Non-contrast Magnetic Resonance Imaging versus the Multiphase Computed Tomography with Respect to the Asia–Pacific Clinical Practice Guidelines: A Diagnostic Performance Study for Liver Cancer

Yang Wei[1,], Liu Haifen[2,*], Li Xiang[1], Zhang Shutong[1], Chen Yanhao[1], Wang Xiang[1]*

[1]*Department of Radiology, The Central Hospital of Wuhan, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China*

[2]*The First Affiliated Hospital of Hunan College of Traditional Chinese Medicine (Zhuzhou Hospital of Traditional Chinese Medicine), Zhuzhou, Huan, China*

Cite this article as: Wei Y, Haifen L, Xiang L, Shutong Z, Yanhao C, Xiang W. Non-contrast magnetic resonance imaging versus the multiphase computed tomography with respect to the asia–pacific clinical practice guidelines: A diagnostic performance study for liver cancer. *Turk J Gastroenterol.* 2021; 32(3): 318-326.

ABSTRACT

Background: *Guidelines recommend multiphasic computed tomography (CT) and/or contrast-enhanced magnetic resonance imaging (MRI) for the detection of hepatocellular carcinoma. The objectives of the study were to compare diagnostic parameters of non-contrast MRI against multiphase CT for diagnostic of hepatocellular carcinoma in patients who at risk of liver cancer considering Asia–Pacific clinical practice guidelines as the reference standard.*

Methods: *Medical records of patients with chronic hepatic disease or have suspected liver cancer in surveillance of fewer than 100 days and underwent multiphasic CT, gadoxetic acid-enhanced MRI, and liver biopsy for diagnosis of liver cancer were included in analysis. Enhancement during the arterial phase and wash-out during a delayed phase or portal-venous considered as hepatocellular carcinoma in the multiphase CT. Mild-to-moderate hypersensitivity in imaging, presence of fat on out-of-phase imaging, non-enhancing capsule(s), mosaic appearance, hemorrhagic content, and/or nodule-in-nodule considered as hepatocellular carcinoma in MRI. Asia–Pacific clinical practice guidelines considered for biopsy/histopathology for detection of hepatocellular carcinoma.*

Results: *For detection of hepatocellular carcinoma, non-contrast MRI had higher sensitivity (0.843 vs. 0.762, $P < .001$, $q = 3.919$) and accuracy (0.755 vs. 0.571, $P < .001$, $q = 3.362$) than the multiphase CT. While specificity was the same (0.864 vs. 0.809, $P < .001$, $q = 2.584$). Non-contrast MRI had 0-0.91 diagnostic confidence and multiphase CT had 0.49-0.81 diagnostic confidence for the detection of hepatocellular carcinoma.*

Conclusions: *Non-contrast MRI easily facilitates the decision of chemotherapy and/or radiotherapy than multiphase CT in hepatocellular carcinoma.*

Keywords: *Asia–Pacific clinical practice guidelines, biopsy, computed tomography, hepatocellular carcinoma, liver cancer, magnetic resonance imaging*

INTRODUCTION

Hepatocellular carcinoma is diagnosed by imaging modalities.[1] Current guidelines recommend multiphasic computed tomography (CT) and/or contrast-enhanced magnetic resonance imaging (MRI) for diagnosis of liver cancer.[2-7] However, there are chances of false-negative results[1] which are corrected by alternative imaging methods, imaging modality with contrast-agent, or biopsies.[2,3,7] Liver cirrhosis, blood flow redistribution, and hepatic parenchymal distortion may make false-positive results in these imaging methods,[1] which can be corrected by contrast (gadoxetic acid)-enhanced MRI.[8] According to these guidelines, CT, MRI, contrast-enhanced CT, biopsies, and contrast-enhanced MRI are required for the evaluation of hepatocellular carcinoma in suspected liver cancer patients.[2-7] This method of diagnosis is very costly.[1] Therefore, there is a need for single, non-invasive, and cost-effective diagnostic methods for the assessment of hepatocellular carcinoma.

**These authors contributed equally to this work.*

Corresponding author: ***Chen Yanhao*** *or* ***Wang Xiang****, e-mail:* ***rbygnt@163.com*** *or* ***NickMarvinaFnGt@yahoo.com***

Received: ***May 30, 2020*** *Accepted:* ***August 11, 2020*** *Available Online Date: X XX 2021*

DOI: ***10.5152/tjg.2021.20386***

The objectives of the retrospective study were to compare diagnostic parameters of non-contrast MRI against multiphase CT for the diagnostic of hepatocellular carcinoma in patients who at risk of liver cancer using the results of full-sequence gadoxetic acid-enhanced MRI and liver biopsy/histopathology (as per Asia–Pacific clinical practice guidelines for hepatocellular carcinoma) as the reference standard.

MATERIALS AND METHODS

Ethics Approval and Consent to Participate

The designed protocol (CHW/CL/15/2020 dated 26 February 2020) of the established study was approved by the radiology review board of the institute. The study reporting adheres to the strengthening the reporting of observational studies in epidemiology (STROBE) statement: cross-sectional studies, the law of the country, and the 2008V of Declarations of Helsinki. All the enrolled patients or their relatives (legally authorized person) signed an informed consent form regarding diagnosis, biopsies (if required), and the publication of the study in all formats of the publication including personal data and images irrespective of time and language during hospitalization.

Study Population

From 1 December 2017 to 14 September 2019, the study retrospectively searched medical records of patients with the chronic hepatic disease who underwent contrast (gadoxetic acid)-enhanced MRI and liver biopsy to detect liver cancer which was found by multiphasic CT or have suspected liver cancer in surveillance of fewer than 100 days while attending at the parent hospital and the referring hospitals. The study found 355 such records of patients. Among them 103 patients treated by chemotherapy and/or radiotherapy and not performed biopsies (if required). Complete medical records of 51 patients were not available. Therefore, data of these patients were not considered for analysis. A total of 248 nodules of 201 patients were included in the study.

Multiphasic CT

All examinations performed by a multidetector CT scanner (SOMATOM Sensation 64, Siemens Healthineers, Forchheim, Germany) with 2-5 mm a reconstruction thickness, 120-130 kV, and 360-365 mA. Examinations included unenhanced late hepatic arterial (25-40 s), portal venous (70-95 s), and delayed (175-185 s) phases. 1.75 mL/kg, 300 mg/mL concentrated Iodine (not exceeding 150 mL) was injected by a power injector (OptiVantage®, Guerbet, Villepinte, France) at 3.5-4 mL/s

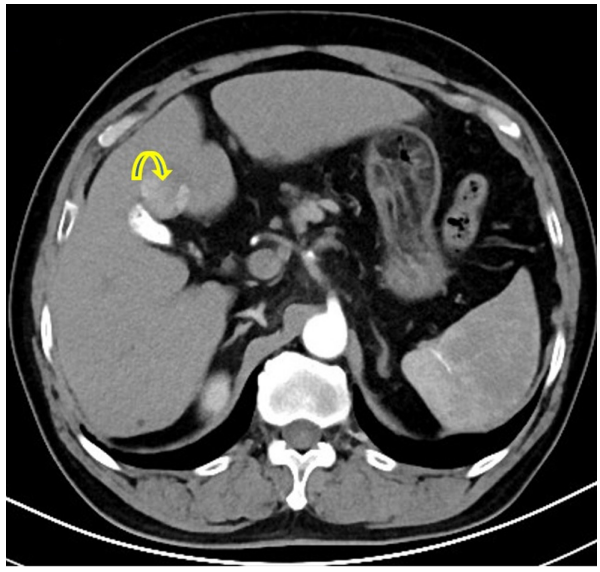

Figure 1. The multiphase computed tomography of hepatitis B positive 49-years-old man. The arrow indicates 1.7 cm enhancement during the arterial phase in the seventh segment of the liver.

for contrast-enhanced images.[1] Images performed by a radiologist (at least 7 years of experience in hepatic imaging) of institutes.

Image analysis of multiphase CT

An enhancement during the arterial phase (Figure 1) and wash-out during portal-venous (Figure 2) or delayed

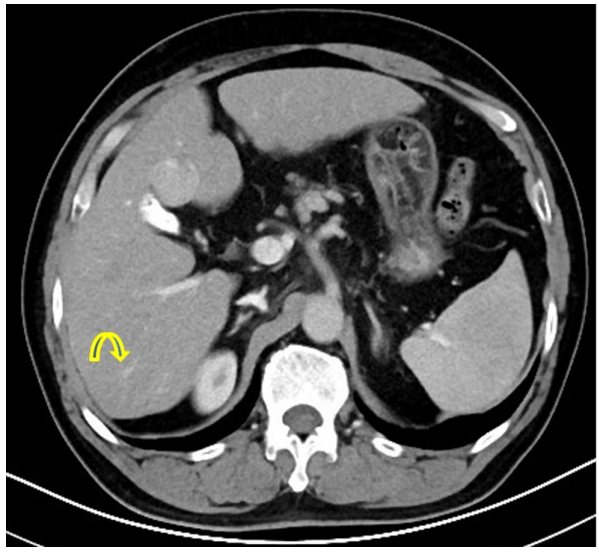

Figure 2. The multiphase computed tomography of hepatitis B positive 49-years-old man. The arrow indicates a 1.1 cm wash-out during portal-venous.

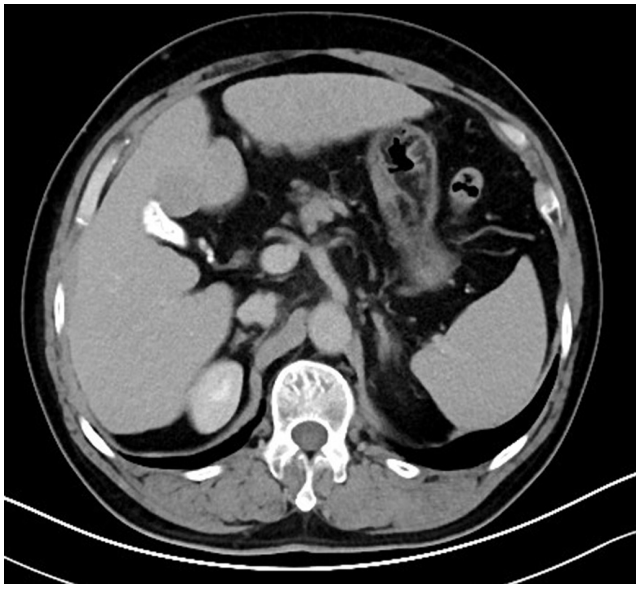

Figure 3. The multiphase computed tomography of hepatitis B positive 51-years-old man. The image is wash-out during the delayed phase.

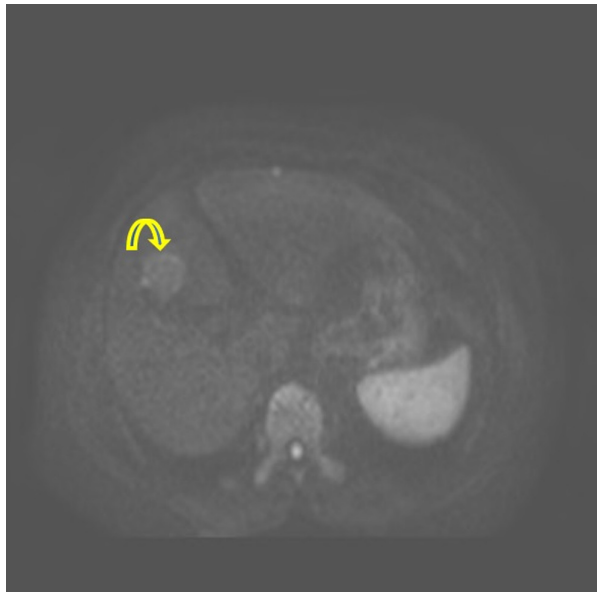

Figure 4. Magnetic resonance imaging (T2WI) of hepatitis B positive 50-years-old man. The arrow indicates mild hypersensitivity.

phase (Figure 3) is considered as hepatocellular carcinoma. Nodules with none of these characters are considered benign nodules.[1] Images analyzed by radiologists (at least 7 years of experience in hepatic imaging) of institutes.

MRI Technique

MRI examinations performed by a 3.0 T MRI scanner (Skyra, Siemens Healthineers, Forchheim, Germany). 0.1 mL/kg gadoxetic acid injected by a power injector and hepatobiliary phase imaging obtained after 20 min of injection. T1-weighted imaging (T1WI), T2-weighted imaging (T2WI), diffusion-weighted imaging (DWI), out-of-phase imaging, and hepatobiliary phase imaging are derived for diagnosis purposes.[1] Images performed by radiologists (at least 7 years of experience in hepatic imaging) of institutes.

Image Analysis of MRI

Mild-to-moderate hypersensitivity on T2WI (Figure 4), hyperintensity on DWI (Figure 5), hyperintensity on hepatobiliary phase imaging (Figure 6), fat content on out-of-phase imaging, hemorrhagic content, mosaic appearance, nodule-in-nodule, and/or non-enhancing capsule(s) was considered as hepatocellular carcinoma. Nodules with none of these characters are considered benign nodules.[9] Images analyzed by radiologists (at least 7 years of experience in hepatic imaging) of institutes.

Full-Sequence Gadoxetic Acid-Enhanced MRI

After at least 2 weeks of non-contrast MRI and the multiphase CT imaging, a full-sequence gadoxetic acid-enhanced MRI was performed by the same radiologists and T1WI, T2WI, DWI, out-of-phase, and hepatobiliary phase images derived for diagnosis purposes.[1] Also, diagnosis made as per the above-mentioned criteria of

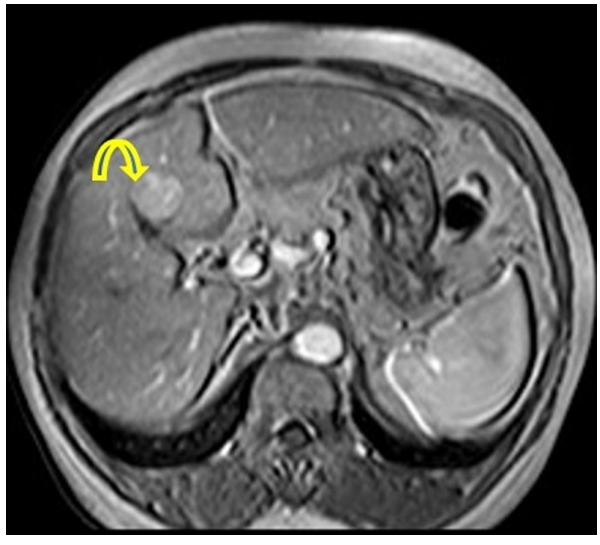

Figure 5. Diffusion-weighted magnetic resonance imaging of hepatitis B positive 50-years-old man. The arrow indicates hyperintensity.

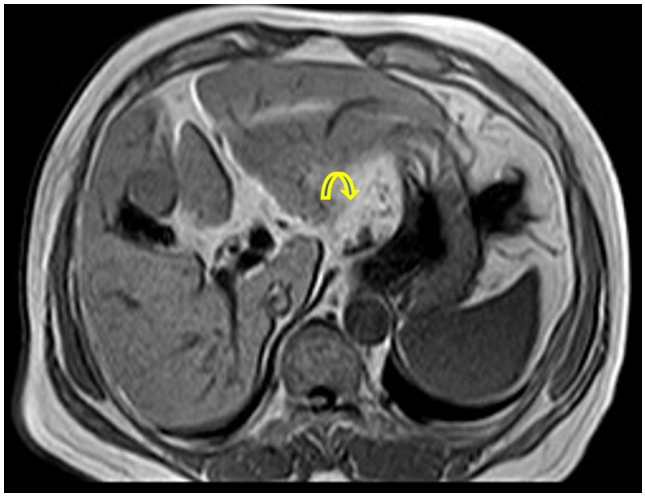

Figure 6. Hepatobiliary phase magnetic resonance imaging in 51-years-old women with cirrhosis other than hepatitis B or C. The arrow indicates hyperintensity.

hepatocellular carcinoma. Images analyzed by radiologists (at least 7 years of experience in hepatic imaging) of institutes.

Liver Biopsy/Histopathology

The results of full-sequence gadoxetic acid-enhanced MRI were confirmed by liver biopsy followed by histopathology for hepatocellular carcinomas and benign nodules as per Asia–Pacific clinical practice guidelines for hepatocellular carcinoma.[3]

Diagnostic Performance

The ratio of the sum of true positive hepatocellular carcinoma present and true negative hepatocellular carcinoma absent (benign nodule present) to nodules studied is considered as sensitivity. The ratio of numbers of true positive hepatocellular carcinoma present by imaging modality to positive hepatocellular carcinoma detected by Asia–Pacific clinical practice guidelines for hepatocellular carcinoma considered as specificity and the ratio of numbers of true negative hepatocellular carcinoma absent (benign nodule present) by imaging modality to negative hepatocellular carcinoma detected by Asia–Pacific clinical practice guidelines for hepatocellular carcinoma considered as accuracy.

Clinical Significance

Clinical significance evaluated by detecting beneficial scores for hepatocellular carcinoma as per Eq. 1:

$$\text{Benefit score} = \frac{\text{True positive hepatocellular carcinoma present}}{\text{Nodules studied}} - \left(\frac{\text{False} - \text{positive hepatocellular carcinoma present}}{\text{Nodules studied}} \times \frac{\text{The level of diagnostic confidence above which chemotherapy and radiotherapy performed}}{1 - \text{The level of diagnostic confidence above which chemotherapy and radiotherapy performed}} \right)$$

True positive hepatocellular carcinoma: Hepatocellular carcinoma detected by imaging modality and confirmed by Asia–Pacific clinical practice guidelines for hepatocellular carcinoma.

False-positive hepatocellular carcinoma: Hepatocellular carcinoma detected by imaging modality but did not confirm by Asia–Pacific clinical practice guidelines for hepatocellular carcinoma.

Statistical Analysis

The Statistical Package for the Social Sciences (SPSS) version 25 (IBM Corp.; Armonk, NY, USA) was used for statistical analysis purposes. The Chi-square independence test was performed for categorical variables and 1-way analysis of variance following Tukey's test (considering critical value [q] > significant) performed for continuous variables.[1] All the results considered significant at a 95% CI.

RESULTS

Demographical and Clinical Characteristics of Patients

A total of 139 (69%) male and 62 (31%) female patients with a mean age of 55.45 ± 11.45 years were included in the analysis. Among enrolled patients, 161 (81%) patients were reported hepatitis B positive. The demographic and clinical conditions of the patients at the time of admission are reported in Table 1.

Multiphasic CT

Out of 248 nodules, enhancement during the arterial phase on 115 nodules, wash-out during portal-venous on 63 nodules, wash-out during delayed phase on 21 nodules, and 49 cases did not report any types of characteristics.

MRI Analysis

Among 248 cases for nodules, mild-to-moderate hypersensitivity on T2WI reported in 65 cases, hyperintensity on DWI reported in 58 cases, hyperintensity on hepatobiliary

Table 1. Demographical and Clinical Characteristics of Patients at the Time of Admission

Characteristics		Population
Patients		**201**
Nodules studied		**248**
Age (years)	Minimum	35
	Maximum	78
	Mean ± SD	55.45 ± 11.45
Gender	Male	139 (69)
	Female	62 (31)
Nodule size (cm)		1.32 ± 1.22
Alcoholic	Current	84 (42)
	Previous	52 (26)
	None	65 (32)
Hepatitis B positive		161 (81)
Hepatitis C positive		11 (5)
Hepatitis B and C positive		2 (1)
Cirrhosis other than hepatitis B and/or C		27 (13)
Alpha fetoprotein (ng/mL)		51.12 ± 15.12
Protein-induced by vitamin K absence (ng/mL)		32.11 ± 6.15

Categorial data demonstrate as frequency (percentage) and continuous data demonstrate mean ± SD.

phase imaging reported in 54 cases, fat content on out-of-phase imaging reported in 11 cases, non-enhancing capsule(s) reported on 3 cases, hemorrhagic content reported on 3 cases, mosaic appearance reported on 2 cases, nodule-in-nodule reported on 3 cases, and 49 cases did not report any types of characteristics.

Reference Standard

Out of 248 nodules, full-sequence gadoxetic acid-enhanced MRI and biopsy/histopathology as per Asia–Pacific clinical practice guidelines for hepatocellular carcinoma reported hepatocellular carcinoma in 199 nodules and a benign nodule on 49 nodules. The study flow chart of the retrospective analyses is presented in Figure 7.

Diagnostic Performance

Non-contrast MRI detected benign nodules exactly as those detected by full-sequence gadoxetic acid-enhanced MRI and biopsy/histopathology as per Asia–Pacific clinical practice guidelines for hepatocellular carcinoma (P=.192). While there were differences in diagnostic parameters between imaging modalities and full-sequence gadoxetic acid-enhanced MRI and biopsy/histopathology as per Asia–Pacific clinical practice guidelines for hepatocellular carcinoma (Table 2).

For detection of hepatocellular carcinoma, non-contrast MRI had higher sensitivity (P < .001, q=3.919) and accuracy (P < .001, q=3.362) than the multiphase CT. While specificity was the same (P < .001, q=2.584). The detailed diagnostic parameters of imaging modalities are reported in Table 3.

Clinical Significance

Non-contrast MRI had 0-0.91 diagnostic confidence for the detection of hepatocellular carcinoma and above 0.91 diagnostic confidence, there were chances of overdiagnosis. The multiphase CT had 0.49-0.81 diagnostic confidence for the detection of hepatocellular carcinoma. Below 0.49 diagnostic confidence, multiphase CT had no importance for the detection of hepatocellular carcinoma and above 0.81 diagnostic confidence, multiphase CT had chances of overdiagnosis (Figure 8).

DISCUSSION

The study reported high sensitivity and accuracy for non-contrast MRI than multiphase CT for the detection of liver cancer but both had the same specificity. The results of the current study agreed with the results of the retrospective study,[1] EASL (European Association for the Study of the Liver) clinical practice guidelines on liver cancer,[2] multicenter prospective trials,[10,11] and observational study.[12] Arterial and transitional phase hypersensitivity have an important role in the detection of hepatocellular carcinoma through non-contrast MRI.[9] The multiphase CT has a lack of differentiating dysplastic nodules from small hepatocellular carcinoma.[11] Gadoxetic acid-enhanced MRI improves sensitivity,[13,14] but decreases specificity.[9,13,15] The study recommended a non-contrast MRI in the diagnosis of liver cancer.

The combined multiphasic CT and non-contrast MRI had better diagnostic parameters (sensitivity, specificity, and accuracy) than the multiphasic CT and non-contrast MRI alone (data are not shown) but the current Liver Imaging and Data Reporting System do not allow integrated interpretation across imaging modalities.[16] Therefore, the combination of multiphasic CT and non-contrast MRI is not valid.

The study reported 12 and 21 false-negative results by non-contrast MRI and the multiphase CT. These nodules lacked hallmarks of hepatocellular carcinoma and/

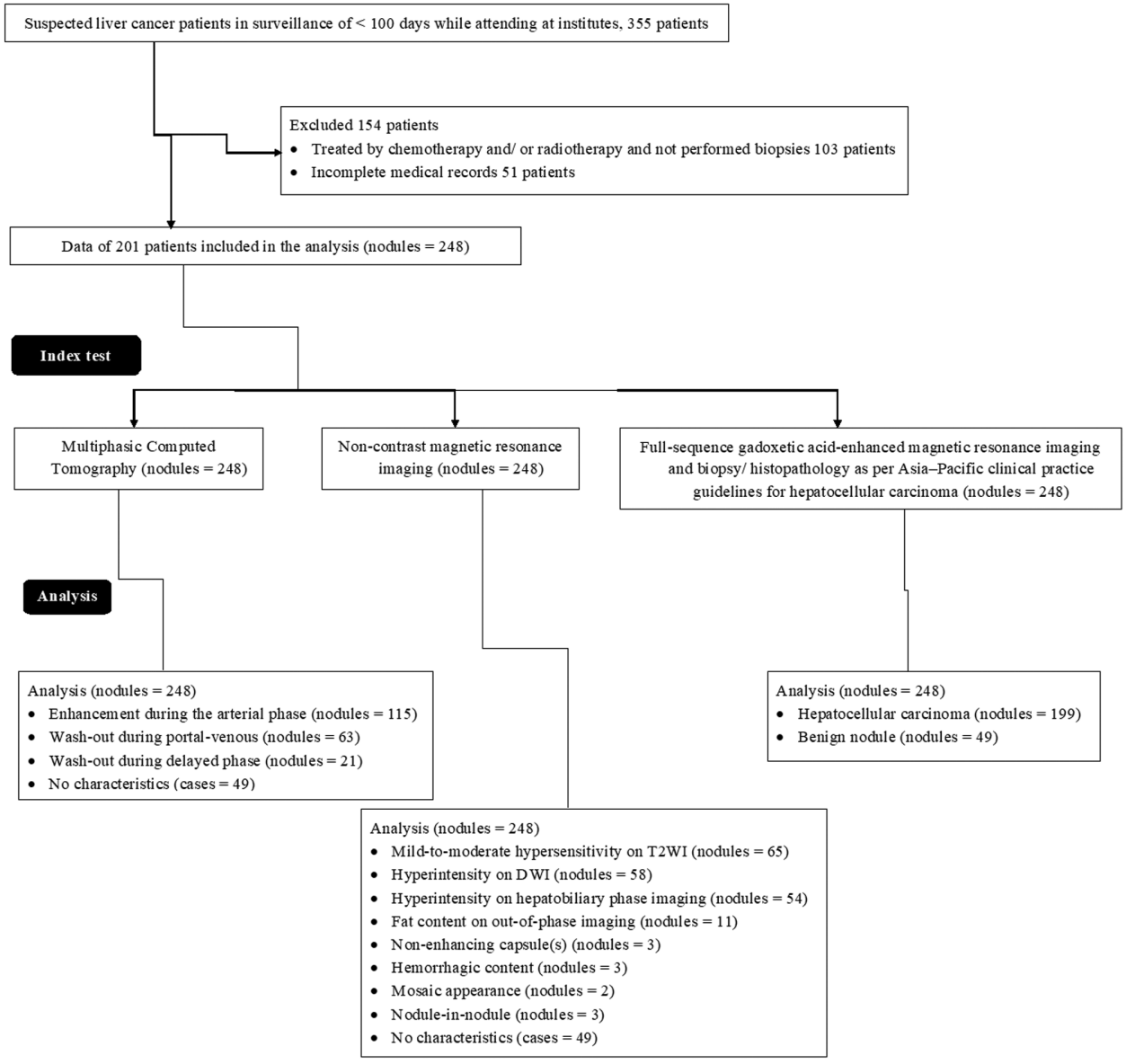

Figure 7. Study flow diagram.

or deemed indeterminate.[1] Small hepatocellular carcinomas do not show washout.[10] Also, non-contrast MRI and multiphase CT reported 27 and 38 cases as false-positive. These results were due to AP shunt showing arterial phase hyperenhancement without washout, focal hyperintensity on T2WI in the liver. Liver cirrhosis, blood flow redistribution, and hepatic parenchymal distortion lead to enhancement of benign nodules.[17] There is a lack of consensus for exact imaging modalities for the detection of hepatocellular carcinoma.

Non-contrast MRI had high hepatocellular carcinoma detectability than the multiphase CT. The results of the current agreed with consistent with the results of the retrospective study[1] and EASL clinical practice guidelines on liver cancer.[2] Non-contrast MRI makes easier the decision making of chemotherapy and/or radiotherapy in patients with suspected liver cancer.

There are several limitations of the study that have to be reported, for example, retrospective study and lack of

Table 2. Diagnostic Parameters of Imaging Modalities

Parameters	Reference	Non-Contrast Magnetic Resonance Imaging		The Computed Tomography		Comparisons Between Non-Contrast Magnetic Resonance Imaging and the Computed Tomography
Nodules studied	248	248	*P Value	248	*P Value	P Value
True positive hepatocellular carcinoma present	199 (80)	172 (69)	.007	161 (65)	.001	.339
True negative hepatocellular carcinoma absent (benign nodule present)	49 (20)	37 (15)**	.192	28 (11)	.013	.287
False positive hepatocellular carcinoma present	0 (0)	27 (11)	<.0001	38 (15)	<.0001	.183
False negative hepatocellular carcinoma absent (benign nodule present)	0 (0)	12 (5)	.001	21 (9)	<.0001	.149

Data demonstrate as frequency (percentage).
The chi-square independence test was used for statistical analysis.
A $P < .05$ was considered significant.
*With respect to Reference.
**Insignificant difference with respect to Reference.
Reference: Full-sequence gadoxetic acid-enhanced magnetic resonance imaging and biopsy/histopathology as per the Asia–Pacific clinical practice guidelines for hepatocellular carcinoma.

dynamic trial. The study did not compare results with multiphase MRI. However, this is beyond the scope of clinical practice for liver cancer. The study used 3.0 T MRI but it is expensive than 1.5 T MRI.[18] The reference standard included biopsies and histopathology but biopsies may have sampling error.[10] False-positive results detected by full-sequence gadoxetic acid-enhanced MRI and biopsy/histopathology did not discuss.

CONCLUSION

Non-contrast MRI had high sensitivity and accuracy than the multiphase CT for the detection of hepatocellular carcinoma. Also, non-contrast MRI may facilitate the easy decision making of chemotherapy and/or radiotherapy in patients with suspected liver cancer. The dynamic study is required to state the superiority of non-contrast MRI in the detection of liver cancer.

Ethics Committee Approval: The designed protocol (CHW/CL/15/2020 dated 26 February 2020) of the established study was approved by the radiology review board of the institute.

Informed Consent: Signed an informed consent form regarding diagnosis, biopsies (if required), and the publication of the study in all formats of the publication including personal data and images irrespective of time and language during hospitalization.

Peer-review: Externally peer-reviewed.

Table 3. Sensitivity, Specificity, and Accuracy of Imaging Modalities for the Detection of Hepatocellular Carcinoma

Parameters	Reference[1]	Non-contrast Magnetic Resonance Imaging[2]	The Computed Tomography[3]	Comparison			
					q Value	q Value	q Value
Nodules Studied	248	248	248	P	Between 1 and 2	Between 1 and 3	Between 2 and 3
Sensitivity	1	0.843	0.762	<.0001	7.641	11.599	3.919
Specificity	1	0.864	0.809*	<.0001	6.343	8.928	2.584
Accuracy	1	0.755	0.571	<.0001	4.483	7.844	3.362

Data demonstrate mean ± SD.
ANOVA following Tukey's test was used for statistical analysis.
A $P < .05$ and $q > 3.314$ were considered significant.
*Insignificant difference with respect to non-contrast magnetic resonance imaging.
Reference: Full-sequence gadoxetic acid-enhanced magnetic resonance imaging and biopsy/histopathology as per the Asia–Pacific clinical practice guidelines for hepatocellular carcinoma.

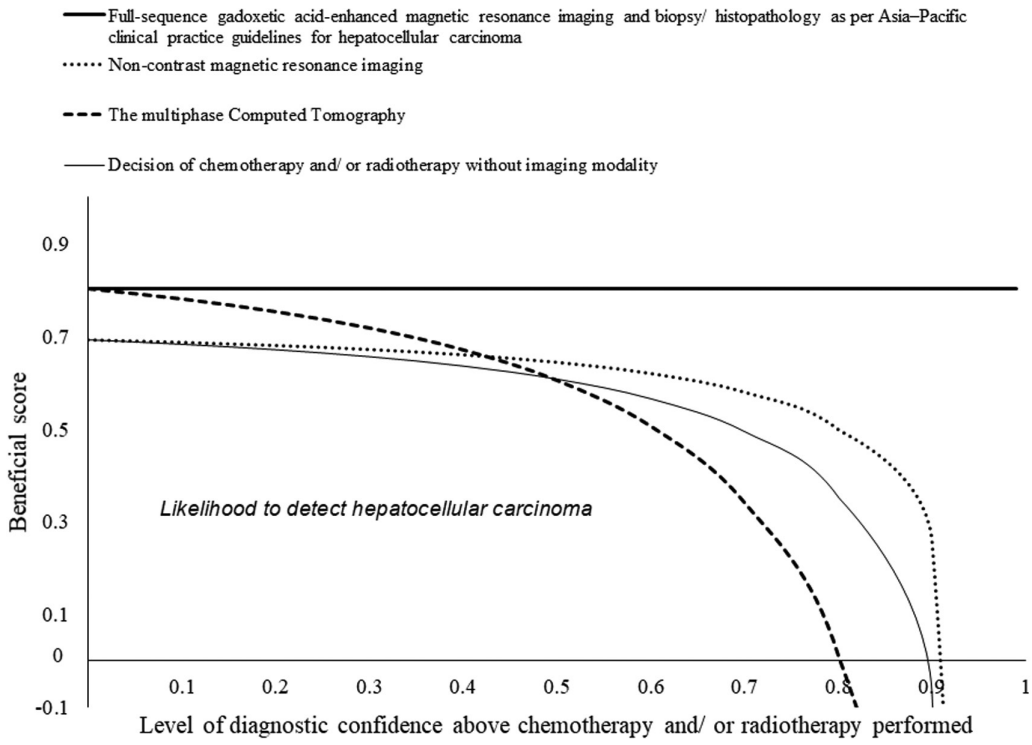

Figure 8. Beneficial score analysis. Images analyzed by the radiologists (a minimum of 7 years of experience in hepatic imaging) of institutes.

Author Contributions: Concept – Y.W., L.H.; Design - Y.W., L.H.; Supervision - L.X.; Resource – Y.W., L.H., L.X.; Materials – Y.W., L.H., L.X., Z.S., C.Y., W.X.; Data Collection and/or Processing – Z.S., C.Y.; Literature Search – Y.W., L.H., L.X., Z.S., C.Y., W.X.; Critical Reviews – Y.W., L.H., L.X., Z.S., C.Y., W.X.

Acknowledgments: Authors are thankful for the medical and non-medical staff of the Central Hospital of Wuhan, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China and the First Affiliated Hospital of Hunan College of Traditional Chinese Medicine (Zhuzhou Hospital of Traditional Chinese Medicine) Zhuzhou, Huan, China.

Conflict of Interest: The authors have no conflict of interest to declare.

Financial Disclosure: This study was supported by the Wuhan Municipal Health Commission (No: WX13A06).

REFERENCES

1. Park SH, Kim B, Kim SY, et al. Characterizing computed tomography-detected arterial hyperenhancing-only lesions in patients at risk of hepatocellular carcinoma: can non-contrast magnetic resonance imaging be used for sequential imaging? Korean J Radiol. 2020;21(3):280-289. [CrossRef]

2. Colombo M. EASL clinical practice guidelines for the management of occupational liver diseases. Liver Int. 2020;40(suppl 1):136-141. [CrossRef]

3. Omata M, Cheng AL, Kokudo N, et al. Asia-Pacific clinical practice guidelines on the management of hepatocellular carcinoma: a 2017 update. Hepatol Int. 2017;11(4):317-370. [CrossRef]

4. American College of Radiology. CT/MRI LI-RADS® v2018 core. https://www.acr.org/-/media/ACR/Files/. Accessed 26 February 2020.

5. Korean Liver Cancer Association (KLCA), National Cancer Center (NCC). 2018 Korean Liver Cancer Association-National Cancer Center Korea practice guidelines for the management of hepatocellular carcinoma. Korean J Radiol. 2019;20(7):1042-1113. [CrossRef]

6. Kudo M, Izumi N, Kokudo N, et al. Management of hepatocellular carcinoma in Japan: Consensus-Based Clinical Practice Guidelines proposed by the Japan Society of Hepatology (JSH) 2010 updated version. Dig Dis. 2011;29(3):339-364. [CrossRef]

7. Heimbach JK, Kulik LM, Finn RS, et al. AASLD guidelines for the treatment of hepatocellular carcinoma. Hepatology. 2018;67(1):358-380. [CrossRef]

8. Motosugi U, Ichikawa T, Sou H, et al. Distinguishing hypervascular pseudolesions of the liver from hypervascular hepatocellular carcinomas with gadoxetic acid-enhanced MR imaging. Radiology. 2010;256(1):151-158. [CrossRef]

9. Choi SH, Byun JH, Lim YS, et al. Diagnostic criteria for hepatocellular carcinoma ≤3 cm with hepatocyte-specific contrast-enhanced

magnetic resonance imaging. J Hepatol. 2016;64(5):1099-1107. [CrossRef]
10. Aubé C, Oberti F, Lonjon J, et al. EASL and AASLD recommendations for the diagnosis of HCC to the test of daily practice. Liver Int. 2017;37(10):1515-1525. [CrossRef]
11. Di Martino M, De Filippis G, De Santis A, et al. Hepatocellular carcinoma in cirrhotic patients: prospective comparison of US, CT and MR imaging. Eur Radiol. 2013;23(4):887-896. [CrossRef]
12. Sersté T, Barrau V, Ozenne V, et al. Accuracy and disagreement of computed tomography and magnetic resonance imaging for the diagnosis of small hepatocellular carcinoma and dysplastic nodules: role of biopsy. Hepatology. 2012;55(3):800-806. [CrossRef]
13. Choi JY, Lee JM, Sirlin CB. CT and MR imaging diagnosis and staging of hepatocellular carcinoma: part II. Extracellular agents, hepatobiliary agents, and ancillary imaging features. Radiology. 2014;273(1):30-50. [CrossRef]
14. Kierans AS, Kang SK, Rosenkrantz AB. The diagnostic performance of dynamic contrast-enhanced MR imaging for detection of small hepatocellular carcinoma measuring up to 2 cm: a meta-analysis. Radiology. 2016;278(1):82-94. [CrossRef]
15. Joo I, Lee JM, Lee DH, Jeon JH, Han JK, Choi BI. Noninvasive diagnosis of hepatocellular carcinoma on gadoxetic acid-enhanced MRI: can hypointensity on the hepatobiliary phase be used as an alternative to washout? Eur Radiol. 2015;25(10):2859-2868. [CrossRef]
16. Sirlin C. Use of the liver imaging reporting and data system in hepatocellular carcinoma. Gastroenterol Hepatol N Y. 2017;13(6):363-365.
17. Wu H, Zhao W, Zhang J, Han J, Liu S. Clinical characteristics of hepatic arterioportal shunts associated with hepatocellular carcinoma. BMC Gastroenterol. 2018;18(1):174. [CrossRef]
18. Chang KJ, Kamel IR, Macura KJ, Bluemke DA. 3.0-T MR imaging of the abdomen: comparison with 1.5 T. RadioGraphics. 2008;28(7):1983-1998. [CrossRef]