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THE ROLE of DIFFUSION WEIGHTED IMAGING in THE EVALUATION of TREATMENT RESPONSE OF HEPATOCELLULAR CARCINOMA AFTER TRANS-ARTERIAL CHEMOEMBOLIZATION

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***Abstract**:*
Background: Hepatocellular carcinoma represents 70 - 85% of the global liver cancer burden. Diffusion-weighted imaging, a non-invasive diagnostic MRI technique, detects MR signal changes in hepatocellular carcinoma after trans-arterial chemo-embolization; tumor necrosis accompany by increasing in ADC values, as such allowing distinction among viable and necrotic tumors portion. An investigation objective was to elucidate diffusion weighted MRI technique efficiency in residual/ recurrent diseases detection after transarterial chemoembolization of non operable HCC lesions.
Results: We performed a cross sectional study over 33 patients with total 49 TACE -treated HCCs and compared DWI results with those of Dynamic contrast enhanced MRI. Diffusion weighted MRI has sensitivity of 86.7%, specificity of 84.7%, positive predictive of 81.2%, negative predictive of 89.2% and agreement of 85.5%. Differentiation among malignant and negative groups' ADC variables were significantly different. ROC curve shows, ADC values could predict residual/recurrence of tumor after treatment at a cut off level ≤1000.5 with 72.1% and 75.4% sensitivity and specificity, respectively.
Conclusion: DWI & ADC values may aid as alternative markers in assessment of HCC cases after TACE in patients having contraindications to contrast administration and in assessing small lesions adjacent/closely related to vessels where intravenous contrast administration is not most effective.

INTRODUCTION

Hepatocellular carcinoma (HCC) represents 70 - 85% of the global liver cancer burden[1].

Trans-arterial chemo-embolization (TACE) is one of the loco-regional therapies employed to treat intermediate-stage HCC cases whose were not eligible for curative surgical resections and is currently approved as their first-line non-curative therapy.

The evaluation of the treatment efficacy is crucial, when histological assessment of each nodule was not conceivable or reasonable for cases, assessing treatment response is limited to radiological imaging to evaluate tumour viability[5].

Triphasic CT is the standard imaging technique to assess the immediate treatment response[4].

However, MRI was very beneficial than multidetector CT in detecting viable residual tumour tissue following TACE. Using MRI is imperative throughout follow-up[4].

Non contrast T1 and T2 weight sequences image elucidate the morphologic and fluid contents changing, while dynamic contrast enhancement could give more information's on perfusion[4].

On dynamic contrast MRI lesional enhancement after TACE indicates granulation and tumor residual tissues mixed by necrotic tissues. Differentiation depending on enhancement phase, granulation tissue elicits delay uptake residual tumor tissues show early arterial enhancement denoting un-successful TACE treatment[6].

Diffusion-weighted imaging is functionally non-invasive MRI techniques which depicts MR signal changing in tissue attributed to water proton motion and changes depend on cell membrane integrity degree. Viable tumour cells' intact membranes restricted water diffusion, while necrotic tumour with disrupted cells membrane elicited increasing water diffusion[3].

Water mobility is quantitatively assessed by constant known as apparent diffusion coefficient. Tumour necrosis associated with increased in ADC [3].

ADC has the capability of predicting the tumour response for treatments weeks pre morphologically changing. DWI increase sensitivity of detecting after TACE residual HCC.

METHODS

The investigation was cross sectional investigation including 33 cases having 49 HCC lesions underwent TACE over 24 months (May 2018– May 2020).

MRI protocol

All cases performed by use of 1.5 T machines (Achieva, Philips medical system, Eindhoven, Netherlands) &/or (Ingenia, Philips medical system, Eindhoven, Netherlands), Torso phased-array coil is used for the abdomen.

a) *Non contrast series:*
Axial T1 in & out of phase, T2 and spin echo based SSh-HvT2WI (heavy T2), axial SPAIR images, coronal T2 and coronal heavy T2.

b) *Dynamic study:*

- Dynamic study post manual bolus injection by 0.1mmol/kg body weight of Gd-DTPA and flushed with 20ml of sterile saline from antecubital vein.
- Dynamic imaging by 3D fat-suppressed T1-weighted gradient echo sequence.
- A dynamic series consisted of one pre contrast series followed by four successive post contrast series including early arterial, late arterial and portal phases with breath-holding technique follow by 5-min delay phase imaging.

c) *Diffusion weighted image:*

- DWI using single-shot spin-echo echo-planar imaging throughout one or more breath holds.
- Three b values (0, 200, and 800 s/mm2) were taken.

Interpretation of the MR images

DWI findings were interpreted and compared to those of DCE MRI. Every case was interpreted separately by two different hepatic imaging experienced readers accorded to AASLD.

Each one of the readers separately interpreted the Dynamic MRI and subtraction MRI images and comparing to diffusion weighted images and ADC value which recorded.

We categorize patients into two groups:

- *Resolved group (LR-TR Non-viable):* No MRI sign for residual or recurrent tumor viabilities by readers.
- *Unresolved group (LR-TR Viable):* Residual Evidences or recurrent tumor tissues through readers.

DATA MANAGEMENT AND ANALYZED

Data analyzed by using SPSS **20.0. Armonk, NY: IBM Corp.**

i. Descriptive statistics:
   1- Data test for normal distrebution by Shapiro Wilk test and express as SD for parametric numerical data or median for non-parametric numerical data
   2- Frequency and % for non-numerical data.

ii. Analytical statistics:
   1. Student T Test use for assessment significantly differences.
   2. Fisher's exact test for examining relationships between 2 qualitative variables when expected count <5 in >20% of cells
   3. The ROC Curve evaluates sensitivities and specificities for quantitative diagnostic measurements which categorize cases into one of two groups
   4. Kappa statistics for examining agreements among 2 qualitative variables < 0 as indicated to no agreement and 0–0.20 (slight), 0.21–0.40 (fair), 0.41–0.60 (moderate), 0.61–0.80 (substantial), and 0.81–1 (almost perfect agreement)

P- value: significance level

P< 0.05: Significant (S).

RESULTS

33 cases with 49 HCCs, 16 of them repeated the follow-up (4 of them underwent two follow ups, 7 underwent three follow-ups, 4 underwent four follow-ups and one underwent eight follow-ups), one of them underwent re-embolization.

Each lesion in each follow-up was interpreted individually with total 104 lesional interpretation and the results were analyzed as follows:

The mean age among cases was 63.3± 6.9, ranging between 47 to 78 years. Males represented 97% of cases and females represented 3% of cases.

The standard reference was treated versus residual/recurrent HCC that was finally diagnosed depending on the follow-up dynamic MRI image findings.

The "negative/well-treated lesions" group included 61 lesions (58.7%), while the "residual/recurrent lesion" group included 43 lesions (41.3%).

Analysis of lesions characteristics

a) Size:

The size of chemo-embolized lesions ranged from 0.9 to 10.7 cm.

b) Relation between DWI results and treatment outcome among cases

The lesions eliciting low DWI signal were predominantly treated cases (83.3%), while the lesions eliciting high DWI signal were predominantly residual/recurrence cases (60%).

c) Comparison between treated and residual/recurrence lesions as regard ADC values:

High significantly differences among treated patient and cases with residual/recurrence as regard mean ADC values, with higher mean values among treated cases (1185.8 vs 878.5 x 10^{-3}) (Figure 1).

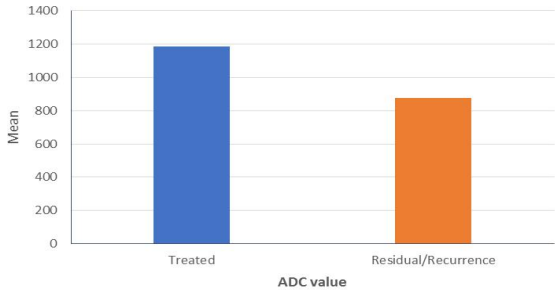

Figure 1: Correlation between mean ADC values and treatment outcome.

d) ROC Curve using ADC values for prediction of residual/recurrence among study case:

Using roc curve, it was shown that ADC values could predict residual/recurrence of tumor after treatment at a cut off level ≤1000.5 with 72.1% and 75.4% sensitivity and specificity respectively (Figure 2).

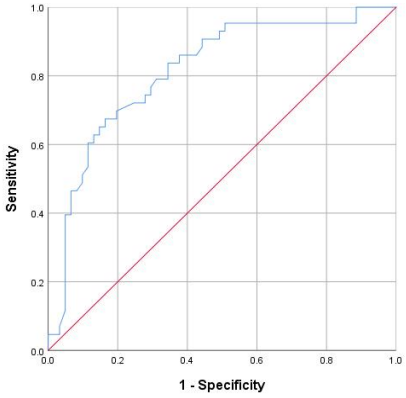

Figure 2: ROC curve showing sensitivity and specificity ADC predictive values for residual/recurrence lesions.

DWI Data interpretation

a) Agreement between Post Contrast enhancement and apparent diffusion restriction among lesions

There was a significant substantial (large) agreement (kappa= 0.709) between Apparent diffusion restriction and Post Contrast enhancement (figure 3).

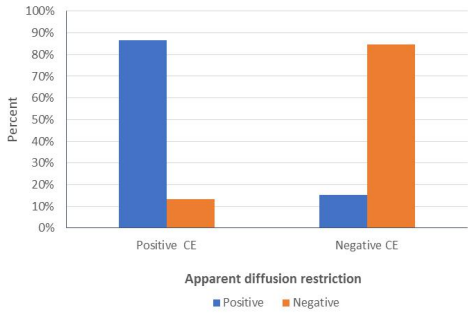

Figure 3: Agreement between post contrast enhancement and apparent diffusion restriction

Diagnostic accuracy (sensitivity, specificity, PPV, NPV and accuracy) of apparent Diffusion restriction

The sensitivity, specificity, PPV, NPV and accuracy of Apparent Diffusion restriction with respect to Post Contrast enhancement result was 86.7%, 84.7%, 81.2%, 89.2% and 85.5% respectively.

b) Agreement between Post Contrast enhancement and true diffusion restriction among lesions:

There was a significant moderate agreement (kappa= 0.544) between True Diffusion restriction and Post Contrast enhancement (Figure 4).

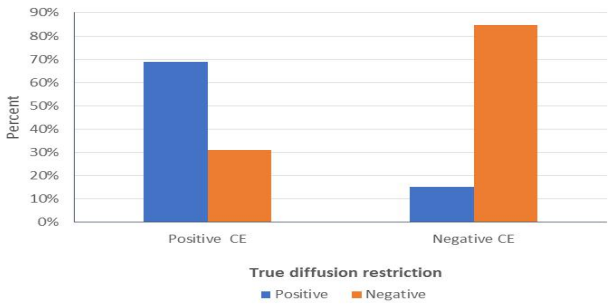

Figure 4: Agreement between post contrast enhancement and true diffusion restriction.

Diagnostic accuracy (sensitivity, specificity, PPV, NPV and accuracy) of True Diffusion restriction:

The sensitivity, specificity, PPV, NPV and accuracy of True Diffusion restriction with respect to Post Contrast enhancement result was 68.9%, 84.7%, 77.5%, 78.1% and 77.8% respectively.

DISCUSSION

HCC is 6th and 4th commonly cancer globally and in Egypt respectively**.**

Hepatitis C virus (HCV) infection is a major risk of advanced hepatic fibrosis and cirrhosis, with notably increased risk for development of HCC[9]**.** All our cases were complicating HCV infection.

Transarterial chemoembolization is gold care standard for intermediate-stages hepatocellular carcinoma (HCC) patients who had rather preserved liver function[10]**.**

Assessing treatment outcome post TACE is crucial for doing therapeutic decisions [11]**.**

Post TACE procedures, HCC tumor cells showed necrosis and apoptosis and increasing cells membranes permeability and enlarged cells gap, thus facilitating motion of water molecule on DWI and increasing ADC value[12].

The LI-RADS v2018 is the gold standard for evaluation treatments results for HCC post TACE, it depended on treated focal lesion's criteria to exclude post-treatments changes in form of coagulative necrosis and hemorrhage [13].

DWI increases the sensitivity for HCC detection, the liver-to-lesion contrast and the specificity in differentiating negative cirrhotic nodules [14].

This study includes 33 patients with 49 TACE treated HCCs aiming to verify the beneficial role of DWI in assessing treatment response of HCCs after TACE in Egyptian patients.

Sixteen of those 33 patients repeated the follow-up, each lesion in each follow-up was interpreted individually with total 104 lesional interpretation and no significant size changes ranging from 0.9 to 10.7 cm.

Forty-three out of the hundred and four HCC treated lesions given radiological observation suggestive of LR-TR viable while 61 treated lesions (including 2 benign enhancements (THAD)) were found to be LR-TR non-viable due to proper tumoral embolization.

The lesions eliciting low DWI signal were predominantly treated cases (83.3%), while the lesions eliciting high DWI signal were predominantly residual/recurrence cases (60%).

Ebeed et al. (2017) and **Osama et al. (2013)** reported that the liquefactive breaking down and intra-lesional necrosis were mainly reason for hyper-intensity in DWI image after therapeutic breaking down.

In **Saleh et.al. (2019)** noted 2 false-positive lesions (from forty lesions) misdiagnosed on diffusion-weighted images.

From our study observations, out of 61 well treated lesions there were 14 (22.9%) & 9 (14.7%) false-positive lesions of true diffusion restriction and apparent diffusion restriction respectively (i.e. positive diffusion restriction but no post contrast enhancement) misdiagnosed on diffusion-weighted and ADC imaging. While out of 43 residual/recurrence lesions there were 6 (14%) & 14 (32%) false negative lesions for true diffusion restriction and apparent diffusion restriction respectively (i.e. no diffusion restriction but positive malignant post contrast enhancement) misdiagnosed on diffusion-weighted and ADC imaging.

Afifi et al. (2016) study proposed that increasing in false-positive originat from Peri-lesional tissue insults and caused sustained hyperintensity on DWI with increased b factors.

Saleh et.al (2019) considered that false-positive findings in their study could be caused by post treatment hemorrhage &/or liquefactive necrosis of tumoral tissue that hindered diffusion facilitation and we agree with them.

The meta-analysis led by **Liu et al (2020)** demonstrated false negative and false-positive values for DWI in diagnosing residual or recurrent HCCs post TACE to be 15 and 17%

respectively. These findings could be caused by adjacent hepatic inflammation that could limit diffusion of water molecules leading to sustained increased DWI signal intensity, TACE induced intralesional hemorrhage or liquefactive necrosis may also cause diffusion restriction in necrotic tumoral tissue, Limited spatial resolution of DWI hindering accurate diagnosis of small tumors, DWI signal intensity is easily affected by tissue T2-relaxation time**.**

Those points also explain the number of false positive and false negative results in our study.

In **Saleh et al's (2019)** study, the difference between ADC variables for the viable and non-viable groups was differ significantly. Best cut off for maximum sensitivities and specificities was 1.35. at ADC value.

Ebeed et al. (2017), Tantawy and Mohamed (2016), also confirmed ADC mapping series increasing in non-viable lesions post TACE than viable lesions.

The current study also confirmed their findings and showed a highly significant difference between treated cases and cases with residual/recurrence tumoral tissue with P value < 0.0001. There were also significant difference as regard mean ADC values, with higher mean values among treated cases (1185.8 x 10 -3 ±SD 260.30 vs 878.5 x 10 -3 ±SD 248.54) (Figure 1).

Saleh et al's (2019) reported the ROC that ADC variable is good sign to differentiation after TACE tumor viabilities and non-viabilities.

In **Abd El Hak et. al. (2019)** differentiation among ADC variables of malignant and negative groups differed significantly. The best cut off that maximizes sensitivity and specificity was 1.26. At this ADC value, the sensitivity was 0.95 and specificity was 0.41 (1 –specificity = 0. 59).

Our study showed that using roc curve, ADC values could predict residual/recurrence (LR-TR viable) of tumor after treatment at a cut off level ≤1000.5 with 72.1% and 75.4% sensitivity and specificity respectively (Figure 2) which agrees with the previously mentioned studies.

In **Abd El Hak et. al. (2019)** study, they also found that diffusion MRI increased the sensitivity of local HCC detection on the expense of examination specificity due to increased false positives.

Statistical analysis done by **Saleh et al (2019)** found DCE MRI has 100% sensitivity, 95.24%specificity, 95.00%PPV, and 100%NPV with an 97.50%overall agreement. Nevertheless, DWI has 52.63% level of sensitivity, 90.48% of specificity, 83.33% PPV, 67.86% PPV and 72.50% NPV.

Our study showed sensitivity 68.9%, specificity 84.7%, PPV 77.5%, NPV 78.1% and accuracy of True Diffusion restriction 77.8% with respect to Post Contrast enhancement thus agreeing with **Saleh et al (2019)** with higher specificity than sensitivity unlike **Abd El Hak et. al. (2019)** study.

In **Abd El Hak et. al. (2019)** study, 8 false positive cases out of 50 patients were misdiagnosed on diffusion weighted imaging. When they reviewed the corresponding pattern

of diffusion restriction, 78.2 % of true positive cases exhibited focal peripheral nodular restriction. Meanwhile 62.5% of the false positive cases exhibited intralesional heterogeneous restriction. Thus suggesting that these false findngs originated from Intralesional hge & liquefaction necrosis causing diffusion restriction.

Our findings are matching with those of **Abd El Hak et. al. (2019)** where all the 9 false positive lesions showed central rather than peripheral diffusion restriction mostly due to the same reasons suggested by **Abd El Hak et. al. (2019).**

Abd El Hak et. al. (2019), Ebeed et al. (2017), Yu et al. (2009) and Goshima et al. (2008) stated that dynamic contrast enhanced MRI superior to diffusion weighted MRI in evaluating HCC response to treatment. As dynamical MRI has 90.5% sensitivities, 96.6%specificity of, 95 %positive predictive, 93.3% negative predictive and 94%overall agreement comparing to 95.83%, 69.23%, 74.19%, 94.74% and 82% , respectively of diffusion weighted imaging.

While our study showed that true diffusion restriction sensitivity 68.9%, specificity 84.7%, PPV 77.5%, NPV 78.1% and overall agreement of 77.8% with respect to Post Contrast enhancement .And that there was a significant moderate agreement (kappa= 0.544) between True Diffusion restriction and Post Contrast enhancement (Figure 4).

As 8 of the 64 lesions interpreted as negative true diffusion restriction showed apparent/facilitated diffusion restriction ie high DWI and low ADC signal but high ADC value, we decided to interpret all the apparent/facilitated diffusion restriction as a separate entity with total number of positive apparent/facilitated diffusion restriction 48 lesions and total number of negative apparent/facilitated diffusion restriction 56 lesions.

We found that there was a significant substantial (large) agreement (kappa= 0.709) between Apparent diffusion restriction and Post Contrast enhancement (figure 3) with sensitivity 86.7%, specificity 84.7%, PPV 81.2%, NPV 89.2% and accuracy of 85.5% with respect to Post Contrast enhancement result. Thus higher level of agreement with post contrast enhancement than that of the true diffusion restriction.

Taouli et al. (2010) found that ADC values were affected by intravoxel perfusions and usually overestimated when using a low b value. Therefore, avoided using low b values in their study on TACE treated HCCs which could interpret the conflict of interest found between true and apparent/facilitated diffusion restriction in our study inspite of using b value of 800.

Taouli et al. (2010) used a middle-range b value (of 500 s/mm$^{2)}$ despite high b values are in need to determining virtually true ADCs and found that liver contours were obscured when using high b values due to weak signals in the liver, which hampered radiologist interpretation in the clinical setting.

On the other hand the meta-analysis conducted by **Liu et. al. (2020**) showed that using lower b values lead to better DWI performance for the diagnosis of residual or recurrent HCCs after TACE than when using higher b values, revealing that the b value of DWI was one of the factors affecting diagnostic accuracy.

In our study though, we used b values 0, 500 and 800 s/mm2 to avoid the intravoxel perfusion effect that results from using low b values (less than 50 s/mm2) as well as image degradation from high b values (more than 1000 s/mm2).

In our study, we also found that respiratory triggered diffusion weighted images compensated the false results by the dynamic MRI in our patients who could not perform adequate breath hold technique.

In our study, we had some diagnostic limitations. First, it was difficult to obtain pathologic confirmation in patients who underwent chemoembolization because all of these patients were not subjected to surgery so we depended on the post treatment LIRADs system. Second, lesions included in our study were mostly larger than 1 cm in diameter, and some of them were located at the hepatic dome.

The fore mentioned factors could cause selection bias leading to increased sensitivity of diffusion-weighted images since hepatic lesions close to the diaphragm pose a challenge to DW-MRI evaluation as they are more sensitive to motion and susceptibility artifacts.

CONCLUSION

Our study showed that DW MRI has sensitivity of 69- 87 % compared to 97-100% of dynamic contrast enhanced MRI via application of LI-RADS v2018 diagnostic algorithmic approach system so cannot replace dynamic contrast enhanced MRI.

Yet our study suggests that DWI is a good complementary sequence in diagnosing residual or recurrent HCCs post TACE.

DWI & ADC values might serve as alternative indicator in further evaluating for HCC cases post TACE in patients having contraindications to contrast administration (like low GFR) and in assessing small lesions adjacent/closely related to vessels where intravenous contrast administration is not most effective.

List of abbreviations

ADC: Apparent diffusion coefficient.
CT: Computed tomography.
DCE: Dynamic contrast enhancement.
DWI: Diffusion weighted imaging.
GFR: Glomerular filtration rate.
HCC: Hepatocellular carcinoma.
MRI**:** Magnetic resonance imaging.
NPV: Negative predictive value.
PPV: Positive predictive value.
RF: Radiofrequency.
TACE: Transarterial chemoembolization.
THAD: Transient hepatic attenuation differences.

REFERENCES

[1] Jemal A, Bray F, Center MM, et al. (2011) Global cancer statistics. CA Cancer J Clin. 61(2):69-90.
[2] Yuan Z, Li WT, YeXD, et al. (2014) Utility of diffusion weighted imaging to assess hepatocellular carcinoma viability following transarterial chemoembolization. Oncology Letters 8: 831-836.
[3] Chung JC, Naik NK, Lewandowski RJ, et al. (2010 July 7) Diffusion-weighted magnetic resonance imaging to predict response of hepatocellular carcinoma to chemoembolization. World J Gastroenterology 16(25): 3161-3167.
[4] ElSaid NA, Kaddah RO, Abdel Fattah MS, et al. (2016) Subtraction MRI versus diffusion weighted imaging: Which is more accurate in assessment of hepatocellular carcinoma after Trans Arterial Chemoembolization (TACE). The Egyptian Journal of Radiology and Nuclear Medicine 1251–1264.
[5] Kloeckner R, Otto G, Biesterfeld S, et al. (2010) MDCT versus MRI assessment of tumor response after transarterial chemoemboli¬zation for the treatment of hepatocellular carcinoma. Cardiovascular Intervention Radiology 33: 532 540.
[6] Lee C, Kim KA, Park CM, et al. (2011) Hepatic tumor response evaluation by magnetic resonance imaging. European Society Of Radiology, 1-24.
[7] Osama RM, Abdelmaksoud AHK., El-Tatawy SAM, et al. (2013) Role of dynamic contrast-enhanced and diffusion weighted MRI in evaluation of necrosis of hepatocellular carcinoma after chemoembolization. The Egyptian Journal of Radiology and Nuclear Medicine 44:737–46.
[8] Rashed WM, Kandeil MAM, Mahmoud MO, et al. (2020) Hepatocellular Carcinoma (HCC) in Egypt: A comprehensive overview. Journal of the Egyptian National Cancer Institute 32 (5).
[9] Axley P, Ahmed Z, Ravi S, et. al. (2018 March) Hepatitis C Virus and Hepatocellular Carcinoma: A Narrative Review. Journal of Clinical and Translational Hepatology 6(1): 79–84.
[10] Lencioni R, Pasquale P & Crocetti L. (2013 March) Chemoembolization of Hepatocellular Carcinoma. Semin Intervent Radiology. 30(1): 3–11.
[11] Omar HO, Hassan MS, & Tawfik A. (2018) Role of MRI in Assessment of Hepatocellular Carcinoma (HCC) after (TACE) Transarterial chemoembolization) with Persistent High Alfa Fetoprotein (AFP). The Egyptian Journal of Hospital Medicine 71(1): 2315-2321.
[12] Chapiro J, Wood LD, Lin M, et al. (2014) Radiologic-pathologic analysis of contrast-enhanced and diffusion-weighted MR imaging in patients with HCC after TACE: diagnostic accuracy of 3D quantitative image analysis. Radiology 273:746–758.
[13] Hussein RS, Tantawy W & Abbas YA. (2019) MRI assessment of hepatocellular carcinoma after locoregional therapy. Insights into Imaging 10 :8, 1-16
[14] Abd El Hak MT, Metwally NA & Abdrabo ASM. (2019 July) Role of Diffusion-Weighted MRI in Hepatocellular Carcinoma Patients Following Transarterial Chemoembolization (TACE). The Egyptian Journal of Hospital Medicine 76 (1): 3380-3391.
[15] Ebeed E.A, Romeih A.M, Refat MM, et al. (2017) Role of dynamic contrast-enhanced and diffusion weighted MRI in evaluation of hepatocellular carcinoma after chemoembolization. Egypt J Radiol Nucl Med 48:807–815.
[16] Afifi AH, Naguib AM & Seragaldin F. (2016) Diffusion weighted magnetic resonance imaging in assessment of hepatocellular carcinoma after chemoembolization. Egypt J Radiol Nucl47(1):61–71.

[17] Saleh TY, Bahig S, Shebraya N, et al. (2019) Value of dynamic and DWI MRI in evaluation of HCC viability after TACE via LI-RADS v2018 diagnostic algorithm Egyptian Journal of Radiology and Nuclear Medicine 50:113.
[18] Liu Z, Fan JM, He C, et.al. (2020) Utility of diffusion weighted imaging with the quantitative apparent diffusion coefficient in diagnosing residual or recurrent hepatocellular carcinoma after transarterial chemoembolization: a metaanalysis. Journal of cancer imaging Liu et al. Cancer Imaging 20:3, 1-10.
[19] Andre JB, Zaharchuk G, Fischbein NJ, et al. (2012) Clinical assessment of standard and generalized autocalibrating partially parallel acquisition diffusion imaging: effects of reduction factor and spatial resolution. Am J Neuroradiol 33(7):1337–42.
[20] Duran R, Ronot M, Kerbaol A, et al. (2014) Hepatic hemangiomas: factors associated with T2 shine-through effect on diffusion-weighted MR sequences. Eur J Radiol. 83(3):468–78.
[21] Tantawy HI & Mohamed FF. (2016) Diagnostic value of apparent diffusion coefficient (ADC) in evaluating hepatocellular carcinomas post transcatheter arterial chemoembolization and radiofrequency ablation. Egypt Journal of Radiology and Nuclear Medecine 47(3):699–706.
[22] Kamel I, Bluemke D, Ramsey D, et al. (2006) The Role of Functional MR Imaging in the Assessment of Tumor Response after Chemoembolization in Patients with Hepatocellular Carcinoma. J Vasc Interv Radiol. 17: 505–512
[23] Goshima S, Kanematsu M, Kondo H, et al. (2008) Diffusion-weighted imaging of the liver: optimizing b value for the detection and characterization of benign and malignant hepatic lesions. J Magn Reson Imaging 28 (3): 691-7.
[24] Yu J, Kim J, Chung J-J, et al. (2009) Added Value of Diffusion-Weighted Imaging in the MRI Assessment of Perilesional Tumor Recurrence after Chemoembolization of Hepatocellular Carcinomas. Journal OF Magnetic Resonance Imaging 30: 153–160.
[25] Taouli B & Koh DM. (2010) Diffusion-weighted MR imaging of the liver. Radiology 254: 47- 66.
[26] Chiu FY, Jao JC, Chen CY, et al. (2005) Effect of intravenous gadolinium-DTPA on diffusion-weighted magnetic resonance images for evaluation of focal hepatic lesions. J Comput Assist Tomogr. 29 (2): 176-80.
[27] Koh DM & Collins DJ. (2007) Diffusion-weighted MRI in the body: applications and challenges in oncology. AJR Am J Roentgenol., 188: 1622–1635.
[28] Kandpal H, Sharma R, Madhusudhan KS, et al. (2009) Respiratory-triggered versus breath-hold diffusion-weighted MRI of liver lesions: comparison of image quality and apparent diffusion coefficient values. AJR. 192: 915–922.
[29] Thoeny HC, De Keyzer F, Chen F, et al. (2005) Diffusion- weighted MR imaging in monitoring the effect of a vascular targeting agent on rhabdomyosarcoma in rats. Radiology 234: 756–764.

Case 1

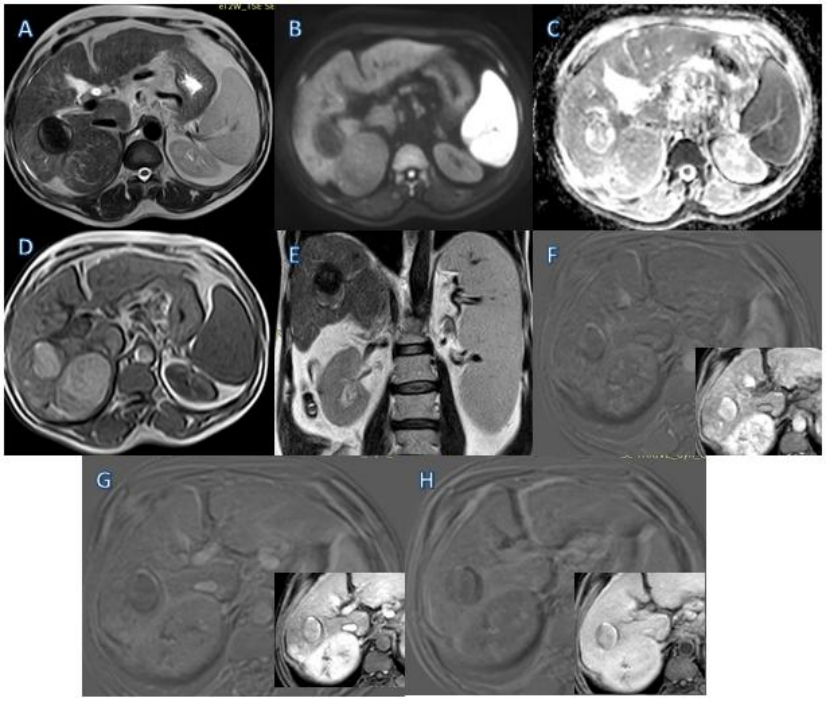

Figure 5: Figures from A to H showing segment VI well ablated HCC as well as liver cirrhotic features and other newly developed HCCs. A: T2 WI eliciting low signal of the HFL. B: DWI eliciting low signal of the HCC. C: ADC eliciting bright signal of the HFL and ADC value 1306 x 10^{-3}. D: T1 WI out of phase eliciting increased signal of the HFL. E: Coronal T2 WI. F to H: Post contrast dynamic images in arterial (F), portovenous (G) and delayed (H) phases with subtraction images showing no contrast enhancement.

Case 2

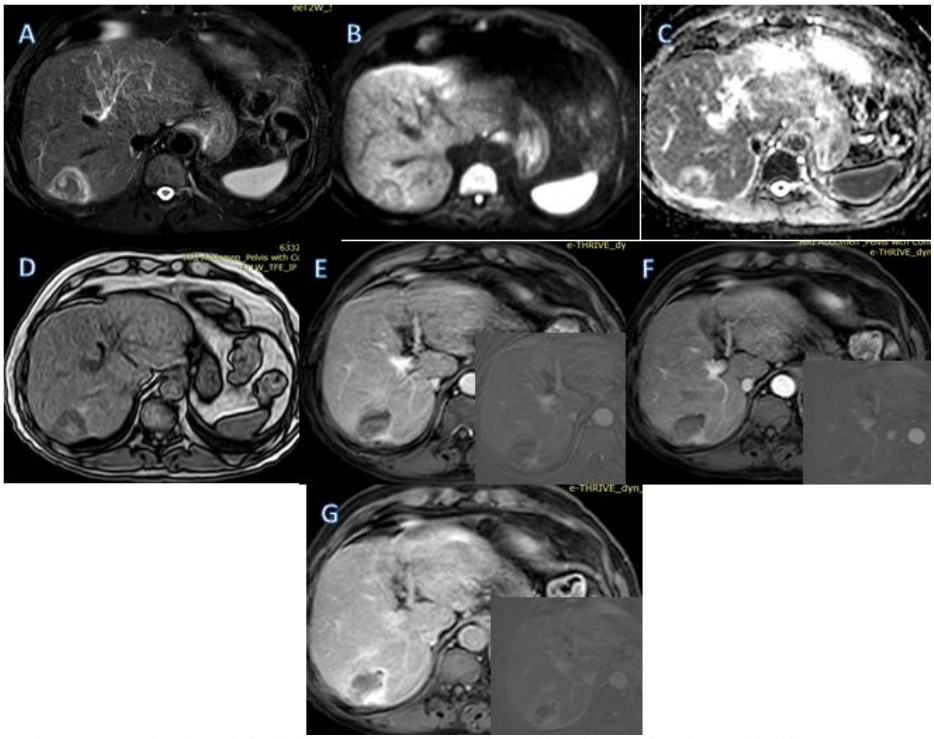

Figure 6: Figures from A to H showing cirrhotic liver with segment VI/VII ablated HCC showing residual/recurrent tumoral tissue. A: T2 STIR WI of post TACE HFL showing heterogenous signal intensity with central low area. B: DWI eliciting heterogenous signal of the HFL. C: ADC eliciting heterogenous signal of the HFL and ADC value 967 x 10^{-3} at lowest area. D: T1 WI out of phase eliciting heterogenous signal of the HFL with central high area. F: T1 WI in phase eliciting low signal of the HFL. E to G: Post contrast dynamic images in late arterial (E), Venous (F) and delayed (G) phases with subtraction images showing posterior basal peripheral nodular contrast enhancement.

Case 3

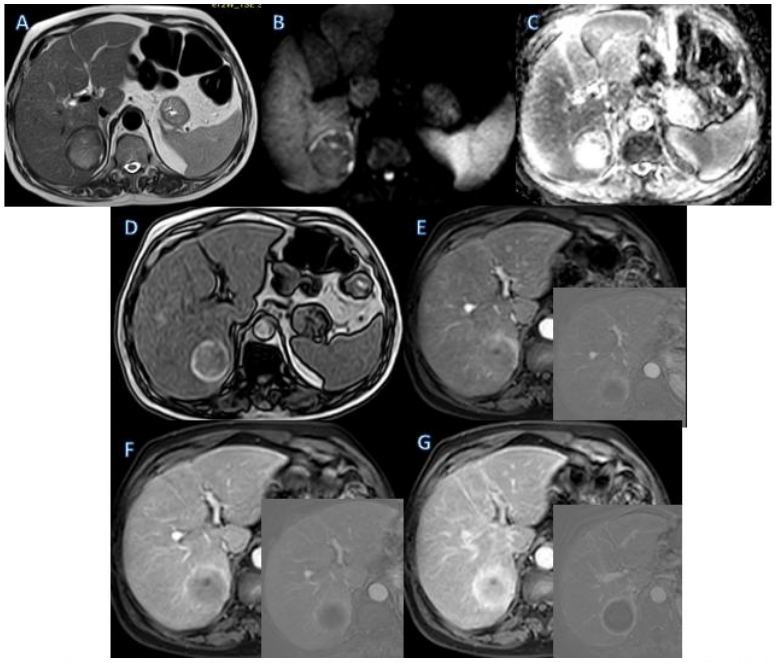

Figure 7: Figures from A to H showing cirrhotic liver with well ablated segment VII HCC. A: T2 WI showing high signal intensity. B: DWI eliciting low signal of the HFL with peripheral foci of high signal. C: ADC eliciting high signal of the HFL (ADC value 1256 x 10^{-3}) with peripheral foci of low signal (ADC value 930 x 10^{-3}) D: T1 WI out of phase eliciting isointense signal of the HFL with peripheral hyperintense rim. E to G: Post contrast dynamic images in late arterial (E), Venous (F) and delayed (G) phases with subtraction images showing no intralesional post contrast enhancement with peripheral arterial contrast enhancement persistent in portovenous and delayed phases likely representing fibrosis.