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肝特异性对比剂Gd–EOB–DTPA增强磁共振成像评价肝功能的研究进展

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背景资料
临床上常用的肝功能评价方法包括Child-Pugh评分、自终末期肝病模型(model for end-stage liver disease, MELD)评分、吲哚青绿15 min滞留实验(indocyanine green 15 retention, ICG R15)、LiMAX test等仅能评价整体肝功能, 存在一定的限制, 而以影像为基础肝功能评价可以同时提供空间分布信息.

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Assessment of liver function by Gd-EOB-DTPA enhanced magnetic resonance imaging

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Abstract

Gadolinium-ethoxybenzyl-diethylenetriamine pentaacetic acid (Gd-EOB-DTPA), a liver-specific magnetic resonance imaging (MRI) contrast agent, is increasingly used for imaging-based liver function tests. Like indocyanine green and mebrofenin, Gd-EOB-DTPA is taken up by hepatocytes through organic anion-transporting polypeptides 1 ($OATP_1$) B_1 and B_3 and is then excreted into the bile by multi-drug resistance protein (MRP_2). The advantages of Gd-EOB-DTPA-based liver function tests include function measurement integrated in an existing MRI protocol, ability of evaluating segmental liver function, and no ionizing radiation. The approaches based on Gd-EOB-DTPA for function measurement are as follows: measurement of biliary elimination, hepatic parenchymal enhancement, MR relaxometry, and MR perfusion. These approaches have potential value for assessing liver reserve, hepatic fibrosis, non-alcoholic fatty liver disease and so on.

Key Words: Liver function; Gd-EOB-DTPA; Magnetic resonance imaging

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摘要

肝特异性对比剂Gd-EOB-DTPA的肝功能评价越来越受到重视, 其吸收和排泄的路径与

吲哚青绿15 min滞留实验及核素肝胆显像剂甲溴苯宁的吸收排泄路径相似即通过肝细胞膜表面的有机阴离子转运系统有机阴离子转运系统1(organic anion transporter 1, OATP1)B_1和$OATP_1B_3$吸收进入肝细胞内, 再通过多耐药蛋白载体排泄入胆道系统. Gd-EOB-DTPA增强磁共振(magnetic resonance, MR)优势在于常规的MR增强检查可同时获得肝功能信息, 可以评价节段性肝功能且没有电离辐射损伤. 其评价方法主要通过胆道内对比剂排泄的量、肝实质的强化率、MR弛豫时间的测定和灌注扫描参数的测定等, 在评价肝功能储备、肝纤维化分级、非酒精性脂肪肝程度等有广泛的应用前景.

关键词: 肝功能; Gd-EOB-DTPA; 磁共振成像

核心提要: Gd-EOB-DTPA增强磁共振成像可以“一站式”的获得临床所需的解剖和肝功能的信息, 同时可以评价肝节段性功能储备, 为慢性肝病或手术患者的治疗和预后提供有用的依据.

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0 引言

肝功能的评价, 一直是临床医生关注的一个焦点, 无论是肝外科手术前的准确预测、术后的有效随访还是对于内科患者对于肝脏弥漫性病变(如肝纤维化/肝硬化、脂肪肝等)的随访监测, 对于提高手术的成功率及延长患者的生存期, 都有十分密切的联系, 而就迄今运用于临床的各种肝功能评价方法, 都有其一定的局限性. 目前临床上最常用的肝功能评价方法包括Child-Pugh评分、终末期肝病模型(model for end-stage liver disease, MELD)评分、吲哚青绿15 min滞留实验(indocyanine green 15 retention, ICG R_{15})、LiMAX test等[1-3], 都只能评估整体肝功能的变化, 对于不同肝段之间的肝功能的区别, 难以有效评价.

近年来以影像为基础的肝功能储备的评价应运而生, 开始受到临床的关注和重视[4-7], 尤其是肝脏特异性对比剂Gd-EOB-DTPA(gadolinium-ethoxybenzyl-diethylenetriamine pentaacetic acid)(商品名普美显, Primovist)不仅对于肝局灶性病变的检出、定性具有优势[8-11], 而且对于肝功能评价有潜在的应用价值[12-16]. 本文就Gd-EOB-DTPA增强磁共振(magnetic resonance, MR)成像对肝功能的评价的方法和价值的相关研究进行综述, 旨在提高读者在相关领域的研究的认识和兴趣.

1 Gd-EOB-DTPA增强MR评价肝功能的机制和优势

静脉团注Gd-EOB-DTPA可通过肝窦面的肝细胞膜表面的有机阴离子转运系统1(organic anion transporter 1, $OATP_1$)B_1和$OATP_1B_3$吸收进入肝细胞内, 滞留数小时至24 h之久, 再通过主要位于胆道面的肝细胞膜上多耐药蛋白载体(multi-drug resistance protein, MRP)MRP_2排泄入胆道系统, 其通过肝脏吸收比例约为注射剂量的50%, 且其化学结构不会改变[17-19]. Gd-EOB-DTPA的吸收和排泄的路径与ICG R_{15}及核素肝胆显像剂甲溴苯宁的吸收排泄路径相似, 因此Gd-EOB-DTPA增强MR可用于肝功能的评价. 当肝脏发生不同的病变时, 部分肝细胞遭破坏、肝细胞的正常功能受损, 肝实质吸收和排泄入胆总管对比剂Gd-EOB-DTPA的量会发生变化, 从而引起MR信号强度的改变, 以此来反映肝功能的改变.

Gd-EOB-DTPA增强MR的优势在于在常规的MR增强检查方案中的基础上同时获得肝功能信息. Gd-EOB-DTPA增强MR在术前可以“一站式”的获得外科手术前所需的信息, 包括肝肿瘤的体积及分布、肝脏的解剖、血供和其他肝外的信息如有无淋巴结转移等, 这是其他肝功能检查所不具备的; 而且其克服了整体评价的肝功能的缺点, 可以显示肝实质的损害分布的不均匀性, 实现节段性肝功能的评价[20,21]. 研究发现Gd-EOB-DTPA增强MR与^{99m}锝-甲溴苯宁、ICG R_{15}对肝功能储备的准确性相似[12,13], 而Gd-EOB-DTPA增强MR较核素检查具有更高的空间和时间分辨率, 同时MR没有辐射的损害, 因此更具有临床的应用价值.

2 Gd-EOB-DTPA增强MR评价肝功能的方法

Gd-EOB-DTPA增强MR检查评价肝功能的主

研发前沿
本文研究着重于Gd-EOB-DTPA增强磁共振(magnetic resonance, MR)成像在评价节段性肝功能的应用, 目前需要确定最优的测量方法和评价指标的标准化.

相关报道
目前此方面研究都处于动物实验或单中心的临床研究阶段, 常用的测量方法各异, 但是在肝功能评价方面已初步显示其优越性.

创新盘点
本文介绍了Gd-EOB-DTPA增强MR成像评价肝功能的机制、优势, 并比较目前不同测量方法的优缺点及应用的注意点.

要通过测量胆道内对比剂的排泄和肝实质的强化程度的变化来反映肝细胞的功能状态. 具体方法主要有以下几点: 胆道内对比剂排泄的量、肝实质的强化率、MR弛豫时间的测定和灌注扫描参数的测定等.

2.1 胆道内对比剂排泄的量的评价 Gd-EOB-DTPA增强MR后20 min在所有正常健康人群中均看到肝内外胆道内很好的显示[22], 在慢性肝病伴肝功能损害的患者中胆道的显影会相应延迟. 常采用的评价方法主要包括: 特异期主观评价胆道结构显影的清晰度、胆总管显影的时间和信号值(signal intensity, SI)测定、胆总管与肌肉相对值、胆囊充盈时间和程度等.

研究显示[23-27]慢性肝病/肝硬化患者Gd-EOB-DTPA增强MR主要表现: (1)肝功能损害时(MELD≥11和总胆红素≥30 μmol/L)肝内外胆道结构的显示不清, 严重时甚至不显影[23]; (2)胆道充盈时间明显延迟, 而且强化程度(直接强化或相对强化)明显减弱; (3)胆囊管开放充盈时间延长(>30 min); (4)胆管强化的程度与ICG R_{15}显著相关, 因此可以潜在反映肝功能的程度.

胆道强化的评价方法比较简单、直观, 只需应用常规序列就可以做出判断, 不需要额外的序列和复杂技术, 但是胆道的强化程度和时间不仅仅与肝功能有关, 而且与胆道的压力和胆汁流量有关, 如果胆汁动力学发生改变如胆道结石、胆道炎症等, 其评价肝功能准确性受到限制[27,28].

2.2 肝实质的MR SI的改变 这是目前临床和研究最常用的一种方法, 采用的评价方法: 特异期主观观察或MR SI测量肝实质的强化改变、肝实质的信噪比、利用肌肉或脾脏作为内在参照物校正等.

“延迟期高信号门静脉”征即静脉注射Gd-EOB-DTPA延迟30 min后门静脉与周围肝实质相比呈相对高信号, 此征出现的概率约13%, 并与血直接胆红素相关, 判断胆红素高于2.18 mg/dL的敏感性为89%, 特异性为96%[29]. 肝实质强化程度的测量可以反映肝细胞的功能状态, 在患者中的慢性肝功能损害的特异期肝实质的信噪比或相对强化率明显低于正常功能的患者, 而且与ICG R_{15}显著相关[30,31]. 目前大部分文献利用内参物(肌肉或脾脏)计算校正肝脏强化率[32]、肝实质强化指数[33]和肝细胞吸收指数(hepatocellular uptake index, HUI)[34]等. Watanabe等[33]报道肝实质强化指数对肝纤维化分级的准确性明显优于扩散加权成像、血液检查和临床指标.

肝脏SI的直接测量比较简单, 与测量CT值相似, 直接利用感兴趣区的测量就可以得到相应的值, 这也是目前临床上应用最广的原因. 但是其存在一定缺陷: MR的SI的影响因素比较多如MR的扫描参数不同SI亦不同, 而且MR SI与钆的浓度成正相关而不是线性相关[35]. 虽然采用内参校正, 可减少误差, 但是计算相对比较麻烦不适合临床常规使用, 尤其HUI测量和计算均比较复杂, 限制其广泛应用.

2.3 MR弛豫时间的测定 Gd-EOB-DTPA不仅可以缩短T_1弛豫时间, 亦可缩短T_2*弛豫时间. 因此可以通过T_1mapping参数图和T_2*加权成像参数图测量相应的T_1值和T_2*值来评价肝功能[15,36-42]. 我们研究[15]发现肝硬化患者MELD分数越高肝胆特异期的T_1弛豫时间明显延长, 而且增强前后T_1弛豫时间的降低率明显下降. 同时发现Gd-EOB-DTPA肝胆特异期T_1弛豫时间的测量有利于早期发现梗阻性黄疸的肝损伤[36]、肝纤维化的分级[37]以及有助于非酒精性脂肪肝的分级[38]. 理论上, Gd-EOB-DTPA缩短T_1弛豫时间较T_2*弛豫时间更明显, 有报道显示慢性肝损伤患者肝胆特异期的T_2*弛豫时间与肝功能正常的患者无明显区别, 但是T_2*弛豫时间的降低率明显下降[42].

弛豫时间的测量比较客观的反映肝细胞内Gd-EOB-DTPA的浓度, 因此对于肝功能的评价优于SI的直接测量[43]. 全肝测量T_1弛豫时间测量有助于提高肝功能评价的准确性[44], 但是T_1和T_2*弛豫时间的测量尤其全肝测量需要有特殊序列和软件的支持, 而且肝细胞吸收Gd-EOB-DTPA的量除了受肝细胞功能影响外, 还受到肝脏血流灌注的影响.

2.4 MR灌注扫描技术 MR肝脏灌注是利用灌注参数来定量肝脏肿瘤或肝实质的微循环状态[45,46]. Saito等[13]运用Gd-EOB-DTPA动态增强扫描运用示踪动态计算模型, 与ICG_{15}及^{99m}Tc-乙二烯三胺戊乙酸半乳糖基人血清白蛋白(^{99m}Tc-labeled diethylenetriaminepentaacetic acid galactosyl human serum albumin, ^{99m}Tc-GSA)的单光子发射型计算机断层显像(single photon emission computed tomography, SPECT)图像相关性很好, 适合评价肝功能储备. 另外有研究

发现Gd-EOB-DTPA动态灌注扫描有望用于原发性硬化性胆管炎的节段及亚段性肝功能的评价[47,48]、肝纤维化分级[49]和炎症活动度[50]的评价.

MR灌注扫描不仅考虑了肝细胞功能不同导致吸收Gd-EOB-DTPA的浓度不同, 还考虑肝脏血流状态的不同, 从这一点上其优于其他的方法, 但是由于Gd-EOB-DTPA被肝细胞吸收与常规MR对比剂不一样, 因此其灌注分析需要特殊软件和复杂的数学模型的计算. 另外MR灌注分析的困难还在于肝脏双血供、采集图像的呼吸伪影、缺乏统一的标准等. 因此还需要进一步研究和标准化.

3 结论

Gd-EOB-DTPA增强MR成像作为一种无创伤性检查手段, 能同时评价肝脏的解剖和功能储备具有独特的优势, 尤其是定量评价肝段、肝叶的肝脏储备能力, 从而进一步完善肝脏功能检测的方法, 对肝肿瘤手术的术前判断和弥漫性肝病监测有广泛的应用前景, 但其测量方法和评价指标的需要进一步临床验证和标准化.

应用要点

Gd-EOB-DTPA增强MR成像作为一种无创伤性检查手段, 无射线危害, 具备定量评价肝脏功能储备的能力, 对肝肿瘤手术的术前判断和弥漫性肝病监测有广泛的应用前景.

4 参考文献

1 Thirunavukarasu P, Aloia TA. Preoperative Assessment and Optimization of the Future Liver Remnant. *Surg Clin North Am* 2016; 96: 197-205 [PMID: 27017859 DOI: 10.1016/j.suc.2015.11.001]

2 Hsieh CB, Chen CJ, Chen TW, Yu JC, Shen KL, Chang TM, Liu YC. Accuracy of indocyanine green pulse spectrophotometry clearance test for liver function prediction in transplanted patients. *World J Gastroenterol* 2004; 10: 2394-2396 [PMID: 15285026 DOI: 10.3748/wjg.v10.i16.2394]

3 Stockmann M, Lock JF, Riecke B, Heyne K, Martus P, Fricke M, Lehmann S, Niehues SM, Schwabe M, Lemke AJ, Neuhaus P. Prediction of postoperative outcome after hepatectomy with a new bedside test for maximal liver function capacity. *Ann Surg* 2009; 250: 119-125 [PMID: 19561474 DOI: 10.1097/SLA.0b013e3181ad85b5]

4 Lim MC, Tan CH, Cai J, Zheng J, Kow AW. CT volumetry of the liver: where does it stand in clinical practice? *Clin Radiol* 2014; 69: 887-895 [PMID: 24824973 DOI: 10.1016/j.crad.2013.12.021]

5 D'Onofrio M, De Robertis R, Ruzzenente A, Mantovani W, Puntel G, Crosara S, Canestrini S, Guglielmi A, Mucelli RP. Time-to-peak values can estimate hepatic functional reserve in patients undergoing surgical resection: a comparison between perfusion CT and indocyanine green retention test. *J Comput Assist Tomogr* 2014; 38: 733-741 [PMID: 24834884 DOI: 10.1097/RCT.0000000000000102]

6 de Graaf W, van Lienden KP, van Gulik TM, Bennink RJ. (99m)Tc-mebrofenin hepatobiliary scintigraphy with SPECT for the assessment of hepatic function and liver functional volume before partial hepatectomy. *J Nucl Med* 2010; 51: 229-236 [PMID: 20080899 DOI: 10.2967/jnumed.109.069724]

7 de Graaf W, Bennink RJ, Veteläinen R, van Gulik TM. Nuclear imaging techniques for the assessment of hepatic function in liver surgery and transplantation. *J Nucl Med* 2010; 51: 742-752 [PMID: 20395336 DOI: 10.2967/jnumed.109.069435]

8 Zeng MS, Ye HY, Guo L, Peng WJ, Lu JP, Teng GJ, Huan Y, Li P, Xu JR, Liang CH, Breuer J. Gd-EOB-DTPA-enhanced magnetic resonance imaging for focal liver lesions in Chinese patients: a multicenter, open-label, phase III study. *Hepatobiliary Pancreat Dis Int* 2013; 12: 607-616 [PMID: 24322746 DOI: 10.1016/S1499-3872(13)60096-X]

9 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: 82-94 [PMID: 26098460 DOI: 10.1148/radiol.2015150177]

10 Saito K, Moriyasu F, Sugimoto K, Nishio R, Saguchi T, Nagao T, Taira J, Akata S, Tokuuye K. Diagnostic efficacy of gadoxetic acid-enhanced MRI for hepatocellular carcinoma and dysplastic nodule. *World J Gastroenterol* 2011; 17: 3503-3509 [PMID: 21941417 DOI: 10.3748/wjg.v17.i30.3503]

11 Phongkitkarun S, Limsamutpetch K, Tannaphai P, Jatchavala J. Added value of hepatobiliary phase gadoxetic acid-enhanced MRI for diagnosing hepatocellular carcinoma in high-risk patients. *World J Gastroenterol* 2013; 19: 8357-8365 [PMID: 24363528 DOI: 10.3748/wjg.v19.i45.8357]

12 Geisel D, Lüdemann L, Fröling V, Malinowski M, Stockmann M, Baron A, Gebauer B, Seehofer D, Prasad V, Denecke T. Imaging-based evaluation of liver function: comparison of ^{99}mTc-mebrofenin hepatobiliary scintigraphy and Gd-EOB-DTPA-enhanced MRI. *Eur Radiol* 2015; 25: 1384-1391 [PMID: 25447973 DOI: 10.1007/s00330-014-3536-8]

13 Saito K, Ledsam J, Sourbron S, Hashimoto T, Araki Y, Akata S, Tokuuye K. Measuring hepatic functional reserve using low temporal resolution Gd-EOB-DTPA dynamic contrast-enhanced MRI: a preliminary study comparing galactosyl human serum albumin scintigraphy with indocyanine green retention. *Eur Radiol* 2014; 24: 112-119 [PMID: 23949726 DOI: 10.1007/s00330-013-2983-y]

14 Kukuk GM, Schaefer SG, Fimmers R, Hadizadeh DR, Ezziddin S, Spengler U, Schild HH, Willinek WA. Hepatobiliary magnetic resonance imaging in patients with liver disease: correlation of liver enhancement with biochemical liver function tests. *Eur Radiol* 2014; 24: 2482-2490 [PMID: 25030459 DOI: 10.1007/s00330-014-3291-x]

15 Ding Y, Rao SX, Chen C, Li R, Zeng MS. Assessing liver function in patients with HBV-related HCC: a comparison of T_1 mapping on Gd-EOB-DTPA-enhanced MR imaging with DWI. *Eur Radiol* 2015; 25: 1392-1398 [PMID: 25523455 DOI: 10.1007/s00330-014-3542-x]

16 Agnello F, Dioguardi Burgio M, Picone D,

名词解释

T_1弛豫时间: 90度射频脉冲质子由纵向磁化转到横向磁化之后再恢复到纵向磁化激发前状态所需时间. 不同的组织的T_1是相对固定的, 且存在差别. 肝细胞吸收Gd-EOB-DTPA的量的不同, 其T_1弛豫时间亦不同.

Vernuccio F, Cabibbo G, Giannitrapani L, Taibbi A, Agrusa A, Bartolotta TV, Galia M, Lagalla R, Midiri M, Brancatelli G. Magnetic resonance imaging of the cirrhotic liver in the era of gadoxetic acid. *World J Gastroenterol* 2016; 22: 103-111 [PMID: 26755863 DOI: 10.3748/wjg.v22.i1.103]

17 Van Beers BE, Pastor CM, Hussain HK. Primovist, Eovist: what to expect? *J Hepatol* 2012; 57: 421-429 [PMID: 22504332 DOI: 10.1016/j.jhep.2012.01.031]

18 Narita M, Hatano E, Arizono S, Miyagawa-Hayashino A, Isoda H, Kitamura K, Taura K, Yasuchika K, Nitta T, Ikai I, Uemoto S. Expression of OATP1B3 determines uptake of Gd-EOB-DTPA in hepatocellular carcinoma. *J Gastroenterol* 2009; 44: 793-798 [PMID: 19404564 DOI: 10.1007/s00535-009-0056-4]

19 Lee NK, Kim S, Lee JW, Lee SH, Kang DH, Kim GH, Seo HI. Biliary MR imaging with Gd-EOB-DTPA and its clinical applications. *Radiographics* 2009; 29: 1707-1724 [PMID: 19959517 DOI: 10.1148/rg.296095501]

20 Nilsson H, Karlgren S, Blomqvist L, Jonas E. The inhomogeneous distribution of liver function: possible impact on the prediction of post-operative remnant liver function. *HPB* (Oxford) 2015; 17: 272-277 [PMID: 25297934 DOI: 10.1111/hpb.12348]

21 Nilsson H, Blomqvist L, Douglas L, Nordell A, Janczewska I, Näslund E, Jonas E. Gd-EOB-DTPA-enhanced MRI for the assessment of liver function and volume in liver cirrhosis. *Br J Radiol* 2013; 86: 315-331 [PMID: 23403453 DOI: 10.1259/bjr.20120653]

22 Ringe KI, Husarik DB, Gupta RT, Boll DT, Merkle EM. Hepatobiliary transit times of gadoxetate disodium (Primovist®) for protocol optimization of comprehensive MR imaging of the biliary system--what is normal? *Eur J Radiol* 2011; 79: 201-205 [PMID: 20347540 DOI: 10.1016/j.ejrad.2010.03.008]

23 Tschirch FT, Struwe A, Petrowsky H, Kakales I, Marincek B, Weishaupt D. Contrast-enhanced MR cholangiography with Gd-EOB-DTPA in patients with liver cirrhosis: visualization of the biliary ducts in comparison with patients with normal liver parenchyma. *Eur Radiol* 2008; 18: 1577-1586 [PMID: 18369632 DOI: 10.1007/s00330-008-0929-6]

24 Tamada T, Ito K, Sone T, Kanki A, Sato T, Higashi H. Gd-EOB-DTPA enhanced MR imaging: evaluation of biliary and renal excretion in normal and cirrhotic livers. *Eur J Radiol* 2011; 80: e207-e211 [PMID: 20869827 DOI: 10.1016/j.ejrad.2010.08.033]

25 Takao H, Akai H, Tajima T, Kiryu S, Watanabe Y, Imamura H, Akahane M, Yoshioka N, Kokudo N, Ohtomo K. MR imaging of the biliary tract with Gd-EOB-DTPA: effect of liver function on signal intensity. *Eur J Radiol* 2011; 77: 325-329 [PMID: 19726150 DOI: 10.1016/j.ejrad.2009.08.008]

26 Feng ST, Wu L, Chan T, Cai H, Luo Y, Zheng K, Tang D, Li ZP. Functional magnetic resonance cholangiography enhanced with Gd-EOB-DTPA: effect of liver function on biliary system visualization. *J Magn Reson Imaging* 2014; 39: 1254-1258 [PMID: 24115466 DOI: 10.1002/jmri.24277]

27 Smith AD, Veniero JC. Gd-EOB-DTPA as a functional MR cholangiography contrast agent: imaging gallbladder filling in patients with and without hepatobiliary dysfunction. *J Comput Assist Tomogr* 2011; 35: 439-445 [PMID: 21765298 DOI: 10.1097/RCT.0b013e31821f4e29]

28 Krishnan P, Gupta RT, Boll DT, Brady CM, Husarik DB, Merkle EM. Functional evaluation of cystic duct patency with Gd-EOB-DTPA MR imaging: an alternative to hepatobiliary scintigraphy for diagnosis of acute cholecystitis? *Abdom Imaging* 2012; 37: 457-464 [PMID: 21870116 DOI: 10.1007/s00261-011-9785-y]

29 Lee NK, Kim S, Kim GH, Heo J, Seo HI, Kim TU, Kang DH. Significance of the "delayed hyperintense portal vein sign" in the hepatobiliary phase MRI obtained with Gd-EOB-DTPA. *J Magn Reson Imaging* 2012; 36: 678-685 [PMID: 22649000 DOI: 10.1002/jmri.23700]

30 Tajima T, Takao H, Akai H, Kiryu S, Imamura H, Watanabe Y, Shibahara J, Kokudo N, Akahane M, Ohtomo K. Relationship between liver function and liver signal intensity in hepatobiliary phase of gadolinium ethoxybenzyl diethylenetriamine pentaacetic acid-enhanced magnetic resonance imaging. *J Comput Assist Tomogr* 2010; 34: 362-366 [PMID: 20498536 DOI: 10.1097/RCT.0b013e3181cd3304]

31 Sato Y, Matsushima S, Inaba Y, Sano T, Yamaura H, Kato M, Shimizu Y, Senda Y, Ishiguchi T. Preoperative estimation of future remnant liver function following portal vein embolization using relative enhancement on gadoxetic acid disodium-enhanced magnetic resonance imaging. *Korean J Radiol* 2015; 16: 523-530 [PMID: 25995681 DOI: 10.3348/kjr.2015.16.3.523]

32 Motosugi U, Ichikawa T, Oguri M, Sano K, Sou H, Muhi A, Matsuda M, Fujii H, Enomoto N, Araki T. Staging liver fibrosis by using liver-enhancement ratio of gadoxetic acid-enhanced MR imaging: comparison with aspartate aminotransferase-to-platelet ratio index. *Magn Reson Imaging* 2011; 29: 1047-1052 [PMID: 21775085 DOI: 10.1016/j.mri.2011.05.007]

33 Watanabe H, Kanematsu M, Goshima S, Kondo H, Onozuka M, Moriyama N, Bae KT. Staging hepatic fibrosis: comparison of gadoxetate disodium-enhanced and diffusion-weighted MR imaging--preliminary observations. *Radiology* 2011; 259: 142-150 [PMID: 21248234 DOI: 10.1148/radiol.10100621]

34 Yamada A, Hara T, Li F, Fujinaga Y, Ueda K, Kadoya M, Doi K. Quantitative evaluation of liver function with use of gadoxetate disodium-enhanced MR imaging. *Radiology* 2011; 260: 727-733 [PMID: 21712472 DOI: 10.1148/radiol.11100586]

35 Materne R, Smith AM, Peeters F, Dehoux JP, Keyeux A, Horsmans Y, Van Beers BE. Assessment of hepatic perfusion parameters with dynamic MRI. *Magn Reson Med* 2002; 47: 135-142 [PMID: 11754452]

36 Ding Y, Rao SX, Chen C, Li R, Zeng MS. Potential of Gd-EOB-DTPA-enhanced MR imaging for evaluation of bile duct ligation-induced liver injury in rabbits. *Hepatol Int* 2015; 9: 303-309 [PMID: 25788184 DOI: 10.1007/s12072-014-9595-8]

37 Ding Y, Rao SX, Zhu T, Chen CZ, Li RC, Zeng

MS. Liver fibrosis staging using T1 mapping on gadoxetic acid-enhanced MRI compared with DW imaging. *Clin Radiol* 2015; 70: 1096-1103 [PMID: 26164421 DOI: 10.1016/j.crad.2015.04.014]

38 Ding Y, Rao SX, Meng T, Chen C, Li R, Zeng MS. Usefulness of T1 mapping on Gd-EOB-DTPA-enhanced MR imaging in assessment of non-alcoholic fatty liver disease. *Eur Radiol* 2014; 24: 959-966 [PMID: 24463697 DOI: 10.1007/s00330-014-3096-y]

39 Yoon JH, Lee JM, Paek M, Han JK, Choi BI. Quantitative assessment of hepatic function: modified look-locker inversion recovery (MOLLI) sequence for T1 mapping on Gd-EOB-DTPA-enhanced liver MR imaging. *Eur Radiol* 2016; 26: 1775-1782 [PMID: 26373756 DOI: 10.1007/s00330-015-3994-7]

40 Katsube T, Okada M, Kumano S, Hori M, Imaoka I, Ishii K, Kudo M, Kitagaki H, Murakami T. Estimation of liver function using T1 mapping on Gd-EOB-DTPA-enhanced magnetic resonance imaging. *Invest Radiol* 2011; 46: 277-283 [PMID: 21343827 DOI: 10.1097/RLI.0b013e318200f67d]

41 Haimerl M, Verloh N, Zeman F, Fellner C, Müller-Wille R, Schreyer AG, Stroszczynski C, Wiggermann P. Assessment of clinical signs of liver cirrhosis using T1 mapping on Gd-EOB-DTPA-enhanced 3T MRI. *PLoS One* 2013; 8: e85658 [PMID: 24392025 DOI: 10.1371/journal.pone.0085658]

42 Katsube T, Okada M, Kumano S, Imaoka I, Kagawa Y, Hori M, Ishii K, Tanigawa N, Imai Y, Kudo M, Murakami T. Estimation of liver function using T2* mapping on gadolinium ethoxybenzyl diethylenetriamine pentaacetic acid enhanced magnetic resonance imaging. *Eur J Radiol* 2012; 81: 1460-1464 [PMID: 21514080 DOI: 10.1016/j.ejrad.2011.03.073]

43 Kamimura K, Fukukura Y, Yoneyama T, Takumi K, Tateyama A, Umanodan A, Shindo T, Kumagae Y, Ueno S, Koriyama C, Nakajo M. Quantitative evaluation of liver function with T1 relaxation time index on Gd-EOB-DTPA-enhanced MRI: comparison with signal intensity-based indices. *J Magn Reson Imaging* 2014; 40: 884-889 [PMID: 24677659 DOI: 10.1002/jmri.24443]

44 Haimerl M, Schlabeck M, Verloh N, Zeman F, Fellner C, Nickel D, Barreiros AP, Loss M, Stroszczynski C, Wiggermann P. Volume-assisted estimation of liver function based on Gd-EOB-DTPA-enhanced MR relaxometry. *Eur Radiol* 2016; 26: 1125-1133 [PMID: 26186960 DOI: 10.1007/s00330-015-3919-5]

45 Rao SX, Chen CZ, Liu H, Zeng MS, Qu XD. Three-dimensional whole-liver perfusion magnetic resonance imaging in patients with hepatocellular carcinomas and colorectal hepatic metastases. *BMC Gastroenterol* 2013; 13: 53 [PMID: 23530688 DOI: 10.1186/1471-230X-13-53]

46 Aronhime S, Calcagno C, Jajamovich GH, Dyvorne HA, Robson P, Dieterich D, Fiel MI, Martel-Laferriere V, Chatterji M, Rusinek H, Taouli B. DCE-MRI of the liver: effect of linear and nonlinear conversions on hepatic perfusion quantification and reproducibility. *J Magn Reson Imaging* 2014; 40: 90-98 [PMID: 24923476 DOI: 10.1002/jmri.24341]

47 Nilsson H, Blomqvist L, Douglas L, Nordell A, Jacobsson H, Hagen K, Bergquist A, Jonas E. Dynamic gadoxetate-enhanced MRI for the assessment of total and segmental liver function and volume in primary sclerosing cholangitis. *J Magn Reson Imaging* 2014; 39: 879-886 [PMID: 24123427 DOI: 10.1002/jmri.24250]

48 Nilsson H, Blomqvist L, Douglas L, Nordell A, Jonas E. Assessment of liver function in primary biliary cirrhosis using Gd-EOB-DTPA-enhanced liver MRI. *HPB* (Oxford) 2010; 12: 567-576 [PMID: 20887325 DOI: 10.1111/j.1477-2574.2010.00223.x]

49 Chen BB, Hsu CY, Yu CW, Wei SY, Kao JH, Lee HS, Shih TT. Dynamic contrast-enhanced magnetic resonance imaging with Gd-EOB-DTPA for the evaluation of liver fibrosis in chronic hepatitis patients. *Eur Radiol* 2012; 22: 171-180 [PMID: 21879400 DOI: 10.1007/s00330-011-2249-5]

50 Chen BB, Hsu CY, Yu CW, Kao JH, Lee HS, Liang PC, Wei SY, Hwang RM, Shih TT. Hepatic necro-inflammation and elevated liver enzymes: evaluation with MRI perfusion imaging with gadoxetic acid in chronic hepatitis patients. *Clin Radiol* 2014; 69: 473-480 [PMID: 24556468 DOI: 10.1016/j.crad.2013.12.003]

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同行评价

本文综述了肝特异性对比剂Gd-EOB-DTPA增强MR成像评价肝功能的研究进展. 选题有一定的新颖性, 对于指导临床工作有一定的帮助.

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