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Current Research and Perspective of the Role of Microwave Ablation in Managing Hepatocellular Carcinoma: A Systematic Review

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ABSTRACT
Hepatocellular carcinoma is one of the most common leading causes of death especially in Asia. While the main pillars of intervention for hepatocellular carcinoma in Malaysia are chemotherapy, radiotherapy, immunotherapy and surgical resection of tumors, these interventions presence with many weaknesses. Microwave ablation is one of the latest technologies which possess a shorter ablation time compared to other thermal ablation techniques, as well as lesser post-operative complications when compared to surgical resection of tumors. Hence, the aim of this review is to compile available research articles pertaining to microwave ablation in hepatocellular carcinoma. An extensive search was done in PubMed Central, BioMed Central, ScienceDirect, and Wiley Online Library from 2019 to 2024 to identify original research on the use of microwave ablation in managing hepatocellular carcinoma. During the search, 10 articles met our inclusion criteria where eight of the studies were conducted in Asia itself. All studies yield favorable results on the use of microwave ablation. However, more studies should be conducted in comparing microwave ablation with the current trend such as stem cells therapy. Overall, we concluded that microwave ablation is most suitable to be catered for the high number of patient load and lack of hospital bed in Malaysian government hospital considering its shorter ablation time and lesser complications.

Keywords: Microwave ablation, hepatocellular carcinoma, liver cancer, ablation.

INTRODUCTION
Liver cancer is the sixth most common cancer globally, and the third leading cause of death worldwide with its prevalence is still currently on the rise (1,2). In 2020 itself, approximately 906,000 of the population worldwide were diagnosed with liver cancer with the mortality rate of 830,000 per year which are still on the rise (2–4). To further breakdown, 80% of liver cancers were reported to be hepatocellular carcinoma, 15% intrahepatic cholangiocarcinoma, and the 5% were other remaining subtypes (4). Hence, we believed that by treating hepatocellular carcinoma alone could significantly reduce the mortality rate caused by liver cancer.
The main pillars of cancer intervention in Malaysia includes chemotherapy, radiotherapy, immunotherapy and surgery, with radiofrequency ablation remains the most used thermal ablation for localized solid cancer (5–7). Being the most common solid malignancy worldwide, and in view of ethical concerns which arises in modern therapy including the use of stem cell therapy, ablation therapy is one of the most suitable alternative therapy for the treatment of hepatocellular carcinoma or cases of unresectable surgery (8–12). Being said, there are a variety of ablation modalities such as percutaneous radiofrequency ablation, microwave ablation, and laser ablation which are the high-temperature-based modalities, and cryoablation, which is a low-temperature-based modality (13). These modalities differ in their mechanism of action in targeting cancer cells.

Compared to radiofrequency ablation which is the well-known thermal ablation therapy for localized solid cancer in Malaysia, microwave ablation is lesser known which is due to it as one of the newer modalities of thermal ablation (14,15). Yet, microwave ablation has been proven to be safe and effective minimal invasive procedure in tumors and metastatic disease management (16). According to the authors, microwave ablation has good technical success and when compared to the conventional radiofrequency ablation, microwave ablation can reach a high temperature faster, hence causes uniform and larger ablation zone, less susceptible to heat sink effect in liver which is a vascular organ, and able to overcome the disadvantage of low conductivity and high impedance of aerated tissues. Sadly, the major drawback of microwave therapy is the higher cost of microwave antenna as compared to radiofrequency ablation electrode. Therefore, considering the disadvantage on the higher cost of microwave therapy which could further increases the economic burden of Malaysia in cancer management, the objective of present review is to compile research articles pertaining to microwave ablation in hepatocellular carcinoma. Present review aims to assist oncologist in deciding on the use of microwave ablation in hepatocellular carcinoma management considering the benefits outweigh the risk.

Data Acquisitions

Search Methods

Performed a comprehensive search of journals in the PubMed Central, BioMed Central, ScienceDirect, and Wiley Online Library from 2019 to 2024 to identify related studies regarding to microwave ablation in hepatocellular carcinoma. The keywords used were microwaving ablation (Abstract) 'OR' microwave (All fields) 'AND' small hepatocellular carcinoma (Abstract).

Search Outcome, Audit Trail and Quality Appraisal

The selection of articles included original research related to the used of microwave ablation as an intervention for hepatocellular carcinoma. The excluding criteria for this study include any form of review articles such as narrative or systematic review, news, letters, editorials, case studies or studies that is not related to microwave ablation in managing hepatocellular carcinoma, and studies that include other confounding factors such as the used other natural products.

Data Abstraction and Synthesis

The data of related articles were extracted as according to the PRISMA guidelines. In brief, the works of literature were reviewed in three phases (Figure 1) where articles were screened based on its title (first phase) followed by its abstracts (second phase), and finally the full texts (17). All papers were read thoroughly to exclude literature that did not meet our inclusion criteria. A single-blinded review was adopted to minimize bias. As such, two reviewers assigned to review the papers from the first to the third phase. The reviewers were not supposed to discuss their findings with each other during the review process. The differences in the agreement after the final review were resolved by discussion between the reviewers. The works of literature included in this study were the results from a mutual agreement by both reviewers. To standardize our data collection, all data extraction was carried out independently using a standard data collection form. In brief, the following data was recorded from the works of literature: (1) author(s) name and year of publication; (2) study design; (3) sample size, age, and location; (4) the size of tumors and cancer stage; (5) outcome measures; and (6) study outcomes.

RESULTS

A total of 24, 86, 273 and 2 articles were retrieved from PubMed Central, BioMed Central, ScienceDirect, and Wiley Online Library respectively (Figure 2). During the initial screening on the titles and upon the agreement of both reviewers, a total of 356 articles were excluded as those titles itself does not reflect on the scope of present review to study the role of microwave ablation in the management of hepatocellular carcinoma. There were no duplicated articles during the selection process, and upon further consideration, a total of 19 articles were excluded after the screening of abstract and full text as they did not comply with the inclusion criteria of this review. During the selection process, studies which studied the role of adding d-mannose-chelated iron oxide nanoparticles and applying Mn-doped Ti MOFs nanosheets on microwave ablation, using different probes and location to improve the efficacy of microwave ablation therapy for hepatocellular carcinoma, and about the use of nano-delivered chemotherapeutics for synergistic microwave ablation cancer therapy were also excluded upon careful deliberation by the reviewers due to the presence of confounding factors, and there are no individual groups which studied on the effectiveness of microwave ablation only in managing hepatocellular carcinoma without the addition of these confounding factor (18–23). Hence, only 10 articles fulfilled our inclusion criteria and were added into present review.

DISCUSSION

Microwave Ablation for Metastatic Hepatocarcinoma

Hepatocellular carcinoma is a highly prevalent cancer in Asia when compared to the west (24). Therefore, this explains the reason where most of the studies included in present review were conducted in China, that is the country with the largest population in Asia (25). In present review, eight of the studies were conducted in Asia in which seven of the studies were conducted in China and one, Japan. The other two articles included were conducted in the United States of America. One of the possibilities to this is the genetic and lifestyle differences between the Asian and European population (26–28). While the risk factors of hepatocellular carcinoma are mostly related to aging, lifestyle (for example: alcoholic) and presence of underlying conditions such as hepatitis B, hepatitis C and cirrhosis. Considering the liver is a solid and highly vascular organ which receives up to 25% of total cardiac output at rest, more than any other organ (29). According to the authors, its dual blood supply is uniquely divided between the hepatic artery contributing 25% to 30% of its blood supply, and the portal vein, which is responsible for the remaining 70% to 75%. The blood in these vessels was mixes within the hepatic sinusoids before draining into the systemic circulation via the hepatic venous system. As for its lymphatic drainage, the liver produces one third to one half of all body lymph which drains into the lymph nodes in the porta hepatis, intraabdominal lymph nodes as well as the lymph nodes at the posterior mediastinal region. Hence, its metastasis is relatively quick in which the common sites of metastasis are the lungs, intra-abdominal lymph node, bone, and adrenal (30–33). Therefore, its prognosis remains poor which is largely due to the late diagnosis and lack of effective treatments (34).

Since, ablation techniques including microwave and radiofrequency ablation is a locoregional intervention approach while hepatocellular carcinoma is a highly metastatic tumor capable of metastasizing to different parts of the body, its use on hepatocellular carcinoma at later stage posses a real challenge (35). As such, certain metastatic sites can be overlooked by the interventional radiologist, oncologist and/or surgeon administering the intervention. Regrettably, the intervention for metastatic tumors is limited. Therefore, most of the articles included in present review would have their patients underwent either contrast-enhanced computed tomography (CECT)/positron emission tomography–computed tomography (PET-CT) or contras-enhanced magnetic resonance imaging (CE-MRI) as preprocedural test to determine the location of tumors as well as its metastatic sites. Also, the ablation procedure was normally done under general anesthesia with suspended ventilation. To effectively locate the tumor lesion, the antenna or probes of the ablation device was placed under image guidance either under ultrasonography (USG) or CT scan depending on the site of the lesion and were confirmed, prior to starting ablation (35). Although effective placement of the antenna and probes of the ablation device plays an important role in determining the success of the intervention, articles relating to the study of different radiological tools, as image guidance for the location of probes and antenna were also excluded from this review. This is due to the non-fulfillment of our review objective which is to study the effectiveness of microwave ablation in treating hepatocellular carcinoma.

Upon the successful positioning of antenna or probes within the tumor, the power and time of energy delivery were adjusted to covers the entire tumor area and a centimeter of normal parenchyma around it (A0 ablation) to ensure total tumor destruction (35). To protect nearby organs including the gall bladder and diaphragm from thermal injury, adjuvant technique such as hydrodissection or pneumodissection was performed, and the adequacy of ablation was confirmed using CT scan and overlapping ablations were performed until an adequate A0 ablation zone was obtained. Normally, a post ablation radiological scan such as CECT and/or CE-MRI was done, and the patient were followed up within weeks and months to evaluate on the completeness of the ablation and complications arises which is reported in most of the articles included in our review. Additionally, there were also articles that evaluated on the laboratory testing including aspartate aminotransferase (AST), alanine aminotransferase (ALT), total bilirubin, creatinine, international normalization ratio (INR), albumin, sodium and alphafeto protein (AFP) serum levels (36–41)All these articles reported microwave ablation to yield positive outcomes in treating hepatocellular carcinoma in which we believed to be similar to radiofrequency ablation and other ablation techniques. However, since ablation techniques are a local approach, its administration can be relatively challenging for metastatic hepatocellular carcinoma where the location of metastasis should be taken into consideration. Yet, we believed that this factor can be easily overcome with the anatomical knowledge of the vessels and lymphatic drainage of the liver as well as through pre-screening on the metastasis sites prior to the administration of intervention.

Microwave Ablation versus other Thermal Ablation Techniques

Theoretically microwave ablation utilizes dielectric hysteresis to produce heat (42). As such the polar molecules of water presence in the liver are forced to continuously realign with the oscillating electric field generated by the radiating nature of the antenna, increasing their kinetic energy leading to heat generation, hence rises the temperature of the tissue. Anatomically, the liver contains around 70% biological fluid (43). Therefore, the dipole rotation theory utilized by microwave ablation for tumor destruction is applicable for hepatocellular carcinoma. The rise in temperature of the tissues were then followed by tissue destruction occurs when tissues are heated to lethal temperatures from the electromagnetic field, which is typically at 900–2500 MHz creating an ablative zone (figure 3). Being one of the thermal ablation modalities, its mechanism of heating still differs from its counterparts, radiofrequency ablation and laser ablation (44,45).

For radiofrequency ablation, heat was generated via resistive heating when electrical current passes through the ionic tissue medium (46). Radiofrequency heating is strongly dependent on the local electrical conductivity, hence; its heating is limited in areas of low electrical conductivity and resulting only in heating tissues near the electrode (47). Although being one of the more cost effective and widely available devices, radiofrequency ablation devices carry numerous disadvantages (48). One of its main disadvantages as compared to microwave ablation are: (1) risk of skin pad burns, (2) since the liver is a highly vascular organ and contains 70% biological fluid (43), the used of radiofrequency ablation increases its susceptibility to vessel 'heat sink', (3) considering the molecules that are located further from the radiofrequency device electrode are set into motion by other nearby vibrating molecules, the frictional energy losses between adjacent molecules is inevitable. Hence, this results in energy and generated temperature drops exponentially tissues with greater distance from the electrode making ablation of larger lesion difficult (those tumors >5cm). (4) Also, the ablation speed is relatively slow as compared to microwave ablation. Therefore, making microwave ablation a better choice for hepatocellular carcinoma in the liver when compared to radiofrequency device despite being costlier. Present review had identified one article comparing microwave ablation to radiofrequency ablation. According to the retrospective study done by the authors, microwave ablation has been reported to be safer and have a shorter ablation time compared to radiofrequency ablation (49). With these, we believed that more patients can be treated with a shorter amount of time with microwave ablation as compared to radiofrequency ablation. In addition, microwave ablation being a safer intervention technique with lesser complication could also reduce the length of hospital stay and therefore, provide some relieve to the economic burden in managing hepatocellular carcinoma. However, more studies should be conducted in this aspect.

Laser ablation in the other hand employs a focused narrow beam of intense light which is absorbed by tissue and is converted into heat to eliminate or destroy tumor cells (45,50). However, laser ablation is generally effective only for superficial tumors, making it less suitable for applications requiring deeper penetration such as hepatocellular carcinoma which may located deep within the liver along with the difficult placement the laser fibers (51). Additionally, the maintenance and cost of a laser ablation equipment is relatively high as compared to radiofrequency and microwave ablation devices.

All the thermal ablation devices mentioned in this section including the radiofrequency ablation, laser ablation and microwave ablation devices requires insertion and positioning of applicators, electrodes or probes to deliver the thermal energy in situ. With different principles, the selection of the appropriate thermal ablation is crucial in determining the management outcome of hepatocellular carcinoma. Based on present review, microwaves are capable of propagating through and effectively heat various types of tissues including those with low electrical conductivity, high impedance, and/or those with low thermal conductivity. Hence, are more suitable for those tissues including the bone and lungs which are the common metastatic sides for hepatocellular carcinoma and have been associated with suboptimal outcomes with radiofrequency ablation due to high baseline impedance(42). Unlike radiofrequency and laser, microwaves can also penetrate through the charred or desiccated tissues which tend to build up around all hyperthermic ablation applicators which results in limited power delivery for non-microwave energy systems. Despite that, there is one study on the whole blood of 43 patients receiving microwave ablation for hepatic malignancies reported where the microwaves altered the serum levels of several cytokines including interleukin-2 (IL-2) and IL-6. Therefore, causing heat injuries to tissues around the lesion leading to the release of neoantigen into blood circulation, eventually induce a systemic reaction (52). However, there are limited evidence relating to this and the findings are inconclusive. Additionally, to date the intervention for various forms of cancers including are still limited and based on present review microwave ablation still remains the best option. From our opinion based on our current review results, microwave ablation is best applied on single and multiple nodules hepatocellular carcinomas closed to large vessels and large single or multiple nodules hepatocellular carcinomas which are metastatic and non-metastatic in origin.

Microwave Ablation versus Surgical Resection

Since the past decade, surgical resection has been the intervention of choice for patients with hepatocellular carcinoma without cirrhosis and those with Child-Pugh class A cirrhosis without portal hypertension (33,53). However, such intervention is not applicable especially on patients with advanced liver dysfunction due to high risk of postoperative liver failure. Also due to patient's safety, time, and financial factor, it is impossible to perform resection to remove all the hepatocellular carcinoma in those cases where the malignant cells had metastasized to other parts of the body. Present review identified three studies comparing microwave ablation to surgical resection. In general, all these studies reported microwave ablation to be superior compared to surgical resection in terms of lesser blood loss, shorter hospital stay, lower complication rate, faster recovery and lower morbidity (37,40,41). The reason to this was also due to the highly invasive nature of surgical resection. Hence, we strongly believed that microwave ablation technique is also more economically friendly in terms of shorter hospital stay and lesser cost for prophylaxis management as compared to surgical resection for hepatocellular carcinoma.

Microwave Ablation versus Current Trends

Since the past decade, natural products including tea, coffee, and decoction such as Xiao Xian Xiong had been widely studied in reducing the risk and as intervention of hepatocellular carcinoma and other cancer (54,55). Similarly, there were also studies which reported physical activity and exercises to yield positive outcomes for hepatocellular carcinoma (56–59). One of the believes are physical exercise improves circulation and the delivery of natural killer and T cells which is an effective response against cancer (60–63). However, there were no articles identified in present review comparing both natural products and/or physical activity with microwave ablation in the management of hepatocellular carcinoma. The reason to that could be the use of natural products and lifestyle modification as an intervention for hepatocellular carcinoma can be relatively slow when compared to microwave ablation.

Additionally, stem cells therapy is another branch of which recently gain popularity in cancer management including hepatocellular carcinoma (64). The used of stem cells in managing various conditions has been widely studied in various organ systems including hepatocellular carcinoma (65–68). While the used of stem cells can be a promising approach as it can be done in a systemic approach and its exosomes targeting those cancer genes, these findings were mainly confined to laboratory studies due to a number of ethical concerns (69–71). Moreover, there were also no evidence comparing microwave ablation and stem cells therapy in managing hepatocellular carcinoma.

CONCLUSION

Present review reported where microwave ablation to yield positive outcome in managing hepatocellular carcinoma and an ideal choice for large, metastatic and hepatocellular carcinoma cells close to vessels. In addition to that, it is also a safer option when compared to surgical resection. While there are also many other intervention available, current study on the use of microwave ablation for hepatocellular carcinoma in comparison with other approaches such as the recent stem cell therapy are still lacking. While the used of stem cells is believed to offer promising outcomes in ameliorating cancerous cells through systemic approach and targeting of cancer genes, its usage in clinical settings are still limited due to ethical concerns. However, studies comparing both microwave ablation and stem cell approach should commence to compare and study the strength and weaknesses in determining the best approach in the management of hepatocellular carcinoma. Therefore, providing more options for patient's and further reduces the economic burden, morbidity and mortality associated with hepatocellular carcinoma. Also considering the high number of patient load in Malaysian government hospital, we believed that the implementation of microwave ablation over radiofrequency ablation and liver resection could effectively increases the efficiency of our interventional radiologist besides with shorter hospital stays; it is also effective in solving the lack of hospital bed issue.

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Figures

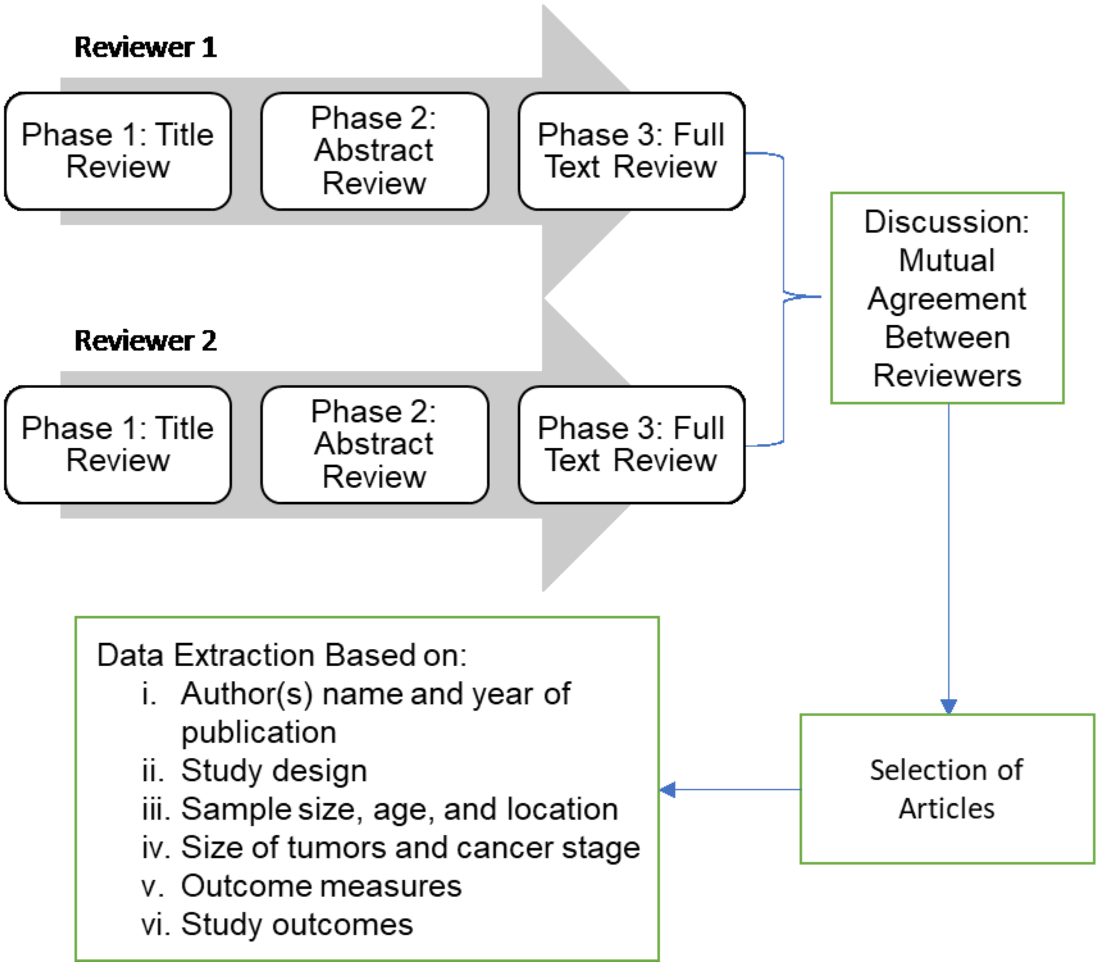

Figure 1: Flow chart on the article selection process

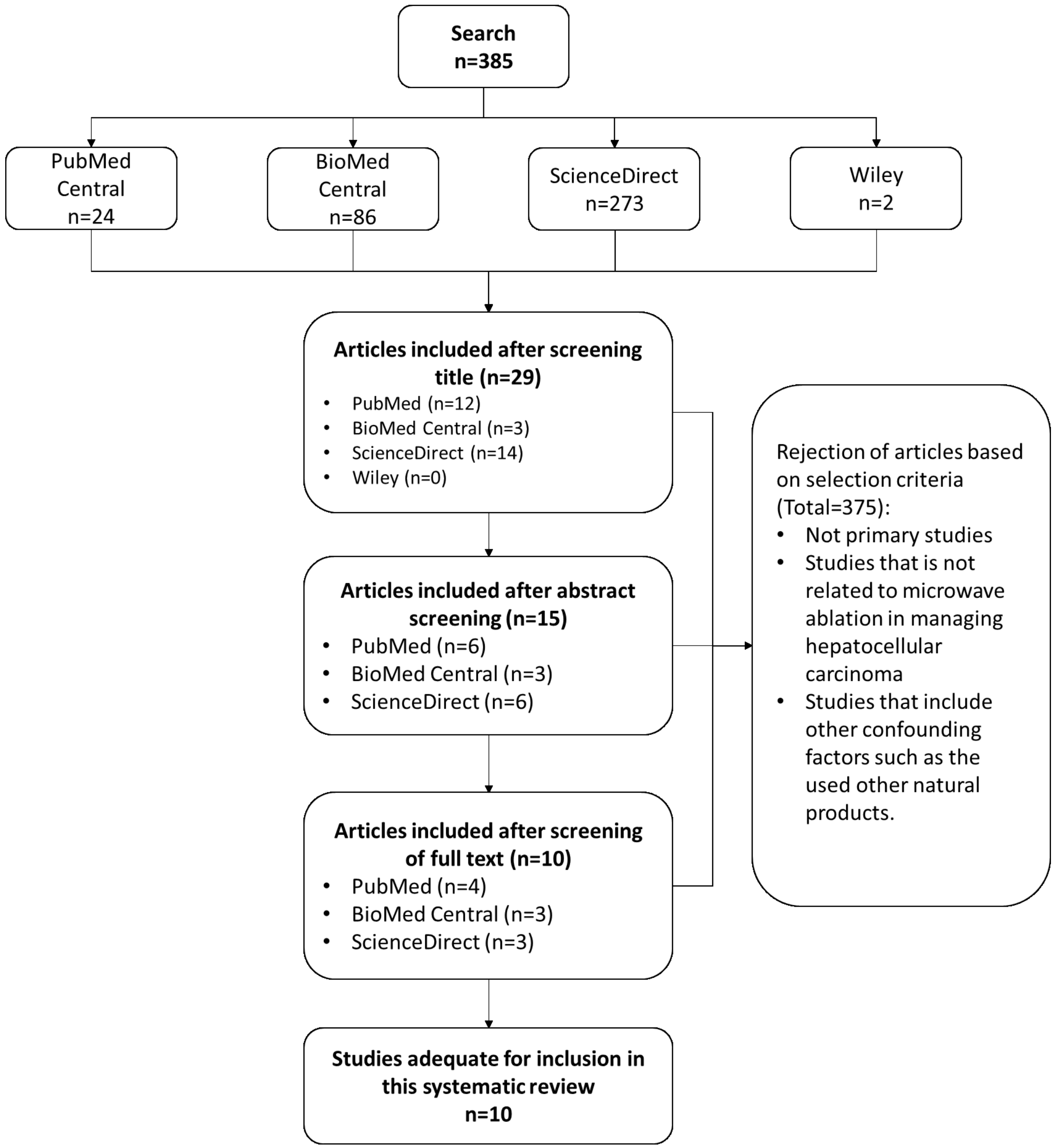

Figure 2: The article selection process

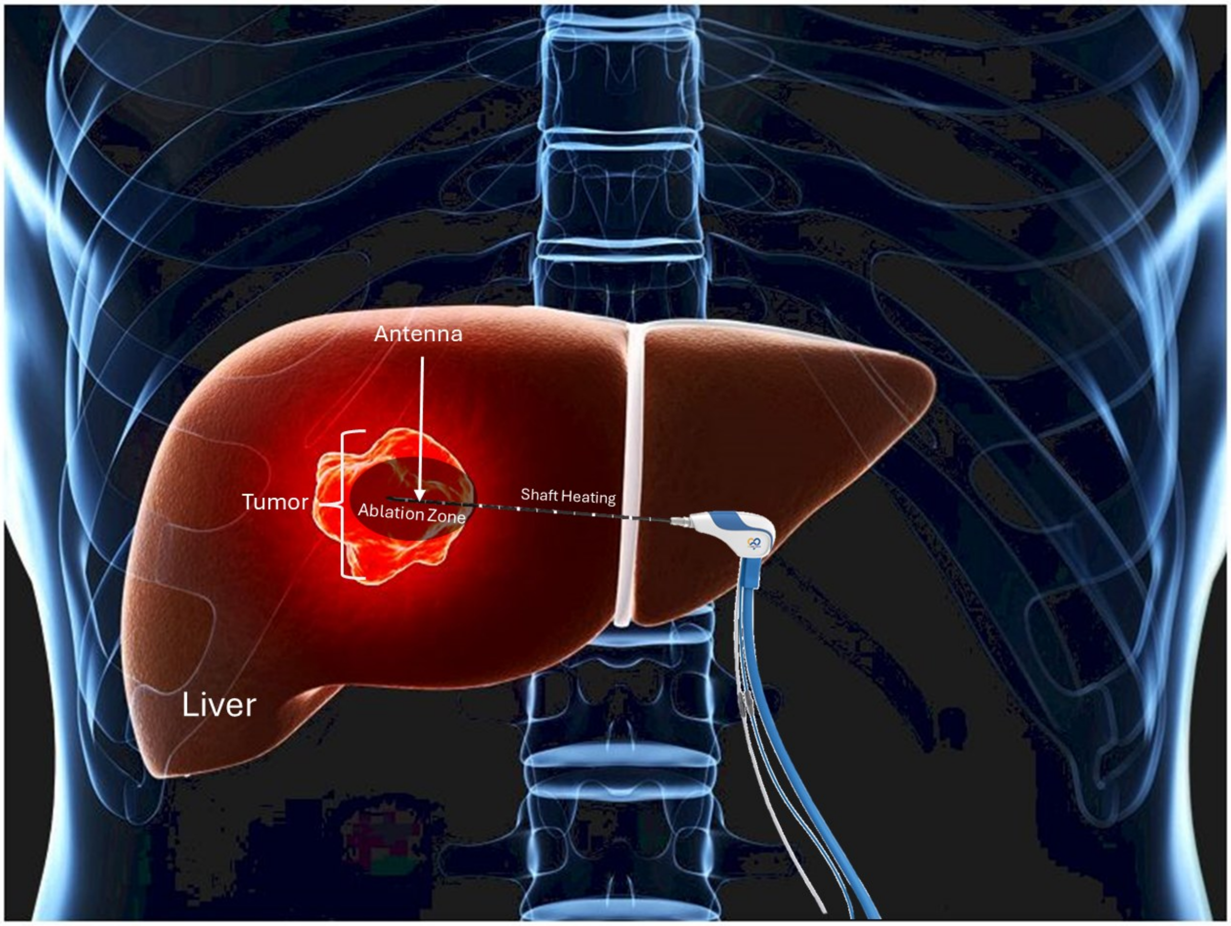

Figure 3: Mechanism and concepts of Microwave Ablation

Table 1: Characteristics of Manuscripts Reviewed

Author(s) name and year of publication	Study Design	Sample size, age, and location	Size of tumors and cancer stage	Outcome measures	Study Outcomes
Hu et al., 2022 (Hu et al., 2022)	Retrospective Study	61 patients (35 males, 26 females); ±58.91 years; He Fei, China	Primary liver cancer; Single or multiple liver cancers with a diameter ≤3 cm and totaling <3; No evidence of vascular invasion, bile duct invasion, or extrahepatic metastases; 2020 China liver cancer staging system of Ia (n = 55), Ib (n = 6)	Contrast-enhanced MR, CECT, CEUS of the liver) and tumor-related indicators (AFP, DCP, and human prothrombin complex)	Laparoscopic microwave ablation with ICG fluorescence navigation achieve better efficacy as compared to compared with conventional laparoscopic microwave ablation. In addition to its ability to detect micrometastases and satellite lesions during surgery.
Dou et al., 2022 (Dou et al., 2022)	Retrospective study	729 patients (366 microwave ablation group, 363 surgical resection group); ±55.4 years; China	Single tumor smaller than 5.0 cm or a maximum of 3 tumors smaller than 3.0 cm; Child-Pugh class A or B classification; No evidence of vein or bile duct tumor embolism, and no extrahepatic metastasis at the time of diagnosis; Eastern Cooperative Oncology Group performance status of 0–1, and no prior anticancer treatment.	CE-MRI/CT or CEUS; Patients with extrahepatic metastasis according to their clinical symptoms or patients with unexplained alpha-fetoprotein (AFP) elevation were also accessed with bone scintigraphy, pelvic MRI, chest CT, or PET-CT.	Patients with small hepatocellular carcinoma of ≤ 4 cm treated with microwave ablation demonstrated comparable long-term oncologic outcomes with those treated with surgical resection. Additionally, these patients have with lower complication rates and faster recovery as compare to those treated with surgical resection.
Tamai &	Retrospective	513 patients (174	Early-stage	CECT, dynamic	Next-generation

Okamura, 2021 (49)	e study	radiofrequency ablation; 339 new microwave thermosphere ablation); ±74 years; Wakayama Rosai Hospital, Japan	hepatocellular carcinoma ≤3 cm	MRI, and CEUS	microwave thermosphere ablation for small hepatocellular carcinoma is safer, and more curative treatment in a shorter ablation time compared to the conventional radiofrequency ablation.
Ji et al., 2022 (38)	Retrospective study	45 patients (28 transcatheter arterial chemoembolization only, 17 transcatheter arterial chemoembolization with microwave ablation); ±59 years; Nanjing Medical University, China	First intrahepatic recurrent hepatocellular carcinoma after initial resection; Recurrent three or fewer tumors under 3 cm prior to receiving the intervention; Child–Pugh A or B; Absence of extrahepatic metastasis or macrovascular invasion; Eastern Cooperative Oncology Group performance score ≤ 2.	Serum tumor makers, enhanced liver MRI or CT	Although transcatheter arterial chemoembolization alone provides equivalent effectiveness for recurrent hepatocellular carcinoma in terms of overall survival rates, patients treated with transcatheter arterial chemoembolization plus microwave ablation had better 1-, 3-, 6-month tumor response rates and may prolong tumor progression free survival time.
Zhao et al, 2020 (52)	Retrospective study	43 patients (37 liver metastasis, 6 primary cancer) (28 male, 15 female); ±62.81 years; Soochow University affiliate hospital, China.	3.36 ± 1.33cm ; liver and metastatic tumors.	Whole blood (4 mL) test for cytometry and cytokine (IFN-γ, IL-2, IL-6, IL-8, IL-10, IL-12 p40, IL-12 p70, IL-1β, TNFα, and VEGF) analyses.	Microwave ablation treatment for hepatic malignancies can alter the serum levels of several cytokines such as IL-2 and IL-6. Hence, causing heat injury to tissues surrounding the tumor site and release neoantigen to blood circulation, eventually induce

					a systemic reaction.
Li et al., 2021 (72)	Retrospective study	101 patients (47 CT-guided microwave ablation, 54 MR-guided microwave ablation); ±56 years; China	Single hepatocellular carcinoma ≤ 5.0 cm or a maximum of three.	Local tumor progression, and overall survival.	Both CT-guided and MR-guided microwave ablation are comparable therapies for the treatment of HCC (< 5 cm), and there was no difference in survival between the two groups. However, MR-guided microwave ablation could reduce the incidence of complications.
Zhang et al., 2022 (73)	Retrospective study	339 patients (106 male, 233 female); ±62 years; Chinese PLA General Hospital, China	Child–Pugh A or B cirrhosis; Single tumor with a maximum tumor size of 5 cm or less, or two to three tumors with a tumor size of 3 cm or less; No evidence of vascular invasion or extrahepatic metastasis	Local tumor progression rate and early recurrence rate	Kaplan–Meier estimates of the rates of ER in the low-risk and high-risk groups were 6.8% (95% CI 4.0 – 9.6) and 30.5% (95% CI 23.6 – 37.4), respectively.
Young et al., 2020 (39)	Retrospective study	86 patients (64 men, 22 women); ±63.9 years; United States	86 patients who underwent a total of 103 microwave ablations with a single microwave ablation system, 89.3% of the microwave ablation procedure were performed on hepatocellular carcinoma; Size not	Distance from the edge of the tumor to the nearest adjacent portal or hepatic vein; Baseline laboratory data including aspartate aminotransferase (AST), alanine aminotransferase (ALT), total bilirubin, creatinine, international normalization ratio (INR), albumin, sodium	2450 MHz 100 Watt generator microwave ablation system able to accurately predicts ablation zone dimensions fairly.

			specified	and alphafeto protein (AFP) serum levels, and model for end stage liver disease (MELD) scores	
Ricker et al., 2024 (40)	Retrospective study	623 patients (791 surgical microwave ablation, 1156 tumors); ±63.9 years; United States	ASA score of **III** (79.5 %) or IV (15.8 %), underlying cirrhosis (89.1 %) as a result of HCV/HBV infection (56.1 % and 4.7 %, respectively) or chronic alcohol abuse (30.2 %). Median tumor size ±2cm (range 0.25–10 cm) with an average of 1 tumor ablated per operation (range 1–7 tumors); Child-Pugh class A.	Perioperative laboratory values, and follow-up information, recurrence, and survival	Surgical microwave ablation to treat hepatocellular carcinoma is a safe and effective modality when used as part of a multidisciplinary strategy, even in patients with advanced liver disease. Compared to resection, minimally invasive liver microwave ablation is associated with lower morbidity. Laparoscopic liver microwave ablation is an effective local therapy as definitive treatment for hepatocellular carcinoma. Surgical microwave ablation can serve as an effective bridge to transplant candidates but can also provide disease control for those patients who are not candidates. Although local recurrence rates are low, patients who do experience a local or regional

					recurrence are often candidates for repeat liver microwave ablation, resection, or transplantation
Feng et al., 2022 (41)	Retrospective Study	426 patients (291 resection of hepatocellular carcinoma, 135 microwave ablation); ±57 years; Shengjing Hospital, China	tumor within the Milan criteria: single HCC ≤5 cm or 2–3 nodules, each ≤3 cm; (b) no evidence of macroscopic vascular or bile duct invasion; (c) no previous or simultaneous malignancies; and (d) no previous treatment for HCC.	US, CT, and/or MRI, and tumour-related indicator such as serum alpha-fetoprotein (AFP).	Microwave resection resulted in survival outcomes that were similar to those of resection of hepatocellular within the Milan criteria. However, it is more favorable in terms of shorter hospital stay and lesser blood loss as compared to those underwent resection of hepatocellular.

AFP = Alpha fetoprotein
AST = Aspartate aminotransferase
CE = Contrast-enhanced
CECT = Contrast-enhanced computed tomography
CEUS = Contrast -enhanced Ultrasound
CT = Computer Tomography
MR = Medical Resonance
MRI = Magnetic Resonance Imaging
PT = Prothrombin Time
US = Ultrasound