CONTRAST MEDIA



ESGAR consensus statement on liver MR imaging and clinical use of liver-specific contrast agents

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Abstract

Objectives To develop a consensus and provide updated recommendations on liver MR imaging and the clinical use of liver-specific contrast agents.

Methods The European Society of Gastrointestinal and Abdominal Radiology (ESGAR) formed a multinational European panel of experts, selected on the basis of a literature review and their leadership in the field of liver MR imaging. A modified Delphi process was adopted to draft a list of statements. Descriptive and Cronbach's statistics were used to rate levels of agreement and internal reliability of the consensus. *Results* Three Delphi rounds were conducted and 76 statements composed on MR technique (n=17), clinical application of liver-specific contrast agents in benign, focal liver lesions (n=7), malignant liver lesions in non-cirrhotic (n=9) and in cirrhotic patients (n=18), diffuse and vascular liver diseases (n=12), and bile ducts (n=13). The overall mean score of agreement was 4.84 (SD \pm 0.17). Full consensus was reached in 22 % of all statements in all working groups, with no full consensus reached on diffuse and vascular diseases.

Conclusions The consensus provided updated recommendations on the methodology, and clinical indications, of MRI

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with liver specific contrast agents in the study of liver diseases.

Key points

- Liver-specific contrast agents are recommended in MRI of the liver.
- The hepatobiliary phase improves the detection and characterization of hepatocellular lesions.
- *Liver-specific contrast agents can improve the detection of HCC.*

Keywords Liver · Biliary tract · Magnetic resonance imaging · Contrast media · Delphi technique

Introduction

The advantages of MR imaging in the investigation of the liver are well documented since this examination provides a comprehensive work-up of focal and diffuse liver diseases. Recent state-of-the-art techniques including fast scanning acquisitions and new MR imaging contrast agents enable improvements in detection and characterization of focal liver lesions. Therefore, together with appropriate clinical information, in most cases, a definitive diagnosis can be adequately achieved avoiding invasive procedures such as liver biopsy. This is based on the unique properties of MR imaging resulting in a high intrinsic soft tissue contrast between normal liver parenchyma and liver lesions, which can be further enhanced with intravenous administration of non-specific (extracellular) and liver-specific (hepatobiliary) gadolinium-based contrast agents [1–4].

Multiphasic dynamic gadolinium-enhanced imaging, which is considered essential in detection and characterization of liver lesions, is routinely obtained by using non-specific intravenous contrast agents that distribute in the extracellular space, both within and outside the vessels, and have imaging dynamics comparable to the extracellular iodinated contrast media used in CT [5, 6].

The so-called liver-specific (or hepatobiliary) contrast agents (gadobenate dimeglumine, Gd-BOPTA, and gadoxetic acid, Gd-EOB-DTPA), are characterized by a dual behaviour: by exhibiting elimination through both renal and hepatic excretion pathways and thereby possessing both early perfusion information (renal elimination pathway) and, later, hepatocyte-selective information (hepatic excretion pathway) mediated through protein transporters, located in the canalicular or sinusoidal pole of the hepatocytes [7–9].

The liver-specific contrast agents are Gd-based compounds and, therefore, shorten the T1 relaxation time that results in an increased signal intensity of the healthy liver parenchyma on T1-weighted images [8, 10].

The clinical use of liver-specific contrast agents allows the physician to obtain morphologic and vascular-related

information, thanks to the dynamic study, as well as functional information, thanks to the hepatocyte-selective phase of enhancement. However, even if a large number of research and review articles on the use of liver-specific contrast agents in different clinical scenarios have already been published, agreement about their clinical indication is still lacking [11–16].

To develop a consensus and provide updated recommendations on the best MRI technique and the clinical use of liverspecific contrast agents, the European Society of Gastrointestinal and Abdominal Radiology (ESGAR) recruited a working group of key opinion leaders in the field of liver MR imaging.

Materials and method

Consensus panel

The working group, composed of a multinational European panel of 18 members and faculty of the ESGAR (composed of X.X.,¹ B.M.A., M.A., B.P., B.G., CA.F., G.F., H.T., L.J.M., M.R., MB.L., M.C., M.EM., ODB.B., S.W., S.S., V.V., Z.C.), used a modified Delphi process to rate the level of agreement on numerous statements pertaining to the MR imaging technique and the clinical applications of liver-specific contrast agents [17]. Two additional panellists, who did not express a vote, were chosen to play the role of facilitators (C.B. and E.N.).

Three Delphi rounds were conducted. In the *first round*, the panellists had a face-to-face meeting and, on the basis of their main area of research and expertise, were split into six working groups (WG) on MR technique (WG 1), benign focal liver lesions (WG 2), malignant liver lesions in non-cirrhotic patients (WG 3), focal liver lesions in cirrhotic patients (WG 4), diffuse and vascular liver diseases (WG 5), and bile duct applications (WG 6). Each WG independently drafted a cluster of statements pertaining to their allocated subject. A preliminary literature review for each WG to support the composition of statements was based on the GRADE system [18]. Each WG then presented the proposed statements to the whole panel for detailed discussion. At this time, the content and wording of statements were modified until a general consensus emerged.

In the *second and third rounds* the panellists were sent electronic copies of the latest statements in order to rate independently their level of agreement using a 5-point Likert scale as follows: 1, strongly disagree with the statement; 2, disagree somewhat with the statement; 3, undecided; 4, agree somewhat with the statement; 5, strongly agree with the statement. To reach the maximum consensus, the number and content of

¹ X.X. refers to a panelist who left the panel after the third round.

statements was modified in the iteration from the second to the third round.

Statistical analysis

All ratings of panellists for each statement were analysed with descriptive statistics measuring the mean score, the maximum and minimum score, and the standard deviation.

A mean score of 4 was considered a good agreement between panellists and a score of 5 a complete agreement.

After the second round, the facilitator collected the ratings from the panellists and calculated the score of agreement for each statement. If the mean score was less than 4, the facilitator asked the panellists to review the statement and reach a higher level of agreement by changing the content and, when necessary, the number of the statements.

To measure the internal consistency of the panellists ratings for each cluster of statements, a quality analysis based on the average inter-item correlation was performed with Cronbach's alpha ($C\alpha$) correlation coefficient, using SPSS (SPSS, Chicago, IL, USA) [19, 20]. The $C\alpha$ test provides a measure of the internal consistency of a test or scale; it is expressed as a number between 0 and 1. Internal consistency describes the extent to which all the items in a test measure the same concept. $C\alpha$ was determined after each round.

The closer C α coefficient is to 1.0, the greater the internal consistency of the items in the scale. An alpha coefficient (α)>0.9 was considered excellent, α >0.8 Good, α >0.7 Acceptable, α >0.6 Questionable, α >0.5 Poor, and α <0.5 Unacceptable. However, in the iterations a α of 0.8 was considered a reasonable goal for internal reliability.

Results

In the second round, the panel elaborated 94 statements. These were reduced to 76 in the third round (Table 1). The overall mean score of agreement of the experts was 4.72 (standard deviation SD \pm 0.22) in the second round and improved to 4.84 (SD \pm 0.17) in the third round. From the second to the third round, the panel reached complete consensus (rating 5), respectively, in 12/93 (12 %) and 17/76 (22 %) statements. Meanwhile, in the remaining statements, in both rounds, no expert rated any individual statement less than 4, confirming, despite the apparent heterogeneity of the sample, that there was generally some agreement amongst them.

Full consensus was reached by the experts panel in 22 % of the statements. In the remaining statements, full consensus was not reached, but all the panellists achieved a "good" level of agreement.

The highest mean level of agreement (4.87 ± 0.21) and questionable internal consistency (C α 0.67) was reached by the WG1 (MR technique), with full consensus on the

statements about the use of *MR coils, type of contrast agent*, and the *specific MR sequences* to be used in liver MR examinations.

The highest number of statements (6/18; 33 %) having full consensus were in the WG4, with a good mean level of agreement (4.85±0.15) and questionable internal consistency (C α 0.61). Such statements clearly addressed the proposed "*state–of-the-art*" *MR protocol* and the *enhancement pattern observed with liver-specific* contrast agents of focal liver lesions in cirrhotic patients.

Discussion

Along the entire consensus process, the experts completed three rounds; the first round served to elaborate the basic statements, whereas the second and third rounds contained the core of the discussion and were necessary to reach the maximum consensus, in order to create an optimized and homogeneous opinion for each statement. Finally, the overall mean score of the panellists was 4.84 (SD ± 0.17), which should be considered an almost excellent result of agreement.

The Cronbach's test used in the study had the value of an additional measure of consistency of the consensus rounds; the highest $C\alpha$ were obtained in the Wg1 and WG4, but with a questionable internal consistency ($0.6 < C\alpha < 0.7$). In the remaining WGs the $C\alpha$ was below an acceptable level. These results do not imply unreliability of the consensus; in fact, from a practical point of view, such results are related to the high number of panellists (n=18) that inevitably raised the variability in the score of agreement. However, such heterogeneity of scores (all higher than 4) did not significantly impact the mean level of agreement. Moreover, this reflects the mediating role played by the two facilitators of the consensus that allowed pushing the levels of agreement above the threshold of 4.

All panellists exhibited a high level of agreement for the MR technique with clear recommendations regarding the use of MR coils, type of contrast agent, and the specific MR sequences to be used in liver MR examinations. These data reflect a consolidated approach to liver MR examination with no significant difference among panel members despite their wide geographical spread. All panel members, belonging to academic and non-academic centres, are regular speakers of ESGAR meetings/workshops, a condition that may have facilitated the information sharing in this field of expertise and, therefore, improved their level of agreement.

However, even if this condition may have facilitated the agreement, the recruitment of experts and specialist belonging to the same peer group does not necessarily compromise expertise. But it has to be taken into account that there is a risk of mutual influencing of opinions and attitudes. A way to overcome this bias would have been to include panel members

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8 All 9 Bo 10 Th 10 Th 11 Do 11 Do 13 Sir 13 Sir 14 No 15 He 16 He 16 He 16 He 17 Su 17 Su 17 Su 18 Be Be Be	is recommended for all gadolinium chelates.	4.93		
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10 10 11 10 11 11 10 11 11 11 11 11 11 1	followed by a 20-mL saline flush at 1-2 mL/s using a power injector. Bolus triggering techniques are recommended for optimized arterial	4.80		
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	should be the preferred imaging modality for the characterization of equivocal focal lesions detected by other imaging modalities.			
19 Unenhanced MR including heavy T2w see considered the definitive protocol for th	DWI can be and characterisation	4.47		
of typical cystic, cystic-like lesion, and	cystic-like lesion, and/or typical haemangioma.	4 87		

Table 1 (continued)					
Working group	statement number	statement	Value of the mean level of agreement by statement	Value of the mean level of agreement by working group	Cronbach's alpha internal consistency coefficient by working group
	5	Contrast-enhanced MR with intravascular-extracellular contrast agents is required for the characterization of atypical "cystic-like" lesions and/or vascular lesions. Unenhanced MR including T1 w "in and out of phase" gradient echo sequence	9. S		
	22	is mandatory for detection of fatty component within the lesion. Unenhanced and contrast-enhanced MR with liver-specific contrast agents are suggested for both solid lesion detection and characterization.	4.93		
	23	(reviewer 2, comment 21) In non-cirrhotic liver, nodule iso-hyperintense on hepatobiliary phase images strongly suggests benign non-adenomatous hepatobiliary lesions. Homonoicome new result hymoiring in the lab vascular whose offer GA FOB	4.80 4 03		
Malignant liver lesions in non-cirrhotic patients (WG 3)	25 24	Tertungtonias may resun typonitense in ure late vascual puase area OU-EUD administration as opposed to sole extracellular agents. The combination of hepatobiliary phase images with DWI yields high detection rate, particularly for very small metastases.	4.93	4.84	0.319
	26 27	I he use of liver-specific contrast agents is recommended in patients with liver steatosis and in patients candidate for liver resection. When the differential diagnosis is primarily between small hemangioma vs. metastasis, the use of a nonspecific (extracellular) MR contrast	4.80		
	28 29	agent is recommended. When the differential diagnosis is primarily between solid benign lesion vs. metastasis the use of a liver-specific contrast agents is recommended, due to the ability to diagnose FNH confidently Liver-specific contrast agents leads to a clear delineation of nvimary liver tunnos including intrahenatic or mass-forming	4.80 4.73		
	30	CCC and may be useful for preoperative local staging Intrahepatic CCC results relatively hypointense after Gd-EOB administration in the late vascular phases, as compared to the delayed phase enhancement with extracellular contrast agents	4.67		
	31 32	(reviewer 4, comment 9) MR with either liver-specific or extracellular contrast agents is suitable for serial measurement of liver metastases according to RECIST criteria ldenical MR technique, sequence timing and contrast agents should ideally be repeated for serial evaluation of the same natient. and measurements should he made on the same sequence/hase	4.93 5.00		
Focal liver lesions in cirrhotic nationis	33 34	for each time point. Quantitative DWI (ADC map) and perfusion techniques are promising for evaluating tumor response, but further evidence is needed. State-of-the-art MR protocol including pre-contrast and multiphase dynamic sequences is mandatory in nationits with liver circhosis	4.86 5.00	4.85	0.616
(WG 4)	35	evaluated for HCC. Late hepatic arterial phase (enhancement of both hepatic artery and portal vein, and lack of enhancement of hepatic veins) is preferred over early arterial phase for HCC diagnosis.	5.00		
	36 37	It available, continuous multi-arterial phase imaging should be acquired to increase detection of hypervascularity in HCC nodules Subtraction imaging (post-processing) may allow accurate detection of arterial enhancement in T1w, hyperintense hepatic nodules.	4.87		
	38 39 40	In currhotic patients, the hepatobiliarly phase may be delayed depending on a reduced liver function. MR examination should be performed in order to characterize an undetermined focal liver lesion of 10 mm or larger in the cirrhotic liver	5.00 4.93 5.00		

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MR cholangiography coupled with MR portography is useful			obstruction syndrome on hepatobiliary phase			
		61	MR cholangiography coupled with MR portography is useful	4.87		

Table 1 (continued)					
Working group	statement number	statement	Value of the mean level of agreement by statement	Value of the mean level of agreement by working group	Cronbach's alpha internal consistency coefficient by working group
	62	Gd-BOPTA yields relatively greater enhancement of the liver vessels than Gd-EOB-DTPA does.	4.47		
	63	Liver-specific contrast agents are sensitive in the detection of vascular and biliary complications	4.60		
BILE DUCTS APPL ICATIONS (WG 6)	64	atter transplantation. MR imaging of the bile ducts should be performed at high field strength (reviewer 2, comment 22) using phase d-array coils and parallel imaging techniques and before	4.93	4.85	0.518
	65		4.93		
	66	state of the art 1.5 1 scanners Pre-contrast series should always include cross-sectional T2-weighted and T1-weighted sequences along with heavily	4.73		
	67	2D and/or 3D T2-weighted MR cholangiopancreatography When considering Gd-based contrast agents administration, dynamic fat sat 3D GRE T1-weighted imaging in the arterial and portal venous phases should always be performed. Additionally delayed inacting schould he obtained when malienancy	4.47		
	68	or inflammation, infection are suspected In the absence of liver function impairment/biliary obstruction, contrast-enhanced MR cholangiography (MRC) can be obtained	4.93		
	69	with Gd-EOB at 20-40 min, and with Gd-BOPTA at 60-120 min To maximize SNR and bile-to-liver contrast, 3D GRE TI-weighted contrast-enhanced MRC should be performed with increased flip	4.93		
	70	angues: over 20 uegrees Contrast enhanced MR imaging may be considered in patients with unweighted solutestesis if ultrascound is non-diarmostic	4.93		
	71	Unenhanced Marka dynamic contrast enhanced MR, including delayed phase, are useful for detecting early bile duct cancers, and can be used to distinguish the intra-ductal	4.93		
	72	cholarguestrementa from the mass-forming type. DWI helps detecting extrahegatic cholangiocarcinoma and may be added to innerhanced and contrast-enhanced MR imaging	5.00		
	73	Unenhanced MR and dynamic contrast-enhanced MR are useful in assessing the longitudinal extent of bile duct cancer, but	4.87		
	74	may underestimate the vascular, nodal, and peritoneal involvement Unenhanced and contrast-enhanced MR are useful for differentiating eventsharedis that dute convisioned from barion drictiones	4.73		
	75	extramplate one duct calculuta nour ornign surfaces. When combined with T2-weighted MRCP, contrast-enhanced MRC allowse memohologie and functional secsestement of the hilliery system	5.00		
	76	autown into purcess, and autocolora assessment or into outary system. Functional information may be of particular interest for the detection of bile duct injury including leakage and stricture,	4.93		
		assessment of biliary-enteric anastomoses, differentiation of biliary from extrabiliary lesions, assessment of bile duct dilation, and evaluation of sphincter of Oddi dystuntion (SOD)			

with expertise in other specialized areas such as hepatology, surgery, and methodology, and a representation from sister medical societies.

As a basic rule of MR technique, all the panellists clearly addressed that the workup of solid focal liver lesions should include *axial T2- and T1-weighted sequences*, followed by *T1-weighted gradient dual echo images*, *DWI (using low and high b-values) and dynamic contrast-enhanced T1-weighted fat-saturated* (see statement 10 in Table 1). However, no full consensus was reached on statements 1 and 2 that addressed similar results of MR imaging at 3 and 1.5 T. This incomplete agreement can be explained by the discrepancies of the comparative studies on the use of 1.5 vs. 3 T MRI [21–24].

The remaining statements regarding MRI technique, even with less than "full" consensus, definitively addressed the modalities of contrast medium administration (flow-rate of 1-2 mL/s followed by a 20-mL saline flush at 1-2 mL/s using a bolus triggering technique) and timing of T2-weighted and DWI sequences (after the acquisition of the contrast-enhanced late dynamic phase).

With regards to the recommendations on the use of the gadobenate dimeglumine (Gd-BOPTA) and the gadoxetic acid (Gd-EOB-DTPA) that are the currently available on the market, the panel was aware there are no data indicating diagnostic superiority of one agent over the other. It must also be noted that to our knowledge there are very few publications comparing Gd-EOB-DTPA and Gd-BOPTA [25–27].

All panellists fully agreed that all non-blood pool gadolinium chelate-based contrast agents are suitable for dynamic liver MRI, but the use of liver-specific contrast agents is mandatory to obtain the hepatobiliary phase in addition to the dynamic phase (statements 4 and 5). Jeong et al emphasized that the "hepatobiliary" phase is where uptake by the hepatocytes and excretion to the bile ductule have reached an optimal level for diagnosis [28]. Kim et al demonstrated no statistically significant difference in the signal intensity of liver parenchyma in the arterial phase between gadobenate dimeglumine and gadoxetic acid [28], and Filippone et al showed a statistically significant higher signal intensity of gadoxetic acid-enhanced MR in the hepatobiliary phase [29]. In a recent article, Ba-Ssalamah et al stated that liver specific contrast agents provide a multiparametric assessment of hepatobiliary diseases, since they combine morphologic and functional information in the same setting and, therefore, can play the role of imaging biomarkers [30].

A mean good level of agreement was reached between the panellists regarding the application of liver specific contrast agents in benign hepatocellular liver lesions, and addressed *MRI as the preferred imaging modality for the characterization of equivocal focal lesions detected by other imaging modalities (statement 18).* The added value of Gd-BOPTA in the evaluation of solid hepatic lesions is supported by literature evidence. Grazioli et al, through a quantitative analysis of signal intensity, lesion-to-liver contrast, and enhancement ratio, demonstrated that Gadoxetic acid-enhanced MR imaging facilitates the differential diagnosis of hepatocellular adenoma (HCA) and focal nodular hyperplasia (FNH) [31]. The same author showed in a previous article that this was possible with Gd-BOPTA [32]. Haimerl et al and Morana et al showed that the hepatobiliary phase images obtained after Gd-EOB-DTPA-enhanced dynamic MRI significantly improved the index of diagnostic performance in the differentiation of focal solid lesions [33, 34].

A mean good level of agreement was also reached between the panellists on the cluster of statements about malignant liver lesions in non-cirrhotic patients, where the use of liver-specific contrast agents has been recommended to improve the differential diagnosis between a solid benign hepatocellular lesion and metastasis, and delineation of primary liver tumors (including intrahepatic or mass-forming cholangiocarcinoma). In a recent study comparing the diagnostic performance of MDCT and gadoxetic acid-enhanced MRI at 3.0, Scharitzer et al found that MRI with the liverspecific contrast agent had better performance in the assessment of small colorectal liver metastases [35]. A similar study comparing MDCT and MRI performed by Kim et al, showed higher diagnostic accuracy for MRI in the detection of hepatic metastases and for the differential diagnosis with hepatic haemangiomas or cysts [36]. However, a hypointense pattern in the hepatobiliary phase has been reported by Han et al [37] as a potential pitfall of liver-specific contrast agents agents in patients who received oxaliplatin as part of their chemotherapy regimen. Specifically, in these patients, due to the sinusoidal obstruction syndrome (focal hepatopathy), the morphologic pattern of the hypointensity at the hepatobiliary phase may contribute to avoid this potential pitfall.

With regard to mass-forming cholangiocarcinoma, the panel clearly stated that concerning the delayed phase enhancement obtained with non-specific extracellular agents, Gd-EOB provides a relative hypointense MRI pattern of the lesion both in the transitional and hepatobiliary phases that improves tumour conspicuity [38]. The panel suggested also the use of DWI and perfusions techniques, and recently, Park et al demonstrated that the target appearance seen on the DWI was the most reliable imaging feature for distinguishing small massforming peripheral cholangiocarcinoma from small HCC [39].

The best agreement among the panellists was reached for focal liver lesions in cirrhotic patients. The panel stated with full agreement that *a confident diagnosis of HCC* by using a complete dynamic study with *pre-contrast and multiphase sequences* (*statement 34*), can be optimally reached with a *late hepatic arterial phase over early arterial phase* (*statement 35*), and *the hepatobiliary phase may be delayed depending on a reduced liver function* (*statement 38*) [40, 41]. Haimerl et al demonstrated that regarding comparability with the MELD (Model for End-Stage Liver Disease) score, decreased Gd-EOB-DTPA accumulation in the hepatocytes during the hepatobiliary phase, and T1 relaxometry correlated with reduced liver function [42]. Verloh et al also found that the relative enhancement during hepatobiliary phase in GD-EOB-DTPA MRI correlates with the MELD score [43].

Of note, the panellists addressed that the use of liverspecific contrast agents has particular usefulness in improving the detection of HCC. In fact, while statements 41, 42, and 43 clearly address the definition of wash-in and wash-out (higher signal intensity than the surrounding parenchyma in arterial phase, lower signal intensity in the portal phase after injection of Gd-chelates), statement 48 addresses the importance of the hepatobiliary phase to differentiate between HCC and arterialenhancing pseudolesion when using liver specific contrast media.

Cereser et al have shown that the delayed phase is superior to the portal venous phase for the wash-out detection in hypervascular HCC with Gd-BOPTA MRI in the cirrhotic liver. This is one of the limitations of Gd-EOB-DTPA, where the hypointensity on the 3–5 min delayed phase, also called the transitional phase, is less effective in detecting washout as it blends into the liver specific phase. Accordingly, often wash-out cannot be assessed with Gd-EOB-DTPA [44].

In a study performed by Bartolozzi et al the hyperintensity on the arterial phase and hypointensity on the transitional phase were highly predictive for HCC, but a further element of HCC diagnosis was the hypointensity on hepatobiliary phase, evident in 39 out of 40 the HCC detected in the study cohort with a 100 % positive predictive value in suggesting nodular premalignancy/malignancy [45]. Yu et al supported the same statement, and has since demonstrated that even the detection of small HCC nodule (<1 cm) in a standard multiphasic study can be improved by the addition of the hypointensity pattern on the hepatobiliary phase [46]. Granito et al found that hypointensity during the MR hepatobiliary phase was observed in all HCC nodules of the study and concluded that gadoxetic acid MRI may enhance the sensitivity of the non-invasive diagnosis of small hepatocellular carcinoma nodules in cirrhotic patients under surveillance [47]. In summary, the panel suggests that in cirrhotic patients, the hepatic arterial phase and portal venous phase might not be sufficient to establish a confident diagnosis of HCC and should be integrated by the hepatobiliary phase.

No statement reached full agreement for diffuse and vascular liver diseases, and it was acknowledged that a correct estimate of the degree of steatosis and iron overload needs multiparametric MRI, even if the administration of contrast agents may alter the quantification of fat and iron liver content. Even with the support of the few literature studies available, the use of liver-specific contrast agents was specifically indicated to evaluate multiacinar regenerative nodules in patients with vascular disorders (*statement 59*) in the study of the sinusoidal obstruction syndrome (*statement 60*) and in the detection of vascular and biliary complications after transplantation (*statement 63*). In a study by Katajiama et al, the hepatic congestion and oedema occurring in Budd-Chiari syndrome were seen as slightly hypointense areas on Gd-EOB-DTPA-enhanced hepatobiliary-phase images, and such a pattern improved the diagnosis of sinusoidal obstruction syndrome with respect to Gd-DTPA enhancement [48]. In a recent study, Shin et al confirmed that Gd-EOB provides a peculiar reticular hypointensity pattern on hepatobiliary phase images and that is highly specific for the diagnosis of sinusoidal obstruction syndrome in patients with treated colorectal hepatic metastases [49].

The final cluster of statements indicates that the evaluation of the biliary tract should be an integrant part of the liver study. and MRCP should be performed on pre-contrast series with heavily 2D and/or 3D T2-weighted sequences. It should be taken into account that in the absence of liver function impairment/biliary obstruction, contrast-enhanced MR cholangiography (MRC) can be optimally obtained with Gd-EOB-DTPA at 20 min after injection (statements 66 and 68). Hepatic excretion of liver-specific contrast agents results in enhancement of biliary structures, and it is likely to have a great impact on better visualization of biliary system. On the basis of these characteristics, it may potentially increase reliability of the MR examination or decrease the occurrence of a non-diagnostic or equivocal interpretation [50]. This emerging diagnostic tool, especially when using Gd-EOB-DTPA, is particularly helpful for delineating the anatomy of the biliary tract and detecting post-operative complications such as anastomotic and non-anastomotic strictures and biliary leaks. In addition, it can provide functional information that is extremely promising in the grading of biliary obstruction. Recently, Boraschi et al in review papers showed the usefulness of Gd-EOB in the evaluation of biliary-enteric anastomoses and in the assessment of biliary complications after orthotopic liver transplantation [51, 52]. The drawbacks of contrastenhanced MRC include its high cost (it is also a timeconsuming technique) and limitations in depicting the biliary system in patients with hepatobiliary dysfunction.

Conclusion

The panel of the ESGAR working group covered most important aspects of liver MRI methodology combined with the clinical use of liver-specific contrast agents, and reached a good level of agreement on most statements. As a result of the consensus process, the working group provided updated recommendations on the best use of MRI in the study of liver diseases.

Such recommendations should be helpful for both the radiologist who is starting MR imaging of the liver and for those who have already applied the technique, but whose practice may need updating in the light of more recent developments.

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Methodology: Retrospective analysis of literature

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