | | 43.0 (12.30–125.00) | 77 (31.3–136.0) | 21 (6.7–54) | **0.024** |
| **AFP (post-treatment) (median/IQR)** | | 13.7 (6.9–43.5) | 18.8 (12.6–76.40) | 11.9 (6.4–18.3) | **0.003** |
| **Scores (count/%)** | | | | | |
| **Child Pugh score** | **A** | 65 (90.3%) | 0 (0%) | 4 (9.8%) | 0.129 |
| | **B** | 7 (9.7%) | 31 (100%) | 37 (90.2%) | |
| **BCLC** | **0** | 4 (5.6%) | 28 (90.3%) | 37 (90.2%) | 0.99 |
| | **A** | 68 (94.4%) | 3 (9.7%) | 4 (9.8%) | |
| **Imaging data (count/%)** | | | | | |
| **Site of HFLs** | **Right lobe** | 58 (80.6%) | 21 (67.7%) | 37 (90.2%) | 0.069 |
| | **Left lobe** | 10 (13.9%) | 7 (22.6%) | 3 (7.3%) | |
| | **Both lobes** | 4 (5.6%) | 3 (9.7%) | 1 (2.5%) | |
| **Focal lesion size or size of largest lesion if 2 or multiple (mean/SD)** | | 3.20 (1.03) | 3.77 (0.97) | 2.78 (0.87) | **< 0.001** |
| **Number of focal lesions** | **Single** | 62 (86.1%) | 1.29 (0.59) | 1.07 (0.26) | 0.058 |
| | **Two** | 8 (11.1%) | | | |
| | **Multiple (three or more)** | 2 (2.8%) | | | |

value < 0.001). A non-significant difference existed also when comparing focal lesions number (*P* value = 0.058).

Almost all patients responded to treatment according to the modified RECIST criteria whether complete response occurred in 62 (86.11%) patients and partial response occurred in 8 (11.11%) patients. On the other hand, only 2 (2.78%) patients had a stationery disease while none suffered from disease progression. Response to treatment did not correlate with the treatment modality used. There was no statistically significant difference between the treatment modalities employed in terms of mortality or post-procedure liver decompensation (Table 2).

Regarding recurrence rate, three patients in each group experienced re-appearance of HCC lesions during their follow-up imaging away from the primary tumor site. Of those six patients, one patient (from the "hepatectomy" group) had multifocal local recurrence and died 4 months post-procedure due to hepatic decompensation. The other five patients had a metastatic recurrence and were referred to receive systemic chemotherapy. Patients who developed recurrence had a significantly higher post-treatment alpha-fetoprotein (mean, 134.63 ng/ml), compared to those who did not develop HCC recurrence (mean, 28.85 ng/ml), *P* value = 0.011. On the other hand, other variables were not shown to affect the rate of recurrence (Table 3).

After a mean follow-up of 14.89 months (SD 7.57), 21 patients died (29.2%) and 51 were still alive (70.8%). The overall survival (OS) at 1-year was 91.5%, and the

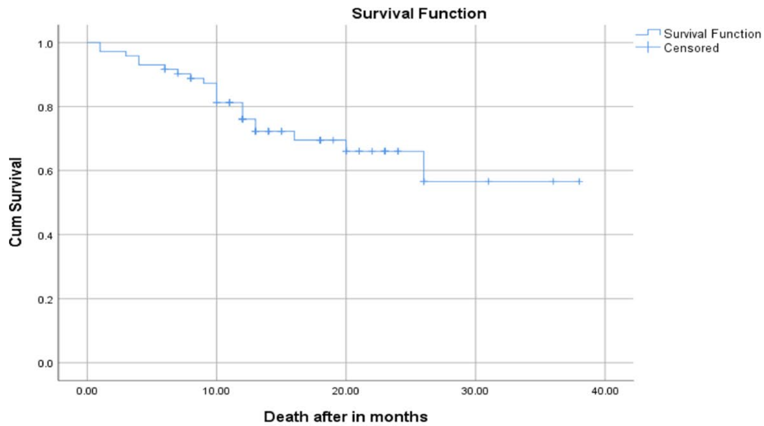
**Table 2** Follow-up and the fate of managed patients

| | | Hepatectomy (*N* = 31) | Percutaneous microwave (*N* = 37) | Intraoperative microwave (*N* = 4) | *P* value |
|---|---|---|---|---|---|
| **Response to treatment (according to mRECIST) (count/%)** | | | | | |
| • **Complete response** | | 29 (93.6%) | 30 (81.1%) | 3 (75%) | 0.331 |
| • **Partial response** | | 2 (6.4%) | 5 (13.5%) | 1 (25%) | |
| • **Stationary disease** | | 0 (0%) | 2 (5.4%) | 0 (0%) | |
| • **Progressive disease** | | 0 (0%) | 0 (0%) | 0 (0%) | |
| **Recurrence and progression (count/%)** | | | | | |
| • **Recurrence** | | **3 (9.7%)** | **3 (8.1%)** | **0 (0%)** | 0.733 |
| • **Portal vein thrombosis** | **Yes** | 0 (0%) | 1 (2.4%) | | 1 |
| | **No** | 31 (100%) | 40 (97.6%) | | |
| • **Lymph node deposits** | **Yes** | 2 (6.5%) | 0 (0%) | | 0.182 |
| | **No** | 29 (93.5%) | 41 (100%) | | |
| **Clinical decompensation (mean/SD)** | | 5 (16.1%) | 5 (13.5%) | 1 (25%) | 0.656 |
| **New ascites** | **Yes** | 1 (3.2%) | 0 (0%) | | 0.431 |
| | **No** | 30 (96.8%) | 41 (100%) | | |
| **Mortality** | | 7 (22.6%) | 13 (35.1%) | 1 (25%) | 0.545 |

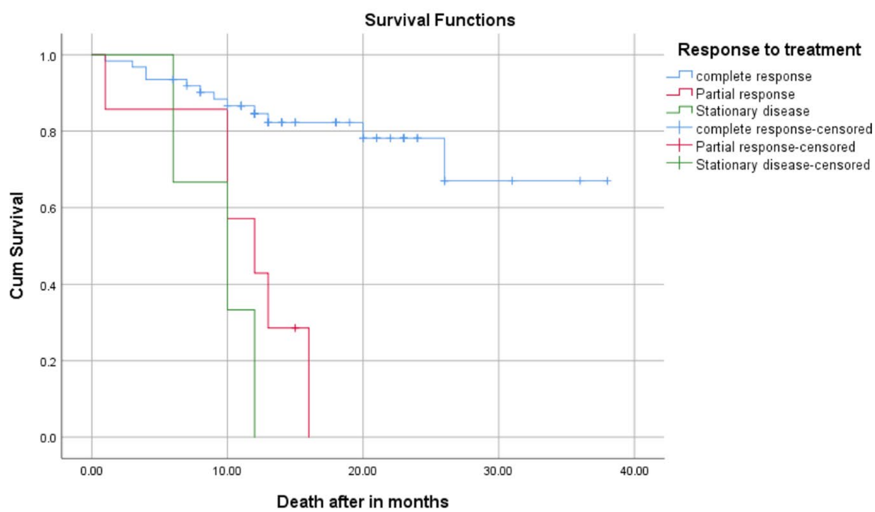
**Table 3** Predictors of HCC recurrence

| | | HCC recurrence (count/%) | | *P* value |
|---|---|---|---|---|
| | | Recurrence | No recurrence | |
| **Gender** | **Female** | 3 (50%) | 20 (30.3%) | 0.376 |
| | **Male** | 3 (50%) | 46 (69.7%) | |
| **Smoking** | **Yes** | 0 (0%) | 19 (28.8%) | 0.331 |
| | **No** | 6 (100%) | 47 (71.2%) | |
| **Diabetes mellitus** | **Yes** | 2 (33.3%) | 21 (31.8%) | 1 |
| | **No** | 4 (66.7%) | 45 (68.2%) | |
| **Child score (mean/SD)** | | 5.67 (0.82) | 5.53 (0.64) | 0.743 |
| **Hemoglobin (mean/SD)** | | 12.27 (1.51) | 13.02 (1.76) | 0.232 |
| **Platelets (mean/SD)** | | 146.67 (63.89) | 165.45 (44.29) | 0.684 |
| **AFP (baseline) (median/IQR)** | | 59.75 (41–132) | 43 (12–124) | 0.293 |
| **AFP (post-ttt) (median/IQR)** | | 100.8 (76.4–213) | 12.75 (6.8–24.8) | 0.011 |
| **Number of HFLs (mean/SD)** | | 1.00 (0.0) | 1.18 (0.46) | 0.557 |
| **Size of HFLs (mean/SD)** | | 3.15 cm (0.74) | 3.48 cm (1.5) | 0.570 |
| **Treatment modality** | **Hepatectomy** | 3 (50%) | 28 (42.4%) | 1 |
| | **Percutaneous microwave ablation** | 3 (50%) | 34 (51.5%) | |
| | **Intraoperative microwave ablation** | 0 (0%) | 4 (6.1%) | |
| **Post-treatment portal vein thrombosis** | **Yes** | 0 (0%) | 1 (1.5%) | 1 |
| | **No** | 6 (100%) | 65 (98.5%) | |
| **Post-treatment clinical decompensation** | **Yes** | 1 (16.7%) | 10 (15.2%) | 1 |
| | **No** | 5 (83.3%) | 56 (84.8%) | |

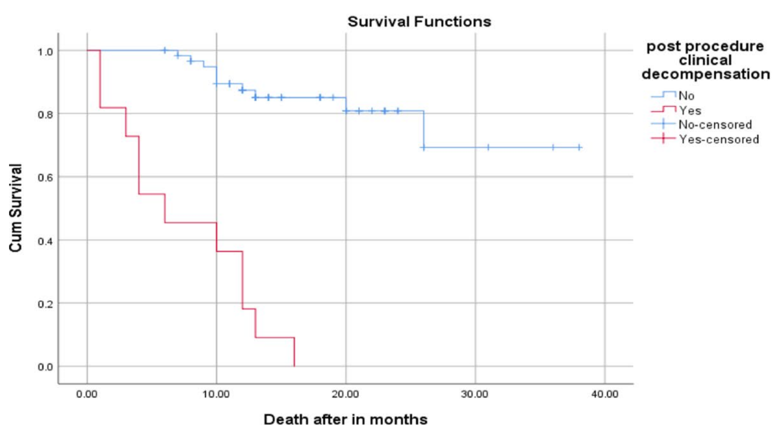
overall mean survival time was 27.427 months (Fig. 1). One-year survival probability was 75.5% and 76.3% in the MWA and resection groups respectively. Of those 21 patients, 3 died within the first 30 days post-procedure (early mortality), where two patients in the "hepatectomy" group died of major bleeding and diabetic keto-acidosis on post-operative days (PODs) 3 and 19 respectively; whereas, one patient in the "MWA" group died of hepatic decompensation on POD 17. Meanwhile, 18 patients died after the first 30 days




**Kaplan Meier curve for survival analysis**




**a: Overall Survival Concerning response to treatment**




**b: Overall Survival Concerning post-treatment clinical decompensation**

**Fig. 1** Kaplan–Meier curve for survival analysis. **a** Overall survival concerning response to treatment. **b** Overall survival concerning post-treatment clinical decompensation post-procedure (late–mortality) ["hepatectomy" group ($n = 5$); "MWA" group ($n = 13$)]. The cause of death was post-treatment hepatic decompensation in 10 of those 18 patients, but was not known in the remaining eight patients who all died late outside the facility where the study was conducted (Figs. 2 and 3).

Univariate logistic regression analysis showed that both post-procedure clinical decompensation and response to treatment were significantly associated with higher mortality. Stationary disease and partial response (based on mRECIST criteria) independently predicted lower survival, with a HR of 9.655 and 6.082; ($P$ value = 0.001; 95% CI, 2.569–36.286) and ($P$ value = 0.001; 95% CI, 2.196–16.840); respectively (Fig. 1a). The odds ratio for survival in patients with post-procedure clinical decompensation was significantly low (CI, 5.773–36.793), compared to those who did not have clinical decompensation; $P$ value < 0.001) (Fig. 1b). On multivariate logistic regression analysis, post-procedure liver decompensation was the only independent predictor of lower survival, with a hazard ratio (HR) of 37.743 ($P$ value < 0.001; 95% CI, 6.251–227.871) after adjusting for age, AFP, and tumor size (Table 4).

## Discussion

Surgical resection is considered the ideal treatment for patients with early-stage HCC confined to the liver with no vascular invasion or distant metastases. However, only a minority of patients with HCC are suitable for the surgical choice due to various factors including the multiplicity of the lesions, poor residual liver functions, or tumor spread. Microwave ablation offers some advantages over surgery being suitable for patients with multiple lesions and those with a general condition that may interfere with fitness for surgery.

One important consideration regarding outcomes following HCC treatment is the response rate as regards ablation whether complete or partial. HCC response

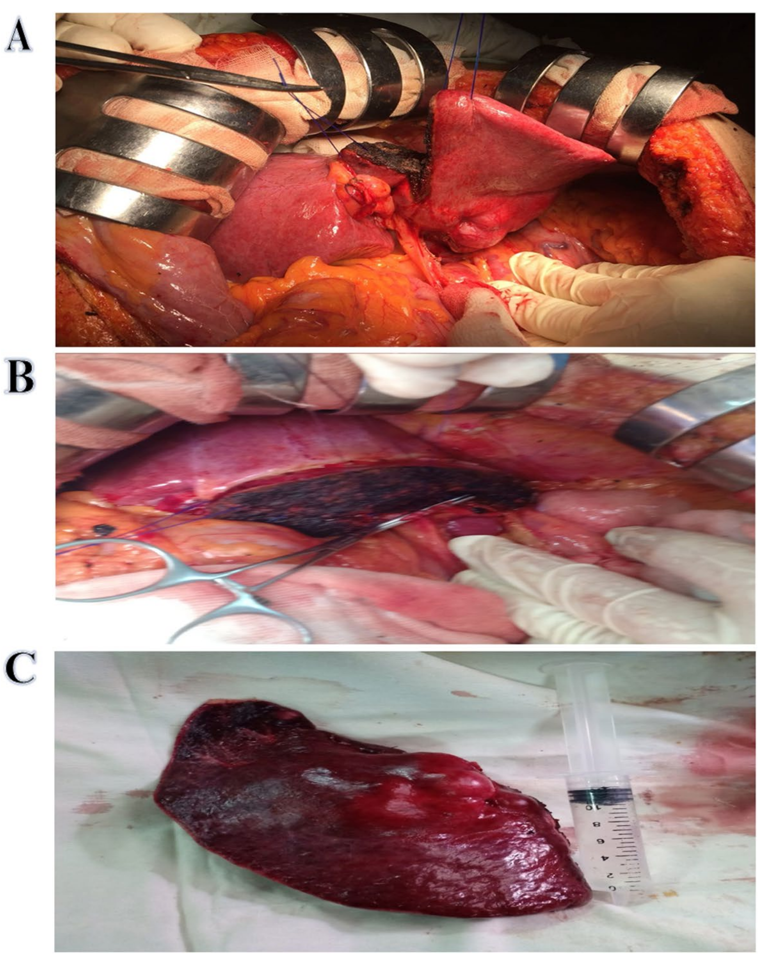


**Fig. 2** **A**, **B** Operative images of left lateral sectionectomy for a segment 2, 3 HCC in one of the study patients. **C** Surgical specimen of the resected left lateral section of the liver

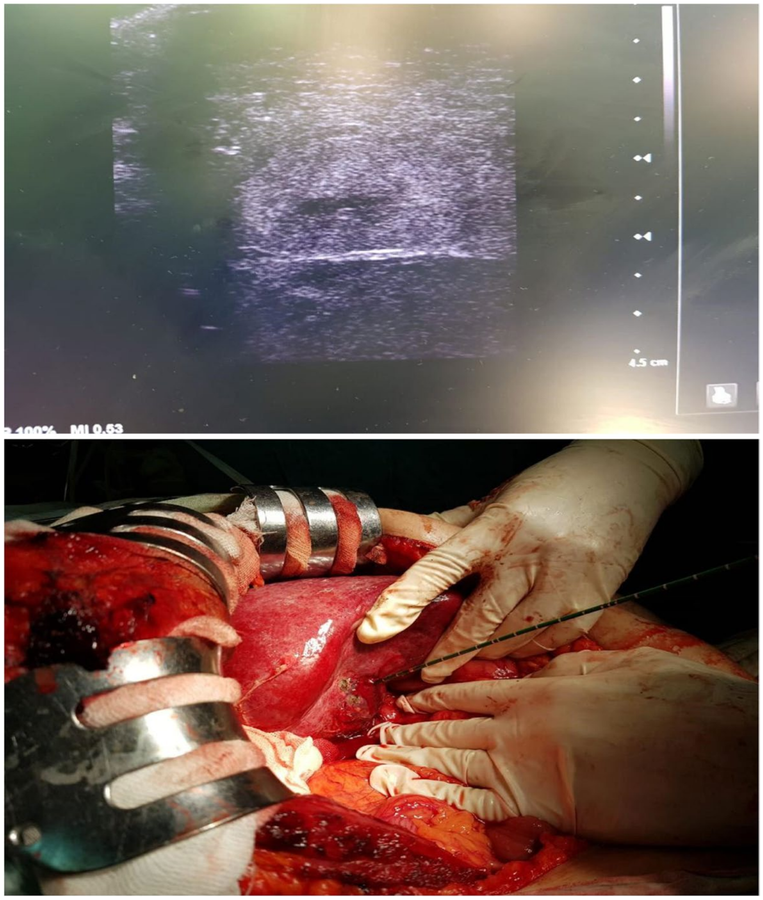


**Fig. 3** Intraoperative MWA for a caudate lobe HCC under ultrasound guidance in one of the study patients

to therapy is typically evaluated using triphasic CT or dynamic MRI and assessment entail measurement of tumor size and the extent of necrosis as well as detection of new lesions, which is crucial in guiding subsequent treatment decisions and predicting patient outcomes [12]. The modified Response Evaluation Criteria in Solid Tumors (mRECIST) are currently adopted to evaluate the treatment response in HCC patients who are treated with loco-regional procedures [13]. Favorable response rates may be predicted in carefully selected patients undergoing surgical resection or locoregional ablation for HCC which was the case encountered in the current study where almost all patients responded to treatment according to mRECIST criteria whether complete or partial response. On the other hand, none of the studied patients had disease progression and only two patients showed a stationary disease. Response to treatment was independent of the treatment modality used which highly confirms that microwave ablation is not inferior to surgical resection in early-stage HCC in terms of cure.

Recurrence is the most frequent serious adverse event observed after treatment of HCC. It is due to micrometastases in the liver or multi-centric carcinogenesis in the underlying cirrhotic liver [14]. The HCC recurrence rate after curative treatment is high, with cumulative 5-year recurrence rates > 60% [15]. Few studies showed that the total and early recurrence rates in patients who underwent MWA were significantly higher than those in patients who underwent liver resection [14, 16, 17]. On the other hand, a recent meta-analysis compared MWA with LR for the treatment of HCC and included nine observational studies from China or Japan. These results showed that there were no significant differences between MWA and LR for recurrence [18]. In the current study, the recurrence rate did not correlate with the treatment adopted whether resection or microwave ablation. The rate of recurrence, however, was significantly higher with increasing AFP levels irrespective of the treatment used while other parameters including liver status or site and size of the focal lesion had no value in predicting HCC recurrence.

**Table 4** Predictors of survival in the studied population

| | | Univariate | | | | Multivariate | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *P* value | HR | 95% CI | | *P* value | HR | 95% CI | |
| | | | | Lower | Upper | | | Lower | Upper |
| **Gender** | **Female** | 0.925 | 1.045 | 0.420 | 2.597 | | | | |
| | **Male** | Reference | | | | | | | |
| **Smoking** | **Yes** | 0.851 | 0.908 | 0.332 | 2.485 | | | | |
| **Diabetes mellitus** | **Yes** | 0.750 | 0.857 | 0.332 | 2.214 | | | | |
| **ECOG status** | **1** | 0.080 | 0.028 | 0.001 | 1.530 | | | | |
| | **0** | Reference | | | | | | | |
| **Post-ttt portal vein thrombosis** | **Yes** | 0.616 | 0.046 | 0.000 | 7887.054 | | | | |
| **Treatment modality** | **Intraoperative MWA** | 0.963 | 1.051 | 0.129 | 8.586 | | | | |
| | **Percutaneous MWA** | 0.386 | 1.503 | 0.598 | 3.778 | | | | |
| | **Hepatectomy** | Reference | | | | | | | |
| **Post-ttt clinical decompensation** | **Yes** | **< 0.001** | 14.574 | 5.773 | 36.793 | **< 0.001** | 37.74 | 6.251 | 227.87 |
| **Age** | | 0.645 | 1.014 | 0.956 | 1.076 | | | | |
| **Hemoglobin** | | 0.544 | 0.927 | 0.726 | 1.184 | | | | |
| **Platelets count** | | 0.480 | 0.997 | 0.987 | 1.006 | | | | |
| **Baseline alpha-fetoprotein** | | 0.183 | 1.000 | 1.000 | 1.000 | | | | |
| **Post-ttt alpha-fetoprotein** | | 0.831 | 0.999 | 0.991 | 1.007 | | | | |
| **Child score** | | 0.381 | 1.344 | 0.694 | 2.605 | | | | |
| **Focal lesions number** | | 0.683 | 1.213 | 0.480 | 3.065 | | | | |
| **Response to treatment** (mRECIST) | **Stationary disease** | **0.001** | 9.655 | 2.569 | 36.286 | 0.537 | 0.543 | 0.078 | 3.776 |
| | **Partial response** | **0.001** | 6.082 | 2.196 | 16.840 | 0.186 | 0.290 | 0.046 | 1.816 |
| | **Complete response** | Reference | | | | | | | |
| **Focal lesion size or size of largest lesion if 2 or multiple** | | 0.517 | 1.109 | 0.812 | 1.515 | | | | |

The ultimate aim of any treatment for hepatocellular carcinoma (HCC) is to improve overall survival (OS) and advances to HCC treatment modalities in recent years had a clear impact on an improved survival rate. Each treatment option for HCC has its OS. However, multiple studies found no significant difference regarding overall survival between groups treated by liver resection or microwave ablation [19–21]. This agrees with the current study where no significant difference in OS was found between the group who was treated using microwave ablation and the other group who had surgical resection exhibiting a 1-year survival probability of 75.5% and 76.3% respectively.

Prognostic factors of HCC were categorized as factors related to the tumor itself, factors related to the liver functions, and general performance status. Univariate logistic regression analysis was performed to figure out predictors of survival in the studied population. Only post-treatment hepatic decompensation and failure to achieve response to treatment were shown to correlate with poor survival outcomes. Stationary disease and partial response to treatment independently predicted lower survival. Similarly, the odds ratio for survival in patients with post-procedure clinical decompensation was significantly low compared to those who did not have clinical decompensation. On the other hand, when multivariate logistic regression analysis was performed, post-procedure clinical decompensation was the only predictor of poor survival rate in treated patients. Similarly, a Chinese study comparing microwave ablation to surgical resection in HCC concluded that poor hepatic functions as stated by Child–Pugh and albumin/bilirubin (ALBI) scores are inversely proportional to overall survival [22]. In addition, a previous study stated that hepatic decompensation, as well as number and size of malignant lesions, are predictors of poor survival in patients with HCC treated by microwave ablation [23]. Other predictors of survival were identified by Jia-Yan et al., such as advanced BCLC stage, portal vein thrombosis, poor performance status, and tumor size [24].

In our study, we have some limitations. This includes the small sample size as well as the absence of the histological assessment for the tumor behavior in the studied population.

In conclusion, hepatic resection and microwave ablation showed similar satisfactory results in the treatment of early-stage HCC. Microwave ablation remains a promising alternative for patients not fit for surgical resection.

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NA

**Code availability**
N/A.

**Authors' contributions**
AM made substantial contributions to the conception and design of the work. He approved the submitted version and agreed both to be personally accountable for the author's own contributions and to ensure that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature. AA made substantial contributions to the conception of the work. He approved the submitted version and agreed both to be personally accountable for the author's own contributions and to ensure that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature. MD made substantial contributions to the conception and design of the work. He approved the submitted version and agreed both to be personally accountable for the author's own contributions and to ensure that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature. AS made substantial contributions to the conception of the work. He approved the submitted version and agreed both to be personally accountable for the author's own contributions and to ensure that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature. All authors read and approved the final manuscript.

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**Availability of data and materials**
All data generated or analyzed during this study are included in this published article.

## Declarations

**Ethics approval and consent to participate**
The study was accepted by the investigational review board (IRB) of Cairo University.
All patients signed informed consent.

**Consent for publication**
All authors accept publication.

**Competing interests**
The authors declare that they have competing interests.

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**References**

1. Rashed WM, Kandeil MAM, Mahmoud MO, Ezzat S (2020) Hepatocellular carcinoma (HCC) in Egypt: a comprehensive overview. J Egypt Natl Canc Inst 32(1):1–11
2. Zakharia K, Luther CA, Alsabbak H (2018) LR Roberts (2018) Hepatocellular carcinoma: Epidemiology, pathogenesis and surveillance - implications for sub-Saharan Africa. S Afr Med J 108(8b):35–40. https://doi.org/10.7196/SAMJ.2018.v108i8b.13499
3. Yang JD, Mohamed EA, Aziz AOA, Shousha HI, Hashem MB, Nabeel MM, Ayawin JP (2017) Characteristics, management, and outcomes of patients with hepatocellular carcinoma in Africa: a multicountry observational study from the Africa Liver Cancer Consortium. Lancet Gastroenterol Hepatol 2(2):103–111
4. Liang P, Yu J, Lu MD et al (2013) Practice guidelines for ultrasound-guided percutaneous microwave ablation for hepatic malignancy. World J Gastroenterol 19(33):5430–5438
5. Poulou LS, Botsa E, Thanou I, Ziakas PD, Thanos L (2015) Percutaneous microwave ablation vs radiofrequency ablation in the treatment of hepatocellular carcinoma. World J Hepatol 7(8):1054
6. Zubrod C et al (1960) Appraisal of methods for the study of chemotherapy in man: Comparative therapeutic trial of nitrogen mustard and thiophosphoramide. J Chronic Dis 11:7–33
7. Abdelaziz A, Elbaz T, Shousha HI, Mahmoud S, Ibrahim M, Abdelmaksoud A, Nabeel M (2014) Efficacy and survival analysis of percutaneous radiofrequency versus microwave ablation for hepatocellular carcinoma: an Egyptian multidisciplinary clinic experience. Surg Endosc 28(12):3429–3434
8. European Association For The Study Of The Liver (2018) EASL clinical practice guidelines: management of hepatocellular carcinoma. J Hepatol 69(1):182–236
9. Chan YH (2004) Biostatistics 203. Survival analysis. Singapore Med J 45:249–256
10. Chan YH (2003) Biostatistics 102: quantitative data–parametric & non-parametric tests. Blood Press 140(24.08):79
11. Chan YH (2003) Biostatistics 103: qualitative data-tests of independence. Singapore Med J 44(10):498–503
12. Semaan S, Makkar J, Lewis S, Chatterji M, Kim E, Taouli B (2017) Imaging of hepatocellular carcinoma response after 90Y radioembolization. Am J Roentgenol 2017(209):W263–W276. https://doi.org/10.2214/AJR.17.17993
13. Vincenzi B, Di Maio M, Silletta M, D'Onofrio L, Spoto C, Piccirillo MC et al (2015) Prognostic relevance of objective response according to EASL criteria and mRECIST criteria in hepatocellular carcinoma patients treated with loco-regional therapies: a literature-based meta-analysis. PLoS ONE 10(7):e0133488
14. Nault JC, Sutter O, Nahon P, Ganne-Carrié N, Séror O (2018) Percutaneous treatment of hepatocellular carcinoma: state of the art and innovations. J Hepatol 68(4):783–797
15. Llovet JM, Schwartz M, Mazzaferro V (2005) Resection and liver transplantation for hepatocellular carcinoma. Semin Liver Dis 25:181–200
16. Sun Q, Shi J, Ren C, Du Z, Shu G, Wang Y (2020) Survival analysis following microwave ablation or surgical resection in patients with hepatocellular carcinoma conforming to the Milan criteria. Oncol Lett 19(6):4066–4076
17. Greten TF, Malek NP, Schmidt S, Arends J, Bartenstein P, Bechstein W et al (2013) Diagnosis of and therapy for hepatocellular carcinoma. Z Gastroenterol 51(11):1269
18. Zhang M, Ma H, Zhang J, He L, Ye X, Li X (2017) Comparison of microwave ablation and hepatic resection for hepatocellular carcinoma: a meta-analysis. Onco Targets Ther 10:4829
19. Lei J, Wang W, Yan L, Wen T, Li B (2014) Radiofrequency ablation versus surgical resection for small unifocal hepatocellular carcinomas. Med 93(29):e271
20. Xu J, Zhao Y (2015) Comparison of percutaneous microwave ablation and laparoscopic resection in the prognosis of liver cancer. Int J Clin Exp Pathol 8(9):11665–9
21. Vietti Violi N, Duran R, Guiu B, Cercueil J, Aubé C, Digklia A et al (2018) Efficacy of microwave ablation versus radiofrequency ablation for the treatment of hepatocellular carcinoma in patients with chronic liver disease: a randomised controlled phase 2 trial. Lancet Gastroenterol Hepatol 3(5):317–325
22. Chong CCN, Lee K-F, Chu C-M, Chan AWH, Wong J, Chan SL, Lok H-T, Fung AKY, Fong AKW, Cheung YS, Yu SCH, Johnson P, Lai PBS (2018) Microwave ablation provides better survival than liver resection for hepatocellular carcinoma in patients with borderline liver function: application of ALBI score to patient selection. HPB 20(6):546–554
23. Liang P, Dong B, Yu X, Yu D, Wang Y, Feng L, Xiao Q (2005) Prognostic factors for survival in patients with hepatocellular carcinoma after

percutaneous microwave ablation. Radiology 235(1):299–307. https://doi.org/10.1148/radiol.2351031944 (Epub 2005 Feb 24)
24. Ni J-Y, Sun H-L, Chen Y-T, Luo J-H, Chen D, Jiang X-Y, Lin-Feng Xu (2014) Prognostic factors for survival after transarterial chemoembolization combined with microwave ablation for hepatocellular carcinoma. World J Gastroenterol 20(46):17483–17490. https://doi.org/10.3748/wjg.v20.i46.17483

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