

·技术研究·

## MR 3D-VIBE 序列多期动态增强扫描在原发性肝细胞癌中的应用

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**摘要:**【目的】通过对原发性肝细胞癌(HCC)的MR三维容积插入屏气检查(3D-VIBE)多期动态增强扫描与多层螺旋CT(MSCT)增强扫描的对照研究,探讨MR 3D-VIBE序列动态增强扫描在显示HCC的动态强化特点中的价值。【方法】收集23例在我院行上腹部3.0T MR 3D-VIBE多期动态增强扫描及MSCT双期增强扫描的HCC患者的临床及影像学资料,对比3D-VIBE序列动态增强扫描及MSCT增强扫描显示肿瘤的强化特点。【结果】23例经手术证实共发现23个HCC, MRI 3D-VIBE序列检出全部23个病灶, CT检出21个病灶。MRI 3D-VIBE序列多期动态增强扫描中病灶显示为“快进快退”征象者占78.3%(18/23), MSCT增强扫描具有此征象者占54.5%。直径 $\leq 3$  cm的肿瘤更易在3D-VIBE序列多期动态增强扫描中观察到明显强化征象( $P=0.037$ )。【结论】MR 3D-VIBE序列肝脏进行多期动态增强扫描,提高了HCC尤其是小HCC诊断的敏感性与准确性。

**关键词:**原发性肝细胞癌;磁共振成像;X线断层摄影术;三维容积插入屏气检查

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## Application of Enhanced MR Multi-Phase Dynamic Scanning with 3D-VIBE Sequence in Hepatocellular Carcinoma

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**Abstract:**【Objective】To investigate the value of multi-phase dynamic enhanced MR scanning with 3D-VIBE sequence in HCC by comparing with enhanced multiple slice computer tomography (MSCT) scanning.【Method】23 patients who were pathologically proven of HCC, and underwent both abdominal enhanced 3.0T MR multi-phase dynamic scanning with 3D-VIBE sequence and enhanced MSCT scanning were enrolled. The enhancement features of HCC on enhanced MR multi-phase dynamic scanning and enhanced CT scanning were compared.【Results】There were 23 lesions confirmed by pathology. All the 23 lesions were detected by enhanced MR multi-phase dynamic scanning with 3D-VIBE sequence, and 21 lesions were detected by enhanced MSCT scanning. The enhanced features of “fast enhanced and fast washout” in HCC can be observed more frequently on enhanced MR multi-phase dynamic scanning with 3D-VIBE sequence than enhanced MSCT scanning (78.3% vs 54.5%). Obvious enhancement feature can be observed more frequently on the enhanced MR multi-phase dynamic scanning when the tumor diameter  $\leq 3$  cm ( $P=0.037$ ).【Conclusion】The enhanced MR multi-phase dynamic scanning with 3D-VIBE sequence can greatly improve the sensitivity and accuracy of HCC diagnosis, especially for the small HCC (tumor diameter  $\leq 3$  cm).

**Key words:** hepatocellular carcinoma; magnetic resonance imaging; X-ray tomography; three-dimensional volumetric interpolated breath-hold examination

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原发性肝细胞癌(hepatic cellular carcinoma, HCC)是我国最常见的恶性肿瘤之一,其发病人数约占全球的一半,而且发病率逐年上升并有年轻化趋势<sup>[1-2]</sup>。早期发现肝细胞癌病灶、明确病变范围及血供情况对临床早期治疗HCC和提高患者生存率具有至关重要的作用<sup>[3-5]</sup>。CT、MR动态增强扫描是目前临床上最常用于HCC的检查方法。国际上多项指南(包括AASLD, EASL和NCCN的CPGs)都强调影像学检查动脉期强化特点对HCC的诊断有重要作用<sup>[6-8]</sup>。HCC的典型的强化特点是动脉期病灶明显强化,密度高于正常肝组织,门静脉期强化迅速减退,密度低于周围正常肝组织,呈“快进快退”的强化模式<sup>[9]</sup>。然而,对于影像学特征不典型的HCC,需行肝穿刺活检,但即使阴性结果亦不能完全排除HCC,仍然需要随访观察<sup>[9-10]</sup>。影像学表现不典型的HCC为临床诊断带来极大不便。其表现不典型的部分原因可能在于常规CT、MR增强扫描通常在对比剂注入后30 s、60 s、120 s分别对肝脏行动脉、门脉及延迟期扫描,在三期增强扫描时间间隔内未行实时扫描,对于部分于此时间间隔内明显强化的HCC病灶,常规CT、MR增强扫描无法捕捉到其“快进”的时相。CT连续动态增强扫描可解决这个难题,但是由于CT辐射量大、软组织分辨率不足等原因限制了它的应用<sup>[11]</sup>。MR三维容积插入屏气检查(3D volumetric interpolated breath-hold examination, 3D-VIBE)序列动态增强扫描能够对肝脏进行多期、快速、薄层动态增强扫描,接近实时地显示HCC的动态强化特点,特别是常规影像学检查表现不典型的HCC,3D-VIBE序列或可显示出其“快进快退”的强化特征<sup>[12]</sup>。本文旨在通过对HCC的MR 3D-VIBE多期增强扫描与MSCT增强扫描的对照研究,探讨3D-VIBE序列在显示HCC的动态强化特点中的价值。

## 1 材料与方法

### 1.1 资料收集

2010年4月1日至2012年12月31日在我院曾行上腹部3.0T MR 3D-VIBE多期动态增强扫描及多层螺旋CT增强扫描,且经手术病理或实验室检查确诊的HCC患者19例共23个病灶,其中男17例,女6例,年龄28-84岁,平均年龄(56±13)

岁,最大径线0.4-12 cm,平均(3.9±3.1)cm。

### 1.2 CT及MRI检查

MRI检查采用西门子3.0T MRI(Magnetom Avanto, Siemens Healthcare Sector, Erlangen, Germany)扫描仪进行扫描。MRI平扫序列:①半傅立叶采集单次激发快速自旋回波(half-Fourier single shot turbo spinecho, HASTE)序列定位;②HASTE T2WI序列冠状位成像;③HASTE T2WI序列轴位成像;④快速小角度激发(fast low angle shot, FLASH)T1WI同反相位(in/out of phase)序列轴位成像;⑤FLASH T1WI脂肪抑制(fat suppression, FS)序列轴位成像。动态增强扫描序列使用3D-VIBE序列扫描,具体参数为矩阵:256×192, TR:3.3 ms, TE:1.1 ms,层厚2 mm,层间距1 mm。对比剂注射方案:13位患者采用钆喷酸葡甲胺盐(Gd-DTPA, Magnevist, Bayer Schering Pharma, Berlin, Germany),剂量依体质量0.2 mmol/kg,采用高压注射,流率为2 mL/s。10位患者采用钆塞酸二钠(Gd-EOB-DTPA, Primovist, Bayer Schering Pharma, Berlin, Germany)作为对比剂,注射剂量为0.025 mmol/kg,人工静脉推注,流率为2 mL/s。两种对比剂注射后用30 mL生理盐水进行冲洗,冲洗流率为2 mL/s。MR动态增强扫描时间在注射对比剂后15 s开始动脉期扫描,每隔8 s扫描一次,扫描3次后,嘱患者换气15 s,再进行门脉期扫描,扫描方式同动脉期,注射对比剂120 s后行延迟期扫描(即注射对比剂后15、23、31、46、54、62、120 s进行扫描),动脉期、门脉期分别连续扫描3次,延迟期扫描1次。

MSCT检查采用多层螺旋CT扫描仪(Aquilion 64, Toshiba Medical Systems, Tokyo, Japan)进行扫描。对比剂采用碘普罗胺注射液(Ultravist 300, Bayer Schering, Berlin, Germany)经肘静脉注入,总量按体质量1.5 mL/kg计算,采用EN VISION CT高压注射器,速率3 mL/s,扫描条件120 kV, 250 mA,矩阵512×512,层厚0.5 mm,螺距为1。MSCT增强扫描时间为注射对比剂后30 s行动脉期扫描,60 s行门脉期扫描。

### 1.3 图像阅片及观察指标

所有扫描图像均由两名副高以上职称医师判读,意见不一致时经讨论后取得一致意见。

病灶检出与否判断标准:在CT及MR平扫及动态增强扫描过程中,若肉眼见病灶与正常肝实

质不同者,认为可检出病灶,反之则认为不可检出病灶。观察指标为所见HCC病灶在MR 3D-VIBE序列多期动态增强扫描及MSCT三期扫描时的强化特点,包括记录病灶信号高于周围肝实质的起始时间及持续时相数,同时测量病灶各时相的径线,以平均径线为该病灶直径(cm)。

#### 1.4 统计学分析

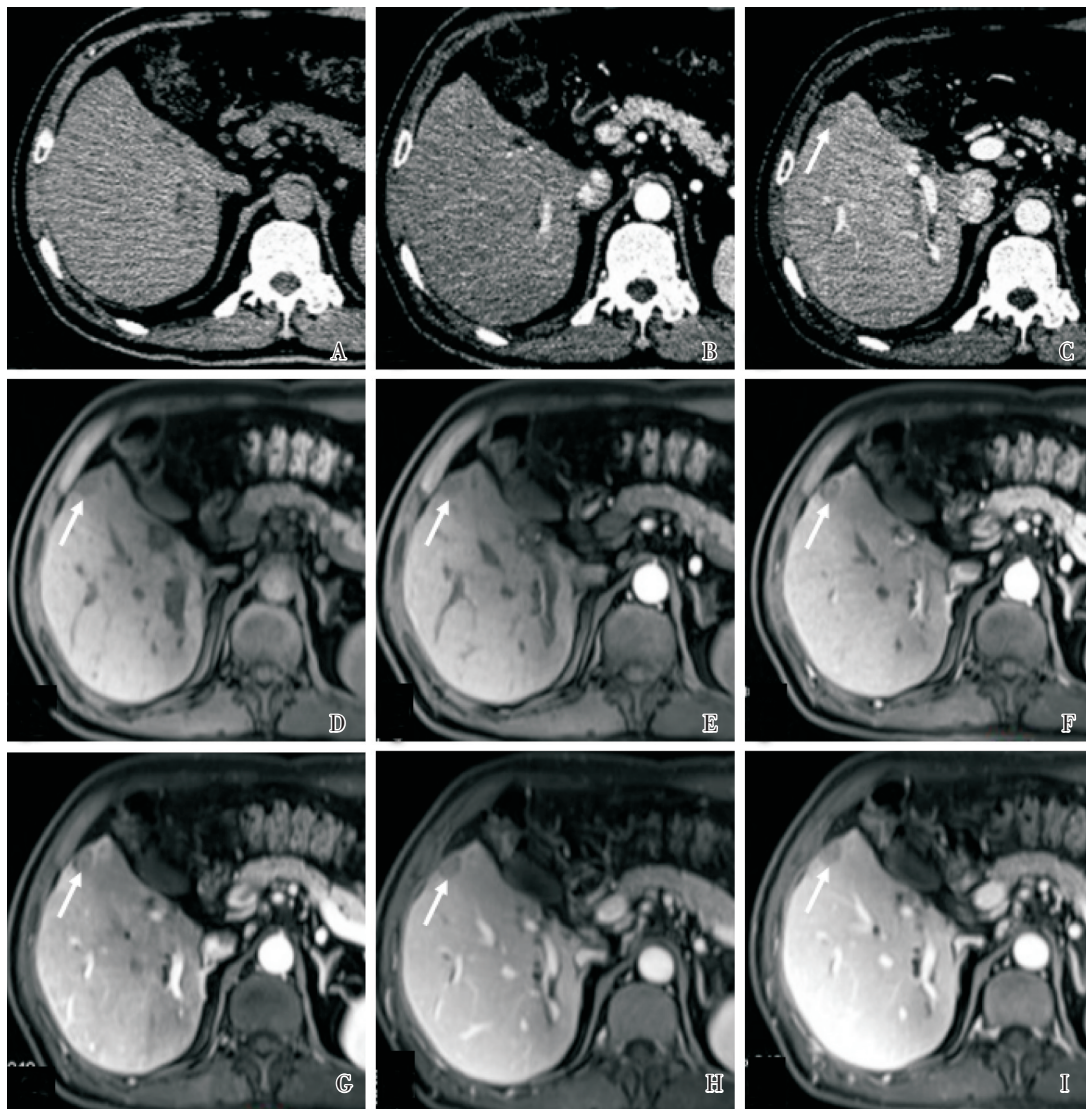
使用SPSS16.0软件。由于本研究总病例数较少,因此使用Fisher精确检验分析两种检查

方法显示HCC强化特点差异的统计学意义及病灶直径与其在3D-VIBE序列上的强化特点的关系。

## 2 结果

### 2.1 MR 3D-VIBE 多期动态增强扫描及MSCT增强扫描显示肿瘤强化特点的比较

本组病例中,MR 3D-VIBE多期动态增强扫



A 58-year old male with elevated serum AFP. Unenhanced and arterial phase CT scanning (A, B) showed no liver lesion. The portal vein phase (C) showed a slight density of small liver nodule in the segment V under the hepatic capsule with an unclear margin. The small nodules were detected more clearly on enhanced MR multi-phase dynamic scanning with 3D-VIBE sequence (D-I), on which the lesion were low signal and no obvious enhancement feature.

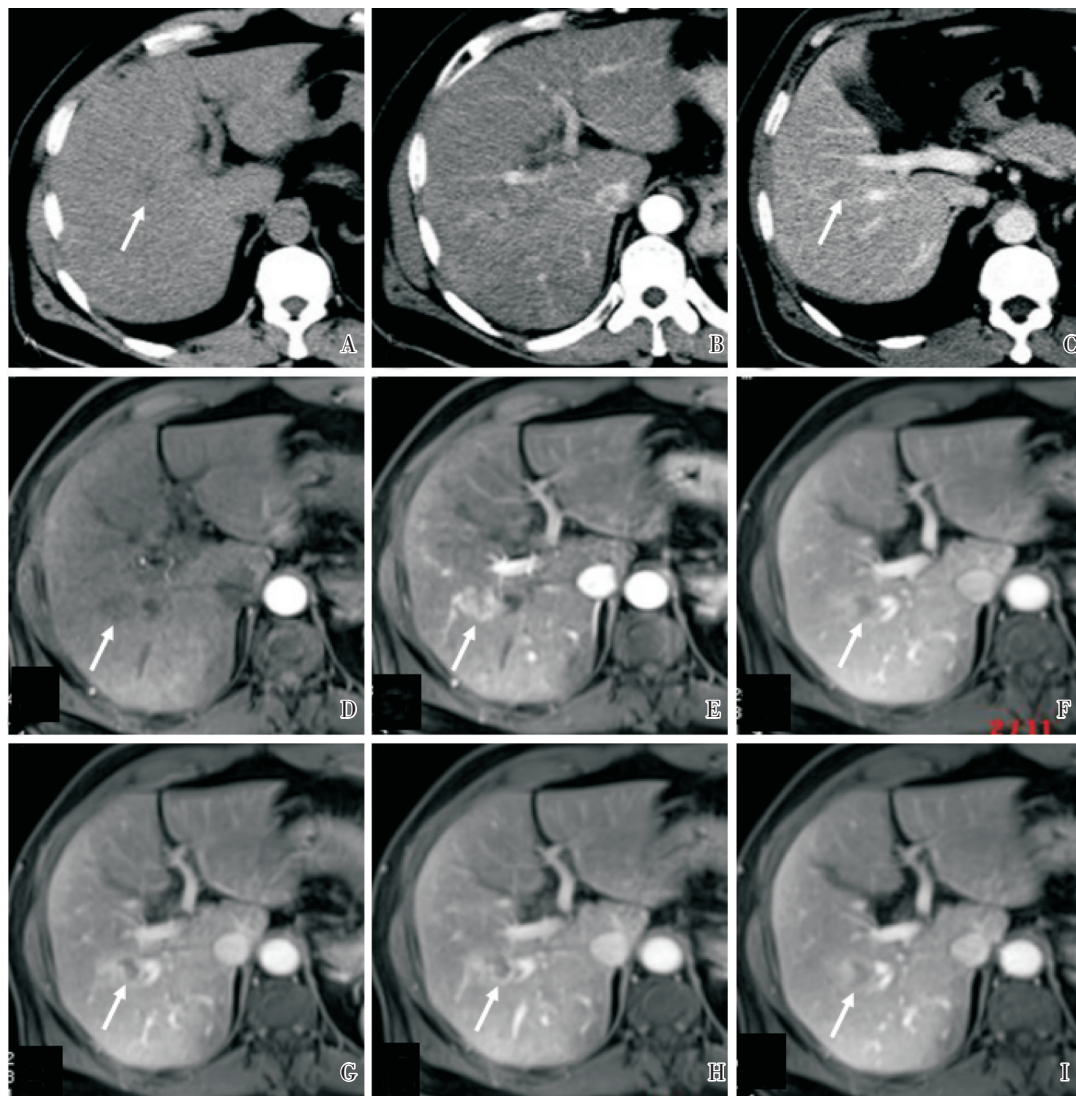
图1 MR 3D-VIBE多期动态增强扫描较MSCT增强扫描更能发现小病灶

Fig.1 Small tumor can be observed more accurately on enhanced MR multi-phase dynamic scanning with 3D-VIBE sequence

描可检出全部23个病灶,平均径线( $3.9\pm 3.1$ )cm,小于1cm者5例,最小病灶直径为0.4cm,MSCT增强扫描可检出21个病灶,平均径线( $4.2\pm 2.9$ )cm,小于1cm者有3例,最小病灶直径0.7cm。对部分小病灶,MR 3D-VIBE多期动态增强扫描更能清楚地显示病灶内部及边缘细节(图1)。

所见全部23个HCC病灶中,有5个HCC病灶

在注入对比剂15s时信号强度即开始高于同层正常肝实质,9个病灶在注入对比剂后23s时信号开始高于肝实质,即14个病灶在动脉早期或中期即明显强化。5个病灶在注入对比剂31s时开始明显强化,有4个病灶在整个平扫及多期增强扫描过程中信号均低于正常肝实质。在增强后31s时,共有12个病灶的MR图像明显强化,该时点病



A 39-year old man with HCC. CT scan showed a nodule with low density in the segment VII of the liver (A-C), unenhanced and portal venous phase scan showed this nodule clearly, the lesions showed unclearly in arterial phase, no signs of "fast enhanced and fast washout". Enhanced MR multi-phase dynamic scanning with 3D-VIBE sequence showed that the lesion enhanced obviously in the early arterial phase on which the signal intensity of the nodule is higher than the liver parenchyma, the remaining phase showed that the signal intensity of the nodule is lower than the liver parenchyma, revealed the feature of "fast enhanced and fast washout".

图2 MR 3D-VIBE动态增强扫描则可见HCC呈快进快退强化特点,而MSCT增强扫描HCC病灶显示不明显且未见快进快退征象

Fig.2 The enhancement features of "fast enhancement and fast washout" in HCC can be observed on enhanced MR multi-phase dynamic scanning with 3D-VIBE sequence rather than enhanced MSCT scanning

灶信号强度特点及数目与CT增强扫描动脉期所见一致,包括增强15、23、31 s开始明显强化的病灶各1、6、5个,其中1个病灶在注入对比剂62 s时仍呈等信号,该病灶在增强后31 s时开始明显强化,余22个病灶在门脉期及延迟期均呈低信号。MR 3D-VIBE多期动态增强扫描中病灶显示为“快进快退”征象者占78.3%(18/23),MSCT增强扫描具有此征象者占54.5%(12/22)(图2)。

2.2 HCC在MR 3D-VIBE多期动态增强扫描中的征象

所有23个HCC病灶及肝脏的时间-平均信号强度线图见图3,可见肝脏呈渐进性强化,HCC平均信号强度迅速上升后随即下降,在整个强化过程中,肿瘤在增强后约25 s时平均信号强度开始高于肝脏,在48 s时肿瘤平均信号强度开始低于肝脏。

在MR 3D-VIBE多期动态增强扫描图像上,病灶强化特点与直径的关系见表1、表2、表3。由表3可见,直径≤3 cm的肿瘤更易在MR 3D-

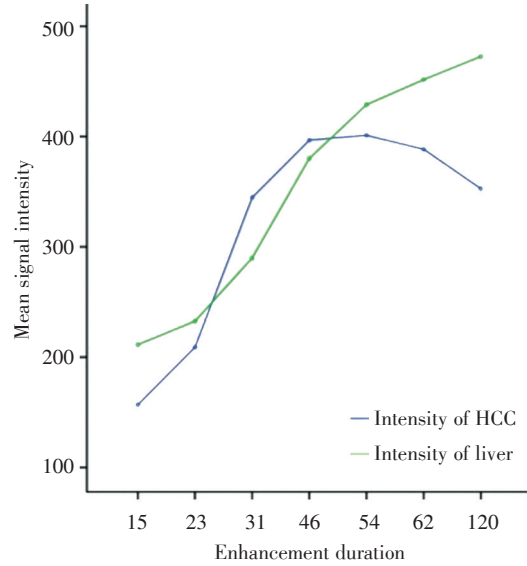


图3 肿瘤及肝脏的时间-平均信号强度线图  
Fig.3 Time-mean signal intensity line of HCC and liver parenchyma

VIBE多期动态增强扫描中观察到明显强化征象( $\chi^2=5.282, P=0.037$ ,图4、图5)。

表1 肿瘤分别在动脉三期开始明显强化的数目与其径线的关系

Table 1 The relation between tumor number of obvious enhancement at three arterial phase and tumor diameter

Tumor diameter	Obvious enhance at 15 s	Obvious enhance at 23 s	Obvious enhance at 31 s	No obvious enhancement	Total
≤3 cm	4	6	2	0	12
> 3 cm	1	3	3	4	11

表2 肿瘤增强扫描动脉早中期与晚期开始明显强化特点与其径线的关系

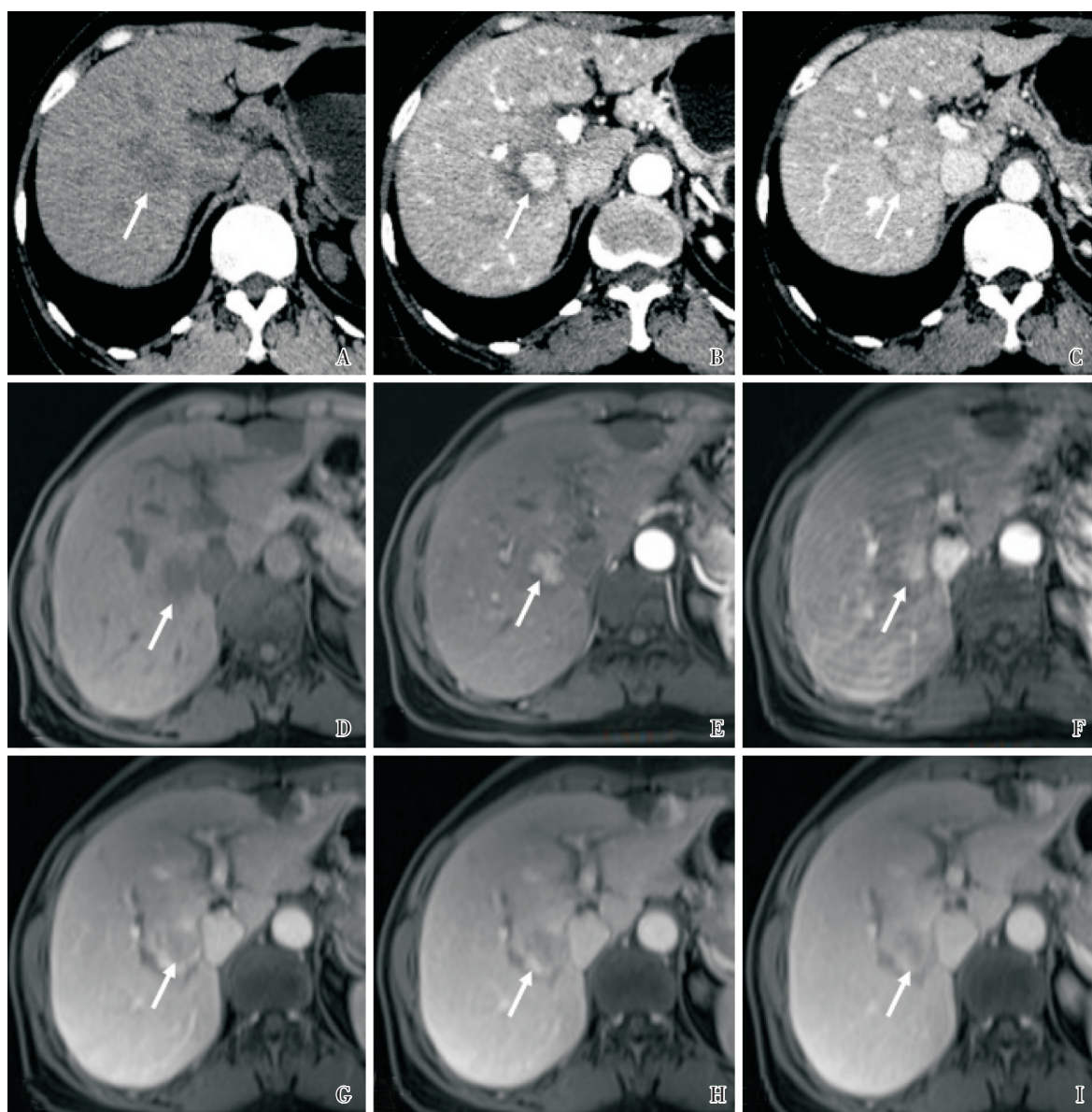
Table 2 The relation between tumor number with obvious enhancement and tumor diameter

Tumor diameter	Obvious enhance at early and middle artery phase	Obvious enhance at late artery phase	P value
≤ 3 cm	10	2	0.305
> 3 cm	4	3	

表3 MR 3D-VIBE多期扫描中肿瘤有无明显强化与其径线的关系

Table 3 The relation between tumor enhancement feature and tumor diameter with enhanced MR multi-phase dynamic scanning with 3D-VIBE sequence

Tumor diameter	With obvious enhancement	Without obvious enhancement	P value
≤ 3 cm	12	0	0.037
> 3 cm	7	4	



A 49-year old female with abdominal pain and discomfort for 1 month. Enhanced MSCT scanning showed a nodule with low density in the segment VI of the liver with a diameter of 2cm (A-C), the nodule enhanced obviously in arterial phase, and decreased in portal venous phase. On enhanced MR multi-phase dynamic scanning with 3D-VIBE sequence (D-I), the nodule enhanced obviously in the early and middle arterial phase, and the signal of nodule decreased gradually in the portal venous phase.

图4 HCC肿瘤径线 $\leq 3$ cm时更多表现为明显强化

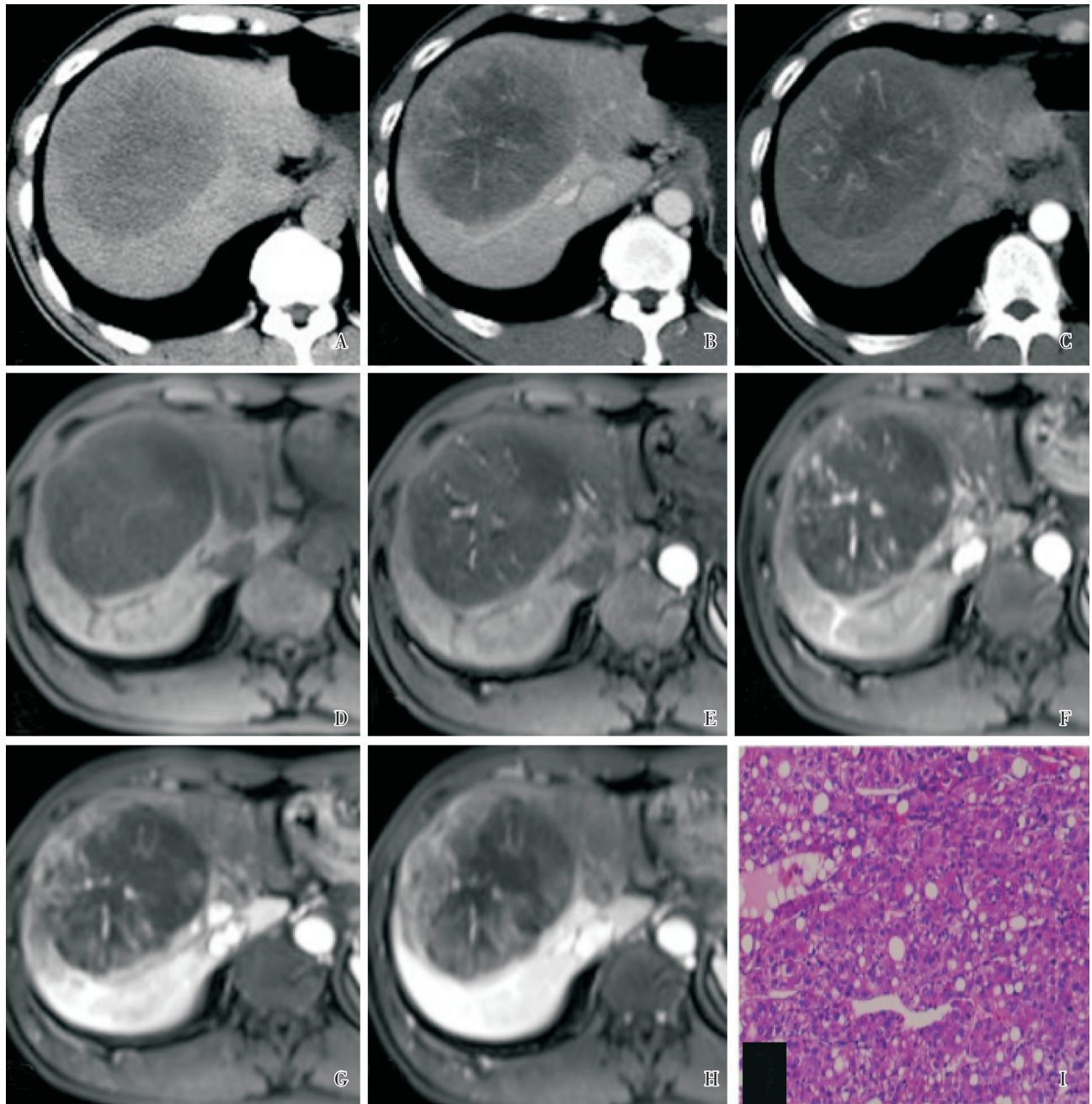
Fig.4 Obvious enhancement feature can be observed when the tumor diameter  $\leq 3$  cm

### 3 讨论

MR 3D-VIBE序列扫描是采用三维扰相梯度回波进行容积式扫描的技术,该方法可产生较高的空间频率信号,提高层面选择方向的空间分辨率的同时,达到薄层扫描的目的,同时保持较高的

空间分辨率及信噪比,且TE、TR时间较短,扫描速度较快,在屏气状态下,可对肝脏进行多期动态增强扫描<sup>[13]</sup>。

肝脏肿瘤的动态增强情况特别是动脉早期明显强化对其定性诊断有着重要的鉴别诊断作用<sup>[14]</sup>,MR 3D-VIBE序列可行多期动态增强扫描,能较完美地捕捉到增强扫描时肝脏各时相特别是



A 53-year old male with right upper abdominal pain for one week. CT and MRI showed a mass in the right lobe of liver, with a diameter of about 8cm, enhanced MSCT scanning (A-C) and enhanced MR multi-phase dynamic scanning with 3D-VIBE sequence (D-H) showed that the mass with low density and low signal intensity on CT and MR images in all phase, and the MR images showed that there were visible thick blood vessels in the tumor. Histopathological examination (I,  $\times 200$ ) showed that the lesion was trabecular type hepatocellular carcinoma.

图5 径线 $>3\text{cm}$ 的HCC增强扫描多表现为大片低强化灶

Fig.5 Obvious enhancement feature cannot be observed when the tumor diameter  $> 3\text{ cm}$

动脉早期的图像,因而在HCC的诊断中有着不可替代的优势。

本研究对23个HCC病灶分别进行了MR 3D-VIBE多期动态增强扫描及MSCT增强扫描,其病灶检出率分别为100%和91.30%,最小病灶的直

径分别为0.4 cm和0.7 cm,说明MR 3D-VIBE多期动态增强扫描对病灶检出能力较MSCT增强扫描高,其原因可能在于MRI具有出色的软组织分辨率,能够较好地地区分不同组织学类型的病灶,同时3D-VIBE序列可对肝脏进行多期动态增强扫描,

能确切观察到HCC病灶的强化特点,进一步提高病灶的检出率<sup>[15]</sup>。

在HCC强化特点的显示上,MR 3D-VIBE多期动态增强扫描对HCC“快进快出”强化特征的显示率为78.3%(18/23),而MSCT增强扫描时,此征象者仅占54.5%(12/22),提示使用MR 3D-VIBE多期动态增强扫描更能确切观察到HCC“快进快退”的强化特点,原因在于VIBE序列行动脉多期扫描,更接近于肿瘤增强后动脉期的实时强化情况,可捕捉到病灶动脉早、中期明显强化的图像,而MSCT增强的动脉期扫描是在注入对比剂后30s进行,对于动脉早中期即开始明显强化、动脉晚期强化消退的病灶,MSCT增强的动脉期扫描可能错过病灶明显强化时相,无法捕捉到肿瘤的“快进”征象,这说明MSCT增强扫描只可检出动脉早期明显强化且持续时间较长或动脉中晚期明显强化的肿瘤,而3D-VIBE多期动态增强扫描则可显示动脉早期强化但强化持续时间不长的肿瘤。Kim等提出,在动脉早期肝脏与部分肿瘤的密度差异较大,可提高肿瘤的检出率<sup>[16]</sup>,Foley及Murakami等研究认为,动脉双期扫描可更加实时地观察肿瘤的强化情况,从而提高病灶的检出率<sup>[17-18]</sup>。本文与上述学者的研究结果一致,提示MR 3D-VIBE多期动态增强扫描相较于MSCT增强扫描可更全面地捕捉到HCC“快进快退”的征象,再结合门脉期病灶的强化特点,进一步提高对HCC诊断的敏感性和准确性。本组研究中未发现门脉早期才开始明显强化的肿瘤,这可能是由于组织学上HCC主要受动脉供血<sup>[19]</sup>。

对本组病例进一步研究提示本组病例中,径线 $\leq 3$ cm的瘤灶倾向于动脉早中期即明显强化(10/12),而径线 $> 3$ cm的肿瘤动脉早中期明显强化者仅占4/7,且多为不均匀强化,但本研究中小肝癌与大肝癌的明显强化起始时间点不具有统计学意义,可能与样本量不足有关( $P=0.305$ )。在增强扫描过程中是否有明显强化的比较上,径线 $\leq 3$ cm与径线 $> 3$ cm的HCC差异有统计学意义( $P=0.037$ ),说明小肝癌可能较大肝癌更具有“快进快退”的典型征象。丛文铭等<sup>[20]</sup>提出,大肝癌与小肝癌之间在DNA含量的倍体水平有显著差异,即小肝癌DNA含量多以二倍体为主,而大肝癌DNA含量以异倍体为主,小肝癌肿瘤细胞可能由于分化程度较高、生长缓慢、动脉血供丰富。这解释了

本研究中在MR 3D-VIBE多期动态增强扫描时,径线 $\leq 3$ cm的HCC动脉早中期即可见明显均匀的强化,大肝癌组成细胞分化程度较低、肿瘤生长迅速、缺血坏死常见、血供较少,因而增强扫描时动脉期趋向于较晚的不均匀强化,对于坏死较多的大肝癌,增强扫描则表现为强化不明显。进一步可推测对于动脉早中期明显均匀强化的HCC,其肿瘤细胞分化较高的可能性更大,患者的预后可能较同等大小但坏死明显的肿瘤好。

综上,MR 3D-VIBE多期动态增强扫描具有扫描速度快、层厚小、组织分辨率良好等优势,可对肝脏进行多期动态增强扫描,提高早期较小的HCC的检出率,且其更显著的优势在于观察并捕捉HCC病灶在各个强化时相的情况,相较于常规MSCT或MR增强扫描,可明确观察到动脉早中期明显强化而动脉晚期强化消退的肿瘤,大大提高了HCC尤其是较小的HCC诊断的敏感性与准确性,有助于小肝癌的早期诊断及治疗,改善患者预后,同时由于其无辐射损伤的特性,可作为HCC年轻患者的首选检查手段。

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