

DYNAMIC AND DIFFUSION MAGNETIC RESONANCE IMAGING IN EVALUATION OF MALIGNANT HEPATIC NEOPLASMS AFTER PERCUTANEOUS RADIOFREQUENCY ABLATION

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ABSTRACT

Background: Evaluation of hepatic malignancies response after loco-regional treatment is crucial to assess treatment success and to guide future therapy. MRI DWI liver added to conventional unenhanced and contrast enhanced MRI always be used in the follow up of RFA showing promising results in the detection of ablation site recurrence/residual lesions.

Objective: Evaluation of the role of dynamic and diffusion MRI in evaluation of recurrent/residual hepatic neoplasms after radiofrequency ablation.

Patients and methods: This prospective study included 50 patients, 40 males and 10 females. Patients ages ranged between 45 and 80 years with the mean age of 57.02 years, (SD±8.07). Patients were referred from Tropical Medicine Department to MRI unit after the procedure of radiofrequency ablation of complete ablated malignant liver tumors.

Results: Thirty seven patients (74%) had resolved lesions, while 13 patients (26%) had recurrent/residual lesions. The border of resolved lesions were smooth, but in unresolved lesions were nodular in 11 patient out of 13 (84.6%), and irregular in two patients (15.4%). The measured cut off value between the completely ablated lesions and residual/recurrent lesions was $1.05 \times 10^{-3} \text{ mm}^2/\text{s}$. The ablation zones can be differentiated from liver parenchyma visually in the DWIs and by means of ADC in all patients. There were no statistical differences in the mean ADC values between the ablation zones of the resolved and unresolved lesions.

Conclusion: Dynamic and DWI showed viable tumor regions, and suspected areas in the periphery of the ablation zone could be identified more easily, and analyzed precisely in conjunction with the conventional T1 and T2 WIs.

Key words: Diffusion weighted Image (DWI); Apparent Diffusion Coefficient (ADC) and Radiofrequency ablation (RFA).

INTRODUCTION

Liver resection and loco-regional therapies which comprise tissue ablation and chemoembolization techniques are utilized for management of hepatic malignancies (Dodd et al., 2000). Ablative therapies could be classified into either chemical or thermal ablation.

Chemical ablation includes the use of acetic acid and ethanol, while thermal ablation is gained by utilizing cold (cryoablation) or heat (radiofrequency ablation, laser ablation, and microwave ablation). RF ablation is the most widely used for both primary and secondary hepatic malignances, but all therapies produce coagulation necrosis, and exhibit

common imaging characters on follow-up. In fact, ablative techniques are a substantial choice for individuals with hepatic tumors who are not fit for surgery. These procedures are known to have low mortality and morbidity, as well as being with lower cost than surgical resection with the possibility to use these techniques on outpatient basis (**Ozkavukcu et al., 2009**). The percutaneous ablation procedures has the ability to destroy the tumor, preserving the normal liver parenchyma with low risk of complication accompanied with the technique and being easily available and relatively inexpensive. There is in addition to the eligibility to easily repeat the procedure in case of recurrent lesions (**McWilliams et al., 2011**). Evaluation of tumor response after loco-regional treatment is crucial to assess treatment success and to guide future therapy (**Vossen et al., 2006**). After RFA, the dynamic contrast enhanced MRI for evaluation of the response of the tumor is still difficult. Residual contrast enhancement may also be hard to appreciate. Hence, some types of secondary tumors are hypovascular (**Tri-Linh et al., 2012**). The MRI characters of the ablated zones should be assessed for lesion size after ablation, the signal intensity on unenhanced images, the presence of perilesional enhancement, and for lesion washout. Moreover, focal liver lesions managed by RFA often contain a high signal on T1WIs, corresponding to coagulation necrosis, which makes any residual tumor contrast enhancement difficult to be differentiated (**Kierans et al., 2010**). DWI is a technique that has been helpful in liver tumor detection, tumor characterization, and monitoring response to treatment (**Bruegel &**

Rummeny 2010, Figueiras et al., 2011 and Lee et al., 2011). ADC value and DWI parameter, has been correlated the presence of necrosis and tumor cell necrosis after successful treatment (**Anzidei et al., 2011 and Padhani & Koh, 2011**). Studies have demonstrated a potential to characterize malignant lesions and to differentiate viable tissue from necrosis on the basis of ADC cut-off values, because necrosis has higher ADC values (**Wagner et al., 2012 and Heijmen et al., 2013**). The European Association for the Study of Liver Disease (EASL) has recommended the use of lesion enhancement, rather than change in size, as the standard method to determine treatment response. However, uniform rim enhancement may also result from post-treatment reactive granulation tissue. Hence, a marker that would assess cellularity, such as DWI, may offer additional benefit to accurately assess tumor necrosis (**Kamel and Morgan, 2011**). DWI in the liver in addition to conventional unenhanced and contrast enhanced MRI always be used in the follow up after RFA shows promising results in the detection of ablation site recurrence/residual lesions (**Kele and Van Der Jagt, 2010**). ADC is used to assess metabolic tumor response after loco-regional treatment. Additionally, some authors have tried to determine whether the intra-lesion measurement of the lowest ADC might be helpful in monitoring tumor recurrence because this value could reflect the persistence of viable and residual tumor cells (**Lu et al., 2010**).

The aim of the current study was to evaluate the role of dynamic and diffusion weighted magnetic resonance imaging in evaluation of recurrent/residual hepatic

neoplasms after radiofrequency ablation, and also aiming to improve the technique and to standardize MR protocol to be used after interventional therapy for malignant hepatic tumors.

PATIENTS AND METHODS

This prospective study was performed in the period between January 2014 to January 2016. The study included 50 patients, 40 males and 10 females. Their ages ranged between 45 and 80 years old with the mean age of 57.02 years, (SD±8.07). Forty patients (80%) with hepatocellular carcinoma and 10 patients (20%) with liver metastases detected. This shows a more prevalence of HCC among hepatic malignancies. Patients were referred from Tropical Medicine Department as well as from outpatient clinic after the procedure of radiofrequency ablation.

Inclusion criteria: Patients with hepatic malignancy (HCC) or metastases after radiofrequency ablation.

Exclusion criteria: Contraindications to magnetic resonance imaging, to contrast media and tumors other than HCC or metastases.

All patients were subjected to the following:

A) History and clinical examinations.

B) Laboratory investigations:

1. Complete blood picture (CBC), hepatitis B surface antigen (HBSAg) and hepatitis C virus (HCV).
2. Liver and renal function tests.
3. Tumor markers: Alpha fetoprotein and carcino embryonic antigen.

C) RF ablation system:

Radiofrequency ablations were performed for less sizable tumors less than 5cm

under real time ultrasound guidance using A 5 or 3.5-MHz curvilinear probe. Patients were treated under conscious sedation. The RITA model 1500 RF ablation system provides multiple temperature displays and simple intuitive panel design. Radiofrequency energy was applied from 12 to 15 minute to ensure predictable controllable ablations. The generator also provided automatic temperature control and impending monitoring. Its needle was 15 G, 13 to 25 cm long insulated cannulae that housed 7 solid expandable curved electrodes. This system allowed ablation of 3.5 to 4 cm spherical tumors tissue per cycle at temperature 70°C or higher. Dispersive electrode pads to be applied to the patient's thighs and connected to the generator to close the electric circuit. Patients were discharged the day following the procedure.

D. MRI examination:

Dynamic MRI of the liver was examined using Resonance Achieva 1.5 Tesla-XR Class IIa 2010, Philips. Technical considerations for dynamic MRI of the liver scanning protocol:

T1 weighted image (T1WIs) gradient echo sequences (GRE) was with and without fat suppression (FS). Repetition time (TR) =100-200 ms, echo time (TE) ≤ 8 ms, number of excitations (NEX) 1-4, matrix 128-256 x 256 with a field of view as small as possible, slice thickness 5-7 mm, slice gap 0-2 mm, flip angle =90°.

T2 weighted image (T2WIs) fast spin echo sequences was with and without fat suppression (FS): (TR) ≥ 2000 ms, (TE) = 90-120 ms, number of excitations (NEX) 1-4, matrix 192-256 x 256 with a field of view as small as possible, slice thickness

5-7 mm, slice gap 0-2 mm, flip angle = 90°.

Dual echo (in and out of phase): (TR) = 99 ms, (TE) = 4.6 ms in phase and 2.3 ms in out phase WIs, flip angle = 80°.

DWI and ADC map was performed before the dynamic imaging using respiratory triggered fat-suppressed single-shot echoplanar sequence that combined the two diffusion (motion-probing) gradients before and after the 180° pulse along the three directions of section-select, phase-encoding, frequency encoding and data acquisition with an EPI readout were obtained by applying three different b factors of 0, 500, and 1000 s/mm².

Dynamic study: It was done after diffusion study to avoid the effect of contrast agents on ADC value. T1 spoiled gradient WIs was used by IV administration of gadopentetate dimeglumine (Gd-DTPA) (0.1mm l/kg) using pump injector at rate of 2ml/s followed immediately by 20 ml of sterile 0.9% saline solution injection, arterial phase (16-20 sec.), porto-venous phase (45-60sec.) and delayed/equilibrium phase (3-5 min.). All patients were imaged in end expiration to limit the risk of image misregistration. The used MRI pulse sequences parameters were detailed in **Table (1)**.

Table (1): MRI pulse parameters sequences.

MRI Parameters sequences	T1WI	T2WI	In phase	Out of phase	DWI	Dynamic T1WIs
Repetition time (msec)	100-200	≥2000	99	99	1600-2000	140
Echo time (msec)	≤8ms	90-120	4.6	2.3	70	5
Matrix	128-256x256	192-256x256	128-256x256	128-256x256	144 X 192	128-256x256
Field of view	380 mm	300 mm	380mm	380mm	300mm	380 mm
Slice thickness	5-7mm	5-7mm	5-7mm	5-7mm	7-8mm	5-7mm
Interslice gap	0-2mm	0-2mm	0-2mm	0-2mm	1 mm	1 mm
Acquisition time	4 min	4min	4min	4min	4 min	15 sec
Flip angle	90°	90°	80°	80°	180°	90°

● **MR images analysis:** Images were sent to the workstation (Phillips Extended MR Workspace) for further image processing.

● **ADC map measurement:-**

- ADC maps were generated on the workstation. Calculation of the

ADC value was an automated process.

- ROI at the ablation zone.
- ROI at the margins of the ablation zone.
- ROI at segment IV or V of the liver.

● **Interpretation of the MR images:**

- Signal of the ablation zone at T1, T2, Dual phase and DWIs.
- ADC measurement (mean and ADC ratios) of the liver parenchyma, ablation zone, at the margins of the ablation zone and periblation zone.

● **Dynamic study interpretation:**

- Pattern of enhancement of ablation zone in arterial, portal and delayed phases.
- Ill-defined perilesional parenchymal enhancement may relate to post interventional changes. This was defined as early arterial phase enhancement beyond the ablated cavity that persisted in the delayed phase.
- Well defined enhancement at the margin of the ablation zone which may be either:
 - a) Granulation tissue persistent on delayed phase enhancement.
 - b) Nodular or hallow enhancement that suggested tumor recurrence/residual.

● **Result of ablation of the tumor:** The border of resolved lesions were smooth but in unresolved lesions were nodular and irregular.

● **Standard of reference:**

- It was difficult to obtain pathologic confirmation in patients who underwent ablation because most of these patients did not undergo surgery. In addition, biopsy may result in sampling error as recurrent lesions were mostly small nodules.

So, resolved lesions were considered if the finding become regressed or disappeared in the follow up studies.

- Unresolved lesions were considered if the findings showed:

Enlargement of the ablation zone.

Focal changes at the margin of the ablation zone with:

- a) Diffusion hyperintensity (restriction) and low ADC value $<1.05 \times 10^{-3} \text{ mm}^2/\text{s}$.
- b) Early arterial phase enhancement of the ablation zone which became hypointense relative to the liver parenchyma in the delayed phase.
- c) The general observation period included clinical, LAB and imaging follow up within first three months after the RFA then every 3 months for 1 year, and every 6 months for 2 years.

Statistical analysis of data: The collected data were organized, tabulated and statistically analyzed using statistical package for social science (SPSS) version 19 (SPSS Inc, Chicago, USA). Mean, standard deviation, frequency and percentage were used as descriptive. Examining the difference in ADC values was performed using unpaired t test. P value less or equal to 0.05 was considered significant

Ethical consideration:

Institutional review board (IRB) approval: The protocol was discussed by the ethical scientific committee for approving the study and informed consent was obtained before participation.

Consent procedure:

The Investigator made certain that an appropriate informed consent process was in place to ensure that potential research subjects, or their authorized representatives, were fully informed about the nature and objectives of the clinical study, the potential risks and benefits of study participation, and their rights as research subjects. The Investigator obtained the written, signed informed consent of each subject, or the subject's authorized representative, prior to performing any study-specific procedures on the subject. The Investigator retained the original signed informed consent form.

Subject Confidentiality:

All laboratory specimens, evaluation forms, reports, video recordings, and other records that lift the site did not include unique personal data to maintain subject confidentiality.

RESULTS

- In our study there were 37 patients (74%) have resolved lesions while 13 patients (26%) have recurrent/residual lesions.
- The signal intensity of the ablation zone in the T1, T2 WIs, DWIs and in dynamic study was 67% of the patients imaged within the 1st month after ablation showing heterogeneous high T1 and low T2, 20% showed homogenous high T1 and low T2 signal and 13.3% showed homogenous low T1 and high T2 signal. In the 4-12

months imaging, most of the ablation zones elicited homogenous high T1 and low T2 signal, (**Fig. 1 & 2**) 77% of patients imaged within 4-6 months and 85% of patients imaged within 9-12 months. DWIs showed high signal (restricted) and low signal in ADC map. In dynamic study revealed non enhancing ablation zones.

- The border of resolved lesions were smooth but in unresolved lesions were nodular in 11 patient out of 13 (84.6%) (**Fig. 3 & 4**), and irregular in two patient (15.4%).
- The signal intensity of the recurrent/residual lesions in the T1, T2, DWIs and in dynamic study were classified into intermediate, high or low signal (relative to the ablation zone). 31% of the recurrent/residual lesions elicited low T1 and 77% elicited high T2 signal, but in DWIs appeared hyperintense (restricted) whereas necrotic regions appeared hypointense and low signal in ADC map. Dynamic study showed early arterial enhancement and rapidly washing out in delayed images.
- We used b values 0, 500 and 1000 s/mm² to avoid intravoxel perfusion effect which resulted from low b values (less than 50 s/mm²) as well as image degradation from high b values (more than 1000 s/mm²). **Table (2)** showed mean ADC values of liver parenchyma, ablation zones, residual/recurrent lesions and periablation tissue changes.

Table (2): Mean ADC values of liver parenchyma, ablation zones, residual/recurrent lesions and periablation tissue changes.

Category	No.	Mean ADC	SD
Liver parenchyma	50	1.18 x 10 ⁻³ mm ² /s	0.07
Ablation zones	50	1.38 x 10 ⁻³ mm ² /s	0.19
Residual/recurrent lesions	13	0.91 x 10 ⁻³ mm ² /s	0.09
Periablation tissue changes	30	1.29 x 10 ⁻³ mm ² /s	0.12

- The measured cut off value between the completely ablated lesions and residual/recurrent lesions was 1.05x10⁻³ mm²/s. Our study showed that ablation zones can be differentiated from liver parenchyma visually in the DWIs and by means of ADC in all patients. There were no statistical difference in the mean ADC values between the ablation zones of the resolved 1.37 x 10⁻³ mm²/s and unresolved lesions 1.39 x 10⁻³ mm²/s (P value 0.7). ADC ratios between the recurrent/residual lesions and the liver parenchyma were 0.77. The mean ADC value within segment VI or V of the liver was 1.18x10⁻³ mm²/s denoting parenchymatous liver disease.
- We studied the presence of periablation thin and regular enhancement area surrounding the ablation zone in all phases of dynamic study. These areas had low signal in T1 and high signal in T2 WIs with mild hypointensity in the DWIs. This was present in 99% of patients imaged within the 1st. month after ablation. This persists in 11% of patients imaged at 4-6 months and only in 7% after 9-12 months. The benign finding (based on the follow up study) represented reactive inflammatory and vascular changes of the liver parenchyma adjacent to the ablation zones (Table 3).

Table (3): Comparison between the mean ADC values.

Ablation zones in all patients (n= 50)	SD	Liver parenchyma in all patients (n= 50)	SD	ADC Ratio	P value
1.38 x 10 ⁻³ mm ² /s	±0.17	1.18 x 10 ⁻³ mm ² /s	±0.06	1.15	0.0001
Residual/recurrent lesions (n=13)		Ablation zones in all patients (n=50)		ADC Ratio	P value
0.91 x 10 ⁻³ mm ² /s	±0.08	1.38 x 10 ⁻³ mm ² /s	±0.17	0.66	0.0001
Residual/recurrent lesions (n=13)		Liver parenchyma in all patients (n=50)		ADC Ratio	P value
0.91 x 10 ⁻³ mm ² /s	±0.08	1.18 x 10 ⁻³ mm ² /s	±0.06	0.77	0.0001
Ablation zones in the resolved lesion (n=37)		Ablation zones in the residual/recurrent lesions (n=13)		P value	
1.37 x 10 ⁻³ mm ² /s	±0.19	1.39 x 10 ⁻³ mm ² /s	±0.08	0.7	
Residual/recurrent lesions (n= 13)		Periablation tissue changes (n=30)		ADC Ratio	P value
0.91 x 10 ⁻³ mm ² /s	±0.08	1.29 x 10 ⁻³ mm ² /s	±0.11	0.70	0.0001

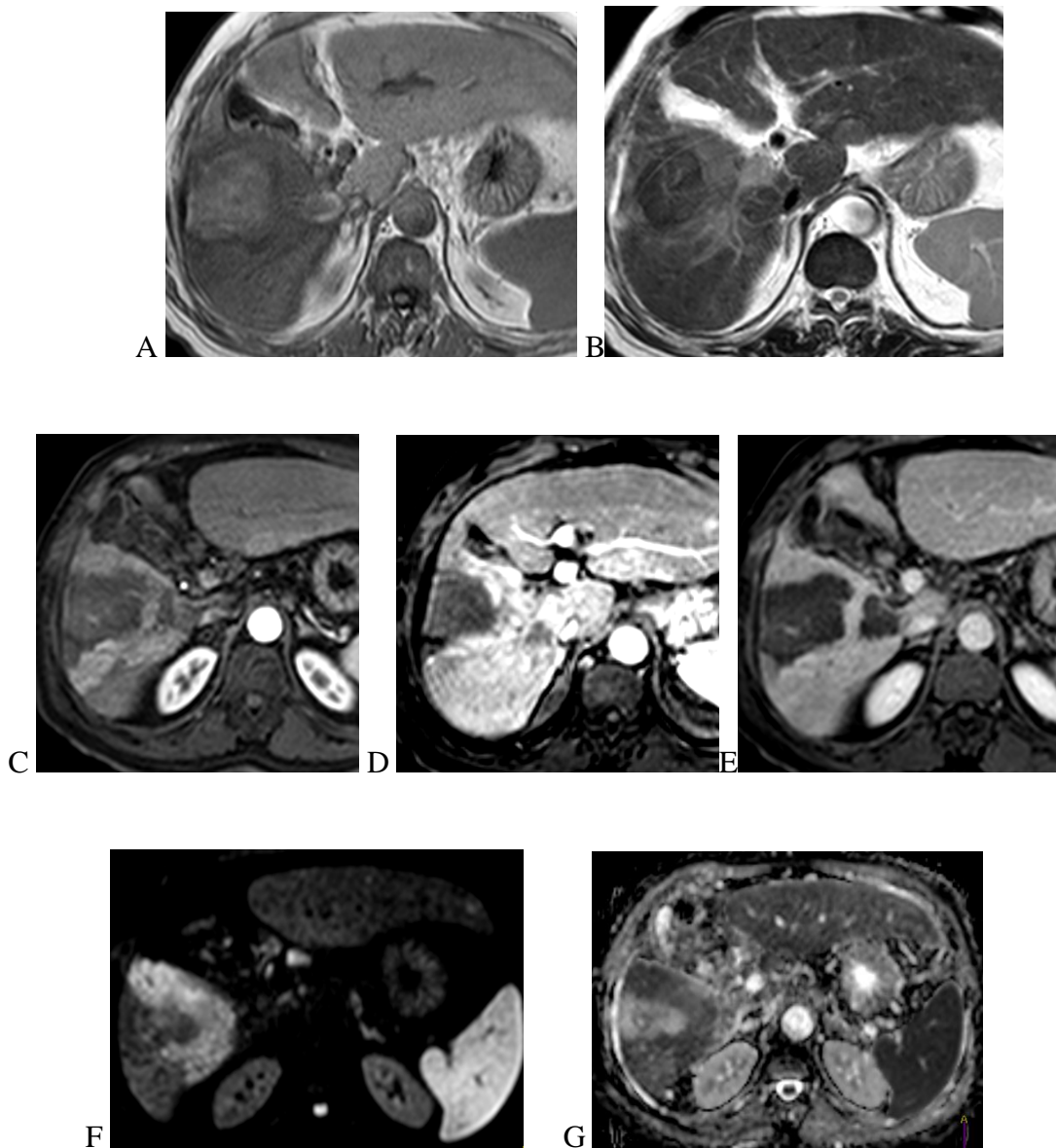


Figure (1): Radiofrequency ablation for HCC at segment V after 1 month. (A) and (B). Precontrast axial T1 and T2 WIs. The ablation zone appeared of high signal in T1 and low signal in T2 WIs. Dynamic MRI examination (C). Arterial, (D)- Portal and (E) Equilibrium phases. The ablation zone revealed no contrast enhancement, while the surrounding parenchyma showed inhomogeneous contrast enhancement during the arterial phase that showed delayed washout in the portal and delayed phases. (F). DWI and (G). ADC map. The ablation zone appeared of low signal in the DWIs and high signal in the ADC map (average ADC value = $1.330 \times 10^{-3} \text{ mm}^2/\text{s}$). The surrounding hepatic parenchyma showing low T1 and intermediate signal in T2 WIs appeared hyperintense in the DWI and low signal intensity in ADC map, representing perfusion changes secondary to portal vein thrombosis.

Diagnosis: Complete ablated lesion with portal vein thrombosis and secondary perfusion changes.

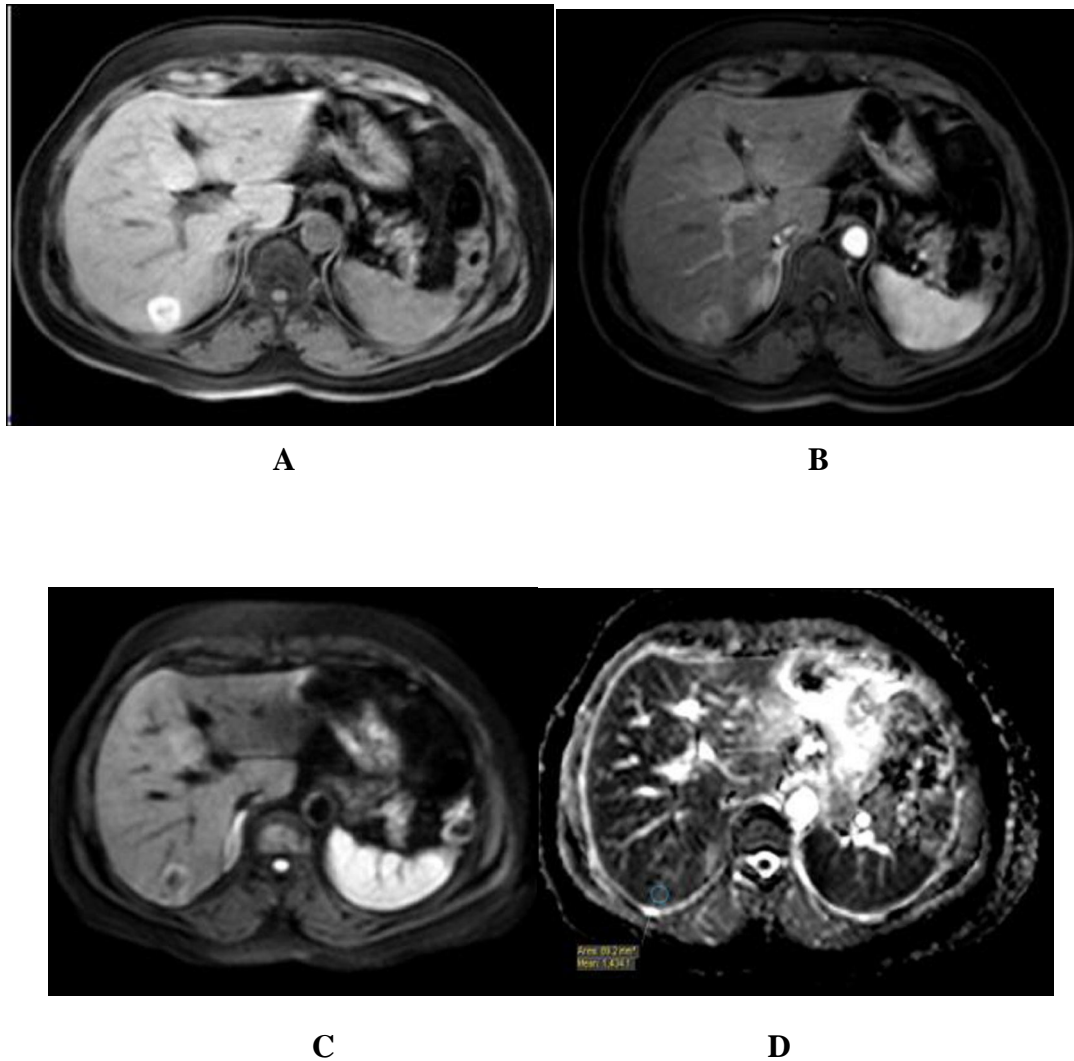


Figure (2): Radiofrequency ablation for solitary hepatic metastases from cancer colon in segment V1 after 12 months. (A). Precontrast axial T1WI the ablated zone showed high signal intensity with pyramidal shape interior low signal intensity. (B) Dynamic study: Late arterial phase showed faint marginal enhancement of the ablated area. (C) DWI: The ablated zone showed interior low signal and marginal high signal intensity.(D).ADC map: The ablated zone appeared isointense to liver parenchyma (average ADC value = $1.380 \times 10^{-3} \text{ mm}^2/\text{s}$).

Diagnosis: Completely ablated lesion.

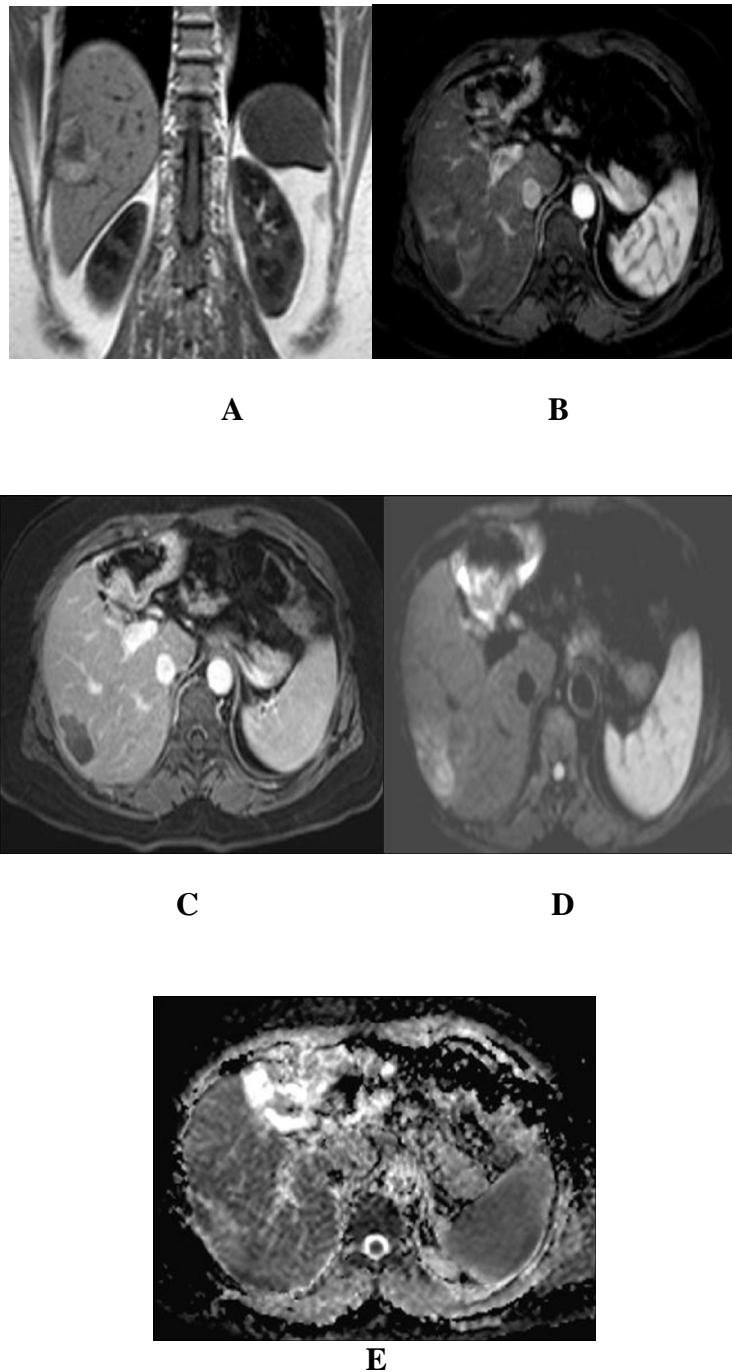


Figure (3): Radiofrequency ablation for HCC at segment V after 3 months (A). Precontrast coronal T1WI, the ablated zone showed peripheral high signal intensity. (B) Dynamic study: Late arterial phase the ablated zone showed marginal contrast enhancement. (C). Portal phase the ablated zone showed early washout of the lesion enhancement. (D) DWI the lesion showed Inhomogeneous bright signal (restrict diffusion). (E) ADC map: The lesion showed superior and anterior subcapsular eccentric and elliptical shape small area of low signal intensity, with heterogeneous low signal of the rest parenchymal lesion (average ADC value = $1 \times 10^{-3} \text{ mm}^2/\text{s}$).
 Diagnosis: Incomplete ablated lesion with eccentric residual area revealed low ADC value.

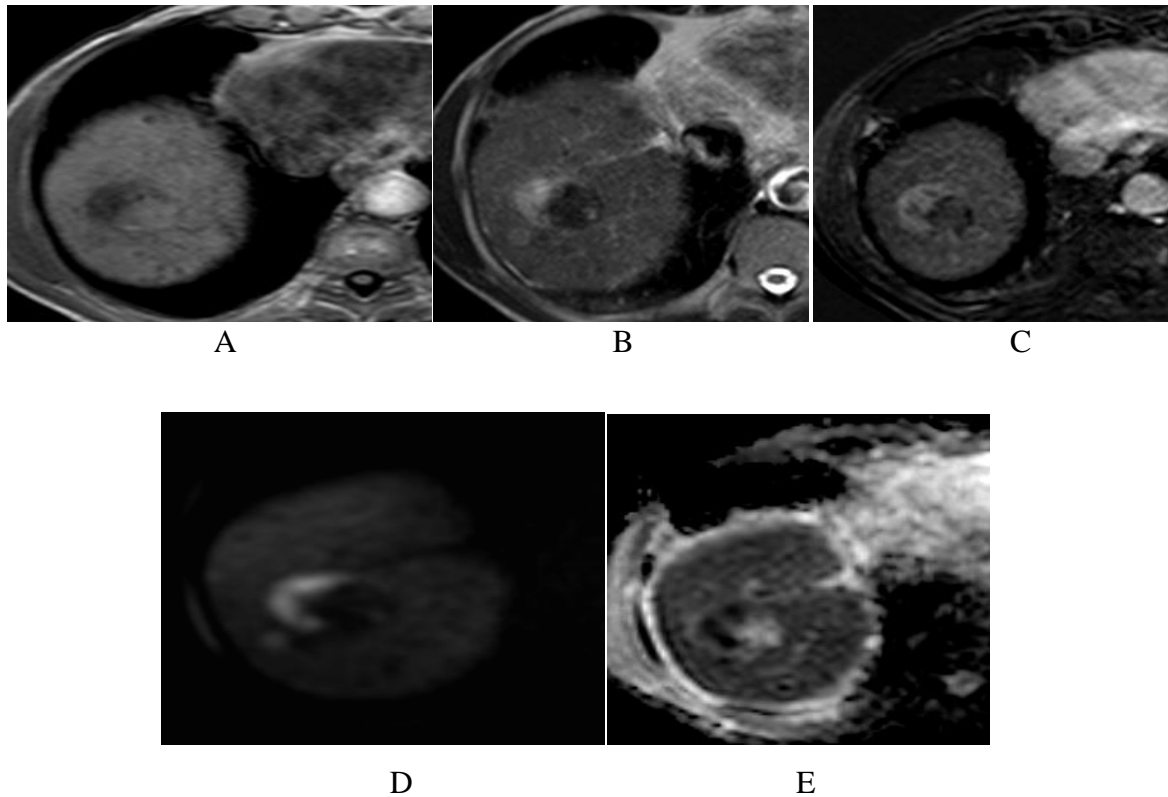


Figure (4): Radiofrequency ablation for metastatic lesions from breast cancer at segment V11 after 9 months. (A) and (B). Precontrast axial T1 and T2 WIs. The ablated zone showed central area of high T1 and low T2 signal intensity and superior crescent margin and small posterior spherical nodule of low T1 and high T2 signal intensity. (C). Dynamic study: Late arterial phase showed enhancement of the nodule and the crescentic superior margin and poor contrast enhancement of the central interior zone. (D). DWIs showed restricted diffusion of the superior margin and the small posterior nodule in contrast to the center of the lesion (low signal intensity). (E). ADC map showed reversibility of the signal intensity where low signal superior margin and the nodule with high signal intensity of the interior lesion (average ADC value = $1.001 \times 10^{-3} \text{ mm}^2/\text{s}$).
 Diagnosis: Incomplete ablated lesion with anterior marginal and posterior residual lesions revealed low ADC value.

DISCUSSION

In the current study, DWI was done by using respiratory triggered fat suppressed single shot echoplanar sequence. **Kandpal et al. (2009)** reported high concordance of results of ADC evaluation by used both breath hold and respiratory triggering examination techniques considering the fact that respiratory triggering imaging

require longer acquisition time. **Kim et al. (2011)** mentioned that the dynamic contrast enhanced MRI can assesses the change in tumor vascularity and perfusion local ablation therapy.

In the present study, the signal intensity of the ablation zone in the T1, T2 WIs, DWIs and in dynamic study was 67% of the patients imaged within the 1st month after ablation showing hetero-

geneous high T1 and low T2. 20% showed homogenous high T1 and low T2 signal and 13.3% show homogenous low T1 and high T2 signal. In the 4-12 months imaging most of the ablation zones elicited homogenous high T1 and low T2 signal (77% of patients imaged within 4-6 months and 85% of patients imaged within 9-12 months). In DWIs appeared high signal (restricted) and low signal in ADC map. In dynamic study revealed non enhancing ablation zones. **Kierans et al. (2010)** found that 87.8% of the ablation zones imaged within the first 4 months after ablation show high T1 signal with persistence of the high signal in about 84.1% in patients imaged >9months after ablation. **Braga et al. (2010)** stated that the treated lesion exhibits increased signal on T1 and decreased signal intensity on T2 WIs. The heterogeneous appearance of the ablation zone reflecting the different post treatment tissue changes that can be found after RFA is mainly due to necrosis, hemorrhage and dehydration. In the study performed by **Batra and Tripathi (2004)** necrosis and microhemorrhage are the cause of hyperintensity in DWIs in post therapeutic necrosis of malignant lesions. **Nisha and Sainani (2013)** reported in dynamic study that the ablation zone is well demarcated and no enhancement suggests a lack of viable tumor.

We reported that the borders of resolved lesions were smooth but in unresolved lesions were nodular in (84.6%) and irregular in two patients (15.4%). This agreed with another study by **Dromain et al. (2002)** who reported that (77.5%) of the recurrent lesions showed small nodules at the ablation zone margins and (22.5%) of the lesions showed thick irregular rim at the ablation

zone margins. Also, **Koda et al. (2012) and Minami et al. (2014)** found that the recurrent or residual rate tends to be lower in HCC patients with an adequate ablation margin.

Our finding demonstrated that 31% of the recurrent/residual lesions elicit low T1 and 77% eliciting high T2 signal but in DWIs appeared hyperintense, whereas necrotic regions appear hypointense. **Nisha et al. (2013)** found that the recurrence lesions appeared isointense to hypointense on T1, and is isointense to moderately hyperintense on T2. **Schraml et al. (2009)** mentioned that viable tumor regions appear hyperintense on DWIs, whereas necrotic regions appear hypointense.

Our study had b values 0, 500 and 1000 s/mm² to avoid intravoxel perfusion effect which resulted from low b values (less than 50 s/mm²) as well as image degradation from high b values (more than 1000 s/mm²). **Jiang et al. (2008)** stated that the signal intensity on DWI is a mixture of diffusion and perfusion. Also they stated that the image quality diminished greatly with increasing b value especially on b 2000 DWI.

We found that the mean ADC value of the liver parenchyma was (1.18 x 10⁻³ mm²/s), ablation zones in all patients were (1.38 x 10⁻³ mm²/s), recurrent/residual lesions were (0.91 x 10⁻³ mm²/s) for ablation zones in the resolved lesions were (1.37 x 10⁻³ mm²/s), while for ablation zones in the residual/recurrent lesions were (1.39 x 10⁻³ mm²/s) and for periablation tissue changes was (1.29 x 10⁻³ mm²/s). This agreed with **Schraml et al. (2009)** who found that mean ADC values of the liver parenchyma was (1.06

$\pm 0.21 \times 10^{-3} \text{ mm}^2/\text{s}$) while for the ablation zones were $(1.19 \pm 0.30 \times 10^{-3} \text{ mm}^2/\text{s})$. They also found that the mean ADC values of the whole ablation zones do not significantly differ between the resolved lesions and the unresolved lesions also the mean ADC value of the recurrent lesions differ significantly from the mean ADC value of the perilesional tissue changes (P value 0.0124). Different studies by **Miller et al. (2010)**, **Vergara et al. (2010)** and **Onura et al. (2012)** worldwide were established to determine the value of DWI in evaluation of hepatic focal lesions and in assessment of malignant lesions response after loco-regional therapy. They reported that ADC values of benign hepatic lesions were significantly higher than that of malignant hepatic tumors **Szurowska et al. (2013)** stated that quantitative measurements of diffusion showed that malignant lesions present lower ADC values than benign ones and surrounding liver parenchyma.

Our study revealed that the ablation zones can be differentiated from liver parenchyma visually in the DWIs and by means of ADC in all patients. This finding was also stated by **(Schraml et al. (2009))**.

We also calculated the ADC ratios between the recurrent/residual lesions and the liver parenchyma was 0.77 ± 0.12 . This agreed with **Schraml et al. (2009)** who found that ADC ratio between the recurrent/residual lesions and the liver parenchyma was 0.90 ± 0.21 .

In the present study mean ADC value within segment VI or V of the liver was $(1.18 \times 10^{-3} \text{ mm}^2/\text{s})$ denoting parenchymatous liver disease. Similar results were also obtained by **Bittencourt et al. (2011)** who mentioned that mean ADC value in

parenchymatous disease was $(1.12 \times 10^{-3} \text{ mm}^2/\text{s})$, while in normal liver was $(1.47 \times 10^{-3} \text{ mm}^2/\text{s})$.

The present work showed presence of periablation thin and regular enhancement area surrounding the ablation zone in all phases of dynamic study. These areas had low signal in T1 and high signal in T2 WIs with mild hypointensity in the DWIs, in 99 % of patients imaged within the 1st month after ablation. This persisted in 11% of patients imaged at 4-6 months and only in 7% after 9-12 months. The benign finding (based on the follow up study) represented reactive inflammatory and vascular changes of the liver parenchyma adjacent to the ablation zones. This was in line with results of **Kierans et al. (2010)** who found the perilesional enhancement in 53.7% of cases imaged < 4 months after RFA, that persists in 25.6% at 4-9 months and only in 12.2% in cases imaged >9 months after RFA. These areas exhibit mild hyperintensity in DWIs in the 20% of the patients imaged within the first 6 months after the ablation, persist in 10% in the next follow up study at 6-9 months and only in 5% of patients at 9-12 months. Also, **Schraml et al. (2009)** reported perilesional ill-defined area of diffusion hyperintensity in 22.5% of the patients imaged within the first 6 months after the ablation, persist in 19.5% in the next follow up study at 6-9 months and only in 6.5% of patients at 9-12 months. **Goldberg et al. (2009)** stated that benign periablation enhancement surrounding the ablation zone is frequently found to show moderate to intense peripheral rim like enhancement on the arterial phase of contrast enhanced MRI which may persist

on the delayed phase. This rim has low signal on T1 and high signal intensity on T2WIs. **Nisha et al. (2013)** mentioned that the signal alterations in the periphery of the ablation one due to the fact that therapeutically induced nontumoral tissue changes show low cellularity and therefore present with less signal in DWI and high ADC, respectively, and can thereby be distinguished from tumoral tissue that presents with high signal in DWI and low ADC value, respectively. Also, **Kim et al. (2011)** found that ADC could be helpful for analyzing unclear hyperintense areas adjacent to the ablation zone. where differentiation between tumor tissue and post treatment changes is unambiguous.

Our finding demonstrated that DWI showed viable tumor regions and suspected areas in the periphery of the ablation zone could be identified more easily, and analyzed precisely in conjunction with the conventional T1, T2, and dynamic contrast enhanced images. **Hayashida et al. (2006)** demonstrated that, in different organs, DWIs has been used to predict and monitor the effect of several treatment options and to differentiate between viable and necrotic tumor tissues. Close and careful follow up is needed in patients who underwent treatment by RFA to detect recurrence at an early stage. **Ajaykumar et al. (2013)** mentioned that radiologists must interpret DWI in conjunction with other MRI pulse sequences, especially keeping in mind the pretest probability of an abnormality. Overall, the limitation of the DWI sequence is predominantly lesion

characterization rather than lesion detection.

CONCLUSION

Dynamic contrast enhanced images and DWI showed viable tumor regions and suspected areas in the periphery of the ablation zone could be identified more easily, and analyzed precisely in conjunction with the conventional T1 and T2WIs. Recognition of abnormal post RFA imaging findings and differentiation of abnormal findings from normal post-procedural changes are important for diagnostic and interventional radiologists. Early identification of residual or recurrent disease can facilitate timely retreatment, management, and follow up care.

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دور التصوير بالرنين المغناطيسي الديناميكي والتصوير الإنتشاري فى تقييم أورام الكبد الخبيثة بعد علاجها بالتردد الحراري

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خلفية البحث: يعتبر من الأهمية تقييم إستجابة الأورام الخبيثة في الكبد بعد علاجها بالتردد الحراري حيث أن التصوير بالرنين المغناطيسي الديناميكي بالصبغة والتصوير الإنتشاري بعد علاج أورام الكبد الخبيثة بالتردد الحراري يستخدم في متابعة الكشف عن علاج أو وجود بقايا للأورام.

الغرض من البحث: تقييم دور التصوير بالرنين المغناطيسي الديناميكي بالصبغة والتصوير الإنتشاري بعد علاج أورام الكبد الخبيثة بالتردد الحراري.

المرضى وطرق البحث: تم عمل هذه الدراسة في الفترة من يناير 2014 م إلى ديسمبر 2015 م وشملت 50 مريضا بأورام الكبد الخبيثة بعد علاجها بالتردد الحراري 40 ذكور (80%) و10 إناث (20%) وتراوح أعمارهم بين 45-80 سنة من العمر.

وقد خضع جميع المرضى للتالي:

1- التاريخ المرضي والفحص السريري.

2- الفحوص المعملية.

3-التصوير بالرنين المغناطيسي الديناميكي بالصبغة والتصوير الإنتشاري.

النتائج: وجد أن 40 مريضا مصابون بسرطان الكبد الأولى، بينما 10 مرضى مصابون بثنويات سرطان الكبد. وقد تم علاج 37 حالة منها بنجاح بالتردد الحراري. ووجد في 13 حالة بقايا من الورم بعد علاجها بالتردد الحراري.

وأظهرت نتائج البحث إرتفاع الأنتشار الظاهري للحالات ناجحة العلاج بالتردد الحراري بالمقارنة بالحالات التى وجد فيها بقايا الأورام الخبيثة.

الخلاصة: التصوير بالرنين المغناطيسي الديناميكي بالصبغة والتصوير الإنتشاري يستخدمان معا فى متابعة مرضى الأورام الخبيثة للكبد بعد علاجها بالتردد الحراري حيث يعتبر الأخير إضافة هامة وفعالة للتشخيص.