



3.0- Versus 1.5-T MR Cholangiography: A Pilot Study

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OBJECTIVE. The purpose of our study was to evaluate quantitative and qualitative image quality of MR cholangiography at a field strength of 3.0 T compared with the standard field strength of 1.5 T.

MATERIALS AND METHODS. A standardized MR cholangiography sequence protocol was used for 15 healthy male volunteers (mean age \pm SD, 32.4 \pm 4.3 years) who underwent both 1.5- and 3.0-T MRI within 2 hr in an alternating fashion. Dedicated circular polarized torso coils (1.5 and 3.0 T) were used. The sequence protocol included breath-hold single-slice rapid acquisition with relaxation enhancement (slice thickness, 50 mm; orientation, coronal and \pm 20° oblique coronal); breath-hold multislice HASTE (slice thickness, 3 mm; coronal only); and a non-breath-hold, respiratory-triggered 3D turbo spin-echo (TSE) T2-weighted sequence (slice thickness, 1 mm; 60 slices per slab; coronal only). Maximum intensity projections were generated from each multislice data set. Bile duct (common bile duct, right posterior segmental branch, and left hepatic duct) to periductal tissue contrast-to-noise ratios were compared at 1.5 and 3.0 T. Qualitative image analysis was performed by three independent reviewers. Qualitative analysis included delineation of the extra- and intrahepatic biliary anatomy, with specific attention given to the presence (or absence) of cystic or intrahepatic ductal variants, using a 4-point confidence scale. Statistical analysis consisted of the paired Student's *t* test and the signed rank test.

RESULTS. Contrast-to-noise ratios between the bile duct and the periductal tissue were higher at 3.0 T in all three locations (common bile duct, right posterior segmental branch, and left hepatic duct). In each magnet class, the 3D TSE sequence offered the best contrast-to-noise ratio and qualitative analysis. Superiority of the 3D TSE sequence was statistically significant in all analyses. Five of the 15 volunteers had intrahepatic biliary variants that were detected with a higher level of confidence ($p < 0.01$) on the 3.0-T system than on the 1.5-T system.

CONCLUSION. Compared with MR cholangiography at 1.5 T, MR cholangiography at 3.0 T offers improved contrast-to-noise ratio and a higher level of confidence for depicting intrahepatic variants.

Keywords: biliary system, cholangiography, MRI, MR technique

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Since its original description in 1991 by Wallner et al. [1], MR cholangiography has gained general acceptance, along with transabdominal sonography, as the noninvasive imaging method of choice for diseases of the biliary system. It has replaced endoscopic retrograde cholangiography, particularly in those cases in which an endoscopic intervention seems unlikely at the outset [2]. Although transabdominal sonography seems to be superior for imaging of the gallbladder, MR cholangiography is favored for evaluation of extrahepatic biliary ductal disease [3]. Unfortunately, both imaging techniques are of limited use for evaluating the intrahepatic biliary anatomy, particularly if the biliary system is

not dilated. The underlying reasons are mainly limitations in spatial resolution and the signal-to-noise ratio. However, a detailed anatomic depiction of the nondistended intrahepatic biliary ductal system is occasionally needed, for example, for the preoperative evaluation of potential living liver donors.

The introduction of whole-body 3.0-T MR systems in combination with dedicated circular polarized receive-only torso coils is an appealing concept with the potential to overcome these limitations. We attempted to determine the potential of MR cholangiography, including visualization of the intrahepatic biliary ductal system, at a field strength of 3.0 T compared with the standard field strength of 1.5 T.

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Materials and Methods

Volunteers and Imaging Protocol

After we obtained written informed consent, 15 healthy male volunteers (mean age \pm SD, 32.4 ± 4.3 years) were included in this trial under a protocol approved by the institutional review board for human investigation. Each volunteer underwent two MRI examinations within 2 hr. All MRI was completed within an 11-month period. One MRI examination was performed using a 1.5-T MR system (Magnetom Symphony, Siemens Medical Solutions), and the other was performed on a 3.0-T MR system (Siemens Magnetom Trio). Dedicated circular polarized torso receive-only coils were used in both MR systems. In a randomized order, seven volunteers underwent their first scan on the 1.5-T MR system, and the other eight volunteers were first imaged on the 3.0-T system. All volunteers fasted for at least 4 hr before the first scan; they also fasted during the interval between the two scans.

MR Cholangiography Protocol

The first sequences (sequences 1–3) were a single-slice T2-weighted rapid acquisition with relaxation enhancement (RARE) with fat saturation, coronal and $\pm 20^\circ$ oblique coronal orientation. The parameters for the 1.5-T sequence were a TR/TE of 2,800/1,100; flip angle, 180° ; number of signal averages, 1; matrix, 256×256 ; slice thickness, 50 mm; field of view, $30 \times 30 \text{ cm}^2$; and acquisition time (TA), 3 sec. The parameters for the 3.0-T sequence were 2,120/964; flip angle, 150° ; number of signal averages, 1; matrix, 256×256 ; slice thickness, 50 mm; field of view, $30 \times 30 \text{ cm}^2$; and TA, 2 sec.

The fourth sequence was coronal T2-weighted HASTE with fat saturation. The parameters for the 1.5-T sequence were 1,100/95; flip angle, 180° ; 1 signal average; matrix, 192×256 ; 13 slices; slice thickness, 3 mm; field of view, $30 \times 30 \text{ cm}^2$; and TA, 14 sec; and for the 3.0-T sequence were 3,000/106; flip angle, 123° ; 1 signal average; matrix, 256×256 ; 16 slices; slice thickness, 3 mm; field of view, $35 \times 35 \text{ cm}^2$; 2 concatenations; and TA, 2×24 sec.

The fifth sequence was respiratory triggered coronal 3D T2-weighted turbo spin echo (TSE) with fat saturation using a navigator technique for detection of the diaphragm position. The parameters for the 1.5-T sequence were TR/TE, $1 \times$ respiratory cycle/648; flip angle, 180° ; 1 signal average; matrix, 222×256 ; 60 slices; slice thickness, 1 mm; field of view, $30 \times 30 \text{ cm}^2$; and TA, 3–6 min, depending on the respiratory frequency; and for the 3.0-T sequence were $1 \times$ respiratory cycle/645; flip angle, 180° ; 1 signal average; matrix, 240×256 ; 60 slices; slice thickness, 1 mm; field of view, $30 \times 30 \text{ cm}^2$; and TA, 3–6 min, depending on the respiratory frequency.

Data Analysis

The initial step of the data analysis consisted of the selection of the best single-slice RARE image (sequences 1–3) with the least superimposition from the duodenum. This solitary image was used for the RARE portion of the quantitative data analysis. In addition, maximum intensity projections (MIPs) in an analogous orientation (either coronal or $\pm 20^\circ$ oblique coronal) were generated from each multislice data set (sequences 4 and 5, HASTE and 3D TSE sequences) on a separate MRI workstation (Siemens Leonardo). In all cases, these steps were performed by the same fellowship-trained senior abdominal radiologist.

Quantitative Data Analysis

Signal amplitudes of the common bile duct, the right posterior segmental branch, the left hepatic duct, and the periductal tissue were measured for each MR cholangiography sequence using the MIP images only by defining regions of interest (ROIs) on the MRI workstation. ROIs for the signal intensity of bile were at least 5 mm^2 and were chosen in homogeneous, artifact-free areas of the common bile duct adjacent to the insertion of the cystic duct, in the left hepatic duct next to the hepatic bifurca-

tion, and in the proximal right posterior segmental branch (Fig. 1). ROIs for signal intensity of the periductal tissue were at least 20 mm^2 and were chosen in homogeneous, artifact-free areas adjacent to the common bile duct at the level of the cystic duct insertion or in the liver (Fig. 1). SD of the noise was also measured with ROIs of at least 200 mm^2 (Fig. 1). Quantitative measurements were again performed by the same fellowship-trained senior abdominal radiologist in all cases.

Each signal amplitude value was calculated as the mean of three separately sampled ROIs. Common bile duct-to-periductal-tissue contrast-to-noise ratios (CNRs) were calculated between the signal amplitudes from the common bile duct and periductal tissue divided by the SD of the background noise. Intrahepatic bile duct-to-liver CNRs were calculated between the signal amplitudes from either the left hepatic duct or right posterior segmental branch and liver divided by the SD of the background noise.

Statistical analysis was performed using the paired Student's *t* test to test the null hypothesis that the CNR was identical at 3.0 and 1.5 T on version 8.2 of the SAS software system (SAS Institute). A *p* value of less than 0.05 was considered statistically significant.

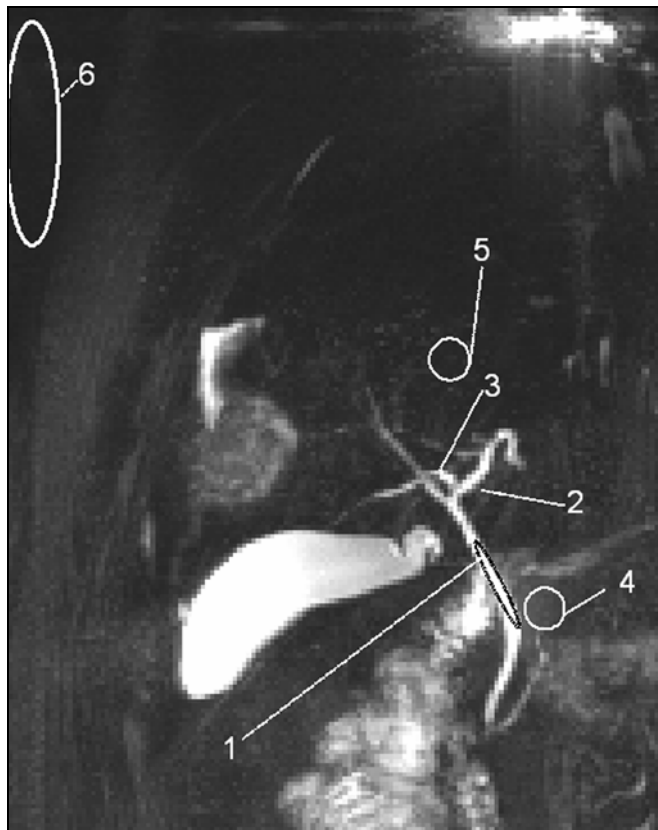


Fig. 1—32-year-old male volunteer with dorsocaudal branch of right hepatic lobe draining into central left hepatic duct. Signal intensity of bile was measured in common bile duct adjacent to insertion of cystic duct (*area 1*), in left hepatic duct next to hepatic bifurcation (*area 2*), and in proximal right posterior segmental branch (*area 3*). Signal intensity of periductal tissue was measured adjacent to common bile duct at level of cystic duct insertion (*area 4*) and in liver (*area 5*). SD of noise was measured outside of body (*area 6*).

Qualitative Data Analysis

Qualitative data analysis was performed by three fellowship-trained abdominal radiologists. They evaluated the three RARE images (sequences 1–3, data set 1), the source and MIP images from sequence 4 (data set 2), and the source and MIP images from sequence 5 (data set 3). All 90 data sets were made anonymous and were evaluated in a randomized order in two sessions and separately by each reviewer. The evaluation protocol consisted of scoring the following: clear depiction of the common bile duct (yes or no); clear depiction of the cystic duct insertion (yes or no); clear depiction of the right posterior segmental branch insertion (yes or no); presence (or absence) of a biliary ductal variant using a 4-point confidence scale (0 = relevant structures not seen; 1 = equivocal; 2 = probably seen; 3 = definitely seen); presence (or absence) of a cystic duct variant using a 4-point confidence scale (0 = relevant structures not seen; 1 = equivocal; 2 = probably seen; 3 = definitely seen).

Classification of aberrant bile ducts and cystic ducts was based on the reports by Huang et al. [4] and Hirao et al. [5]. A consensus interpretation by three senior abdominal radiologists who were otherwise not involved in the qualitative data analysis served as the gold standard for the presence or absence of a ductal biliary variant. This consensus was based on all the imaging data sets available per volunteer. Statistical analysis was performed using the signed rank test to test the null hypothesis that the reviewer confidence scores were the same at 1.5 and 3.0 T on version 8.2 of the SAS software system (SAS Institute). A *p* value of less than 0.05 was considered statistically significant.

Results

Quantitative Data Analysis

CNRs between the common bile duct and the periductal tissue and between the intrahepatic bile ducts (left hepatic duct and right posterior segmental branch) and surrounding liver were higher at 3.0 T than at 1.5 T (Table 1). These differences were statistically significant for the 3D TSE sequence in all three locations, for the HASTE sequence in the left hepatic duct, and for the RARE sequence in the common bile duct and right posterior segmental branch (Table 1).

Within each field strength, the MIP from the 3D TSE sequence offered the best CNR in each biliary ductal location (Table 1). Superiority of 3D TSE was statistically significant in all analyses in all three biliary locations (common bile duct, left hepatic duct, and right posterior segmental branch). The RARE sequence offered the worst CNR in each biliary ductal location (Table 1). Inferiority was

TABLE 1: Contrast-to-Noise Ratios for Field Strengths of 1.5 and 3.0 T

Specific Ratio, by Sequence	Contrast-to-Noise Ratio		<i>p</i>
	1.5 T	3.0 T	
Common bile duct/periductal tissue			
RARE	19 ± 10 (2–38)	30 ± 18 (12–72)	0.01
HASTE	29 ± 16 (7–54)	35 ± 23 (1–77)	0.14
3D TSE T2-weighted	47 ± 20 (22–85)	111 ± 78 (22–274)	< 0.01
Left hepatic bile duct/liver			
RARE	14 ± 12 (1–46)	20 ± 11 (5–37)	0.11
HASTE	21 ± 13 (3–43)	42 ± 35 (10–108)	0.01
3D TSE T2-weighted	38 ± 23 (12–92)	88 ± 61 (13–225)	< 0.01
Right posterior segmental branch/liver			
RARE	10 ± 6 (1–25)	15 ± 4 (7–23)	0.01
HASTE	19 ± 12 (2–40)	33 ± 31 (10–104)	0.06
3D TSE T2-weighted	30 ± 15 (5–68)	69 ± 36 (17–123)	< 0.01

Note—Data are means ± SDs (ranges). RARE = rapid acquisition with relaxation enhancement, TSE = turbo spin-echo.

statistically significant in all but one analysis (CNR measured at the level of the common bile duct, HASTE vs RARE sequence, at 3.0 T: *p* = 0.12).

Qualitative Data Analysis

Delineation of common bile duct, cystic duct insertion, and right posterior segmental branch insertion—Three reviewers independently evaluated the delineation of the common bile duct, the cystic duct insertion, and the right posterior segmental branch insertion in each MR cholangiography sequence on both MR systems (Table 2). Although the delineation of the common bile duct and the cystic duct insertion was highest for the 3D TSE T2-weighted sequence, statistical analysis using the signed rank test did not reveal any significant differences. Delineation of the right posterior segmental branch insertion using the 3D TSE sequence, however, was significantly better for two of the three reviewers on the 3.0-T scanner when compared with the 1.5-T MR scanner (reviewer 1: *p* = 0.19; reviewer 2: *p* < 0.01; and reviewer 3: *p* < 0.01).

Presence (or absence) of ductal biliary variants—A consensus interpretation by three senior abdominal radiologists revealed intrahepatic biliary ductal variants in five of the 15 volunteers (trifurcation of the left hepatic duct, right posterior segmental duct, and right anterior segmental duct: *n* = 2; drainage of the right posterior segmental duct into the left hepatic duct: *n* = 2; and drainage of an aberrant right segmental branch into the cystic duct: *n* = 1).

The detection rate of the intrahepatic biliary ductal variants varied in the three independent reviewers. Sensitivity and specificity for each study reviewer and for the three reviewers combined are provided in Table 3. Overall, the imaging data sets acquired at the 3-T magnet provided better results in terms of sensitivity and specificity in the detection of intrahepatic biliary variants. Confidence levels for the detection of biliary ductal variants were also significantly higher for all three reviewers for the 3.0-T magnet than for the 1.5-T magnet for all sequences combined (reviewer 1: 1.73–2.31; reviewer 2: 1.6–1.96, and reviewer 3: 2.0–2.27). These differences were statistically significant (confidence level for biliary ductal variants at 1.5 T vs at 3.0 T, *p* < 0.01).

Discussion

During the past decade, MR cholangiography has proven to be an accurate imaging tool for the evaluation of the extrahepatic biliary system [6, 7]. Unfortunately, MRI using standard T2-weighted MR cholangiography sequences is of limited use for evaluation of the intrahepatic biliary anatomy, particularly in the absence of ductal dilation [8]. The underlying reasons relate to limitations in spatial resolution and signal-to-noise ratio. However, a detailed anatomic depiction of the nondistended intrahepatic biliary ductal system is occasionally needed—for example, for the preoperative evaluation of potential living liver donors—because biliary variants are seen in up to

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TABLE 2: Delineation of Common Bile Duct, Cystic Duct Insertion, and Right Posterior Segmental Branch Insertion as Evaluated by Three Reviewers

Area Evaluated	Clear Delineation (% of Cases)					
	1.5 T			3.0 T		
	Reviewer 1	Reviewer 2	Reviewer 3	Reviewer 1	Reviewer 2	Reviewer 3
Common bile duct						
RARE	80	93	90	93	90	90
HASTE	80	80	50	87	90	90
3D TSE	93	100	90	100	100	90
Cystic duct insertion						
RARE	27	47	40	47	47	47
HASTE	47	40	47	47	53	33
3D TSE	67	60	67	80	73	87
Right posterior segmental branch insertion						
RARE	53	33	27	47	47	33
HASTE	53	13	47	47	13	27
3D TSE	67	33	27	87	93	73

Note—RARE = rapid acquisition with relaxation enhancement, TSE = turbo spin-echo.

45% of the population [9]. Currently, endoscopic retrograde cholangiography is considered the imaging technique of choice for the evaluation of the nondistended intrahepatic biliary ductal system despite a major complication rate of 1.4–3.2% [10, 11]. Therefore, during the past several years, radiologists have developed new imaging strategies to overcome the limitations previously mentioned by using bile duct-excreted contrast agents for both CT and T1-weighted MRI [12, 13]. Unfortunately, these bile duct-excreted contrast agents carry a risk of allergic reaction or require a slow infusion over 30–45 min with a variable delay before imaging.

The introduction of 3.0-T MR systems combined with dedicated circular polarized receive-only torso coils offers an alternative solution to overcome the limitations of signal-to-noise ratio and spatial resolution. Although 3.0-T MR systems have already been shown to be advantageous for various indications in the brain compared with standard high-field 1.5-T MR systems, only a few 3.0-T MR studies of the abdomen have been published [14–16]. In particular, to our knowledge, no comparison data are yet available to evaluate the potential of 3.0-T MR systems compared with standard high-field 1.5-T MR systems for MR cholangiography.

Quantitative Data Analysis

CNRs between the biliary ductal system in three locations (common bile duct, left he-

patic duct, and right posterior segmental branch) and the periductal tissue were higher at 3.0 T than at 1.5 T. These differences were most evident when using the 3D TSE sequence (3D TSE at 1.5 T vs 3D TSE at 3.0 T: $p < 0.01$ in all three locations) but were also obvious when using the HASTE and RARE sequences (Table 1). These results were expected because twice the number of free water protons per voxel contribute to the MR signal at 3.0 T as at 1.5 T. However, increasing the magnetic field strength results in an increase of the T1 relaxation time and a slight decrease of the T2 relaxation time; these two factors combine to reduce the net increase in MR signal to less than twofold [14]. If twice the net MR signal is sought, longer T1 relaxation times at 3.0 T need to be compensated—for example, by increasing the sequence TR. This may explain why the gain in signal using the breath-hold multislice HASTE sequence was only marginal because of image cross-talk and not significantly higher despite the fact that the TR had been adjusted from 1,000 msec at 1.5 T to 3,000 msec at 3.0 T.

Potential solutions to avoid cross-talk are to acquire images in an interleaved order or with a small gap between contiguous images. However, both attempts may increase artifacts in MIPs and therefore have not been implemented. On the other hand, the prolonged T1 relaxation times at 3.0 T do not affect the signal gain when using the RARE and 3D TSE sequences because the former sequence is a single-shot, single-slice sequence and the

latter sequence is respiratory triggered, with mean sequence TRs in the range of 5 sec, which allows a further recovery of the longitudinal magnetization.

Within each field strength, the MIPs from the 3D TSE sequence offered the best CNR between the biliary ductal structures and the periductal tissue (Table 1). This is in accordance with the results presented by Papanicolaou et al. [17]. In that study, using a 1.0-T MR system, the respiratory-triggered 3D TSE sequence also provided statistically higher CNRs than the breath-hold single-shot techniques [17]. The reason for this increased CNR is not necessarily obvious because the smaller voxel size of the TSE sequence would generally be associated with a lower CNR, but the respiratory triggering permits a dramatic increase in acquisition time that more than compensates for the smaller voxel size.

Qualitative Data Analysis

Statistical analysis did not reveal any significant differences between the two MR systems regarding delineation of the common bile duct or delineation of the cystic duct insertion. On both MR systems, the extrahepatic biliary duct anatomy was seen similarly, with the 3D TSE sequence providing the best results. The insertion of the right posterior segmental branch, however, was significantly better delineated according to two of the three reviewers on the 3D TSE sequence on the 3.0-T MR system when compared with the 1.5-T system, but also within each magnet class. This is of clinical

TABLE 3: Sensitivity and Specificity in the Detection of an Intrahepatic Biliary Ductal Variant in 15 Volunteers, as Assessed by Three Reviewers

Sequence	1.5 T		3.0 T	
	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)
RARE				
Reviewer 1	40	100	80	100
Reviewer 2	40	90	70	87
Reviewer 3	80	60	90	70
All reviewers combined	53	83	80	86
HASTE				
Reviewer 1	40	100	40	100
Reviewer 2	20	100	40	100
Reviewer 3	60	78	80	100
All reviewers combined	40	93	53	100
3D TSE				
Reviewer 1	20	100	80	100
Reviewer 2	40	90	80	100
Reviewer 3	80	100	100	90
All reviewers combined	53	97	87	97

Note—RARE = rapid acquisition with relaxation enhancement, TSE = turbo spin-echo.

importance because right-to-left crossover variants have an incidence of approximately 30% and can be detected with certainty only if the insertion of the right posterior segmental branch is clearly visualized.

This finding contradicts the results reported by Papanikolaou et al. [17] using a 1.0-T MR system. In that study, single-shot breath-hold sequences were slightly superior to the respiratory-triggered 3D TSE sequence in the depiction of the intrahepatic biliary anatomy. A potential explanation may be differences in the analysis used in our study and the one performed by Papanikolaou et al. However, it is more likely that the higher magnetic field strengths of 1.5 and 3.0 T in our study, which offer a higher MR signal and a better signal-to-noise ratio from the beginning, are the main reason for the better depiction of the intrahepatic biliary ductal system. This increased MR signal seems to be particularly helpful in the 3D TSE sequence with an effective slice thickness of 1 mm.

Accurate preoperative radiologic imaging with a high level of confidence is essential to assess the vascular and biliary anatomy of living liver lobe donor candidates. MRI has the unique ability to delineate the biliary system without the need for bile duct-excreted contrast agents, allowing a fast preoperative workup of potential donors using a single imaging approach. Visualization and classification of the intrahepatic biliary variants are the

most challenging parts of the preoperative evaluation, with variants in as many as 45% of cases [9]. A correct understanding of donor biliary anatomy is crucial to achieve safe donor hepatic resections and to minimize recipient biliary complications [8].

Overall, in our study, imaging data sets acquired on the 3.0-T magnet provided better sensitivity in the detection of biliary ductal variants in 15 volunteers, whereas the specificity was only marginally better. Although this was initially disappointing, three aspects must be addressed in more detail: First, the number of volunteers may not be large enough to obtain significant differences. Second, the results regarding specificity provided by the 1.5-T MR system are already very good, and a specificity of 97% as seen on the 3D TSE sequence on the 1.5-T MR system will be difficult to improve further. Finally, the biggest change was seen in the sensitivity in the detection of intrahepatic biliary variants when using the 3D TSE sequence (from 53% at 1.5 T to 87% at 3.0 T). This finding may reflect the true advantage of 3.0-T MR systems, in which the gain in MR signal is particularly helpful in sequences with thin slices of approximately 1 mm.

Reviewers were asked to categorize their certainty of the intrahepatic biliary anatomy by selecting from the following choices: 0 = relevant structures not seen; 1 = equivocal; 2 = probably seen; 3 = definitely seen. The sta-

tistical improvement in confidence levels seen with the 3.0-T studies is evidenced by a shift from an interpretation of “equivocal” to one of “probably seen” (confidence levels of 1.73, 1.6, and 2.0 for the three reviewers) and in the direction of “probably seen” to “definitely seen” (confidence levels of 2.31, 1.96, and 2.27). With the data sets from the 3.0-T system, we are able to shift reviewer confidence toward a more definitive interpretation, thus providing a more persuasive impression that may in the future allow better preoperative planning without further invasive imaging or intervention.

Limitations

The major limitations of our study are the small number of volunteers and the lack of a true gold standard with regard to the presence and type of biliary variants. Obviously, no invasive biliary imaging, such as endoscopic retrograde cholangiography or percutaneous transhepatic cholangiography, can be justified in volunteer studies. However, even contrast-enhanced CT or MRI using bile duct-excreted contrast agents seems to be excessive in a volunteer study and would not be approved by our institutional review board for human investigation. Therefore, the consensus interpretation performed, on the basis of all the available imaging data, by three senior abdominal radiologists who otherwise were not involved in the study, appears to be the best gold standard obtainable.

A minor limitation of our study may be the different sequence parameters used on the 1.5- and 3.0-T MR systems. However, these are the default protocol settings currently recommended by the vendor. This causes TRs and TEs that are sometimes the same, sometimes longer, and sometimes shorter. Thus, CNR differences could theoretically be attributable simply to comparing an optimal 3.0-T sequence to a suboptimal 1.5-T sequence. However, it is more likely that the 1.5-T sequences are closer to optimal and that any advantages of the 3.0-T sequences are real. It is also possible that the differences might be greater in future comparisons with more refined 3.0-T sequences. The same holds true regarding the radiofrequency transmitter and receiver technology, because we are comparing a relatively mature 1.5-T technology to a much newer technology at 3.0 T.

Summary

In conclusion, MR cholangiography at 3.0 T is a reliable means of providing all relevant information of the biliary ductal system.

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Compared with MR cholangiography at 1.5 T, MR cholangiography at 3.0 T offers improved CNR and a higher level of confidence for depicting intrahepatic variants. In addition, the 3D TSE sequence has the highest CNR at both 1.5 and 3.0 T and is more sensitive for detecting intrahepatic biliary ductal variants at 3.0 T than at 1.5 T.

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