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MR Assessment of Bile Duct Size in Healthy Individuals: Comparison with US Measurements

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A B S T R A C T

The purpose of the study was to determine the difference in extrahepatic bile duct (EBD) size measured by magnetic resonance (MR) compared with those measured by ultrasound (US). Changes of EBD size related to aging were analyzed too. Size of EBD was measured in 76 randomly selected healthy individuals. Three radiologists blinded to the result of other study preformed measurements by US and three different T2 weighted MR sequences. Correlation and linear regression analysis of obtained data were performed. The mean diameter of EBD measured by US was 3.17 mm and by MR was 3.14 mm on thick slab rapid acquisition with relaxation enhancement (TSE), 3.26 mm on thin section single-shot TSE (HASTE) and 3.30 mm on coronal fully rewound gradient echo (True FISP). There was no statistical difference between US and different MR sequences ($p<0.05$). A trend of increase of EBD with age (0.0155 mm per year, $p=0.0954$) was observed. Size of EBD highly correlated for each MR sequence with US measurement validating use of MR as a reliable method for evaluation of EBD size. This conclusion is stressed by increase of EBD size with age demonstrated by all measuring methods

Key words: *bile duct, magnetic resonance, ultrasound*

Introduction

Size of bile ducts is important diagnostic sign; dilatation of bile ducts distinguishes obstructive from nonobstructive causes of jaundice. US is initial imaging in suspected gallbladder and bile duct disease[1]. Extrahepatic bile duct measuring 6-7 mm or less in porta hepatis measured by US is widely considered normal in population under age of 65[2,3]. The normal size for EBD measured by conventional radiographic methods is greater, 8 mm for intravenous biligraphy (IVB) and 11 mm for endoscopic retrograde cholangiography (ERC) and percutaneous transhepatic cholangiography (PTC)[4,5]. US is preferred technique for measuring bile duct size because it is accurate and free of variables included in radiographic methods[5].

Magnetic resonance imaging is more and more widely used diagnostic modality for evaluation of biliary pathology. Improvement of MR hardware and software in recent years resulted in imaging sequences, termed magnetic resonance cholangiopancreatography (MRCP), capable of excellent visualizing biliary and pancreatic ducts[6]. Due to many advantages over US and ERC magnetic resonance cholangiography (MRC) is used not only as problem solving tool but also in early diagnostic procedure for patients with biliary obstruction[7].

To the best of our knowledge there is no study comparing size of bile ducts measured by US and MR. The goal of our study was to establish correlation between sizes of EBD measured by these two methods in healthy individuals. Our hypothesis was that there is no significant difference in size of EBD measured by US and any used MR sequence, and between three different MR sequences. Also an effect of aging on EBD size was analyzed by all methods independently.

Materials and Methods

In comparative prospective study from September 2004 to February 2005, 80 individuals were examined. Participants were randomly selected individuals from patients that underwent MR examination of lumbosacral spinal column with no history of biliary disease or opera-

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tion, no icterus, no abdominal pain or other subjective symptom suggesting biliary disease. Patients were in nonfasting state, not prepared for biliary examination. Informed consent was obtained before entering the study.

After completing MR examination of spinal column two breathold T2 weighted MRCP sequences for imaging bile ducts were preformed using phased-array wrap around coil (Harmony, 1T MR unit, Siemens, Erlangen, Germany): thick slab rapid acquisition with relaxation enhancement (RARE, TSE) in coronal and oblique coronal planes and thin section single-shot TSE (HASTE) in coronal plane. In addition coronal fully rewound gradient echo (True FISP) as in conventional abdominal series was performed (Table 1). All scanning was performed in inspiration.

TABLE 1
MAIN SCANNING PARMETERS FOR MR SEQUENCES

	TSE	HASTE	True FISP
Repetition time (ms)		1100	7.1
Time to echo (ms)	1100	90	3.5
Flip angle	150	150	80
Thickness (mm)	55	4	5
Matrix	240x256	218x256	220x256
Field of view (mm)	300	300	350
Acquisition time (s)	4	16	26
Plane	coronal, oblique coronal	coronal	coronal

TSE – thick slab rapid acquisition with relaxation enhancement, HASTE – thin section single-shot TSE, True FISP – fully rewound gradient echo

Within one hour after MR, US examination of the bile ducts were performed by radiologist using 2.5-5 MHz curved array probe (HDI 5000, ATL Ultrasound, Bothell, USA). Gray scale US was performed with patient supine and in left lateral decubitus position using subcostal or intercostal approach. Sonograms were obtained in inspiration optimizing visualization of EBD.

Examinations and measurements of EBD were randomly done by three variously experienced radiologists (GLP, DM, and NB) according to their usual daily schedule. For single individual one of the radiologists performed MR and other US, each blinded to the result of the other. By both modalities the widest diameter of the EBD in porta hepatis where EBD is parallel to portal vein was measured. Using electronic calipers diameter of the EBD lumen was measured perpendicular to its long axis. When needed magnified view was obtained.

On MR images at least one measurement was taken from each sequence, where EBD was adequately depicted in more slices or slabs up to three measurements per sequence were obtained. On US one or two measurements were obtained according to adequate visualization of EBD in supine and left lateral decubitus position.

Before proceeding with statistical analysis all images and measurements were reviewed by all three radiologists. The data of 4 participants were rejected due to US misinterpretation of other structures for EBD. Other data entered the statistical analysis.

The effects of four methods, three MR sequences compared to US, and the age of patients, as well as their interaction, on EBD diameter was examined by general linear model using PROC GLM. The relationship among methods was accessed by correlations between the US and the MR values. Linear regression was used to test the hypothesis that EBD diameter increases with age. All statistical analyses were conducted using PROC GLM, PROC CORR and PROC REG of STAT module of the statistical program SAS System for Win. Release 8.2 (SAS Institute Inc., Cary, NC, USA, 1999-2001).

Results

Of 80 individuals examined data from 76 were included in statistical analysis. There were 41 men and 35 woman, age 20 to 68, mean age 43.9, median 39. Age distribution is shown on figure 1.

General linear model procedure on EBD diameter resulted in non significant effect of methods, highly significant differences between patient age with no significant interaction between methods and age (Table 2). Measured size of EBD in different aging patients is not dependent on different method used.

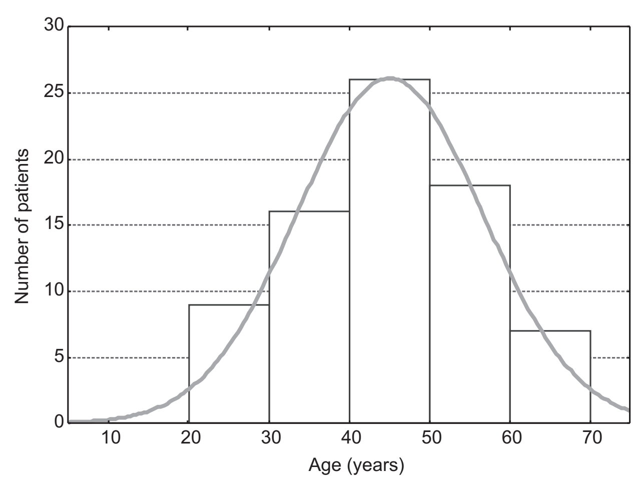

Fig. 1. Graph depicts number of patients per 10-year age interval.

TABLE 2
RESULTS OF TESTING THE MEAN DIFFERENCES BETWEEN METHODS AND AGE AND THEIR INTERACTIONS

Sources of variability	df	F_{exp}	p
Method	3	1.12	0.3403
Age	36	5.21	<0.0001
Method x Age	108	0.71	0.9820

TABLE 3
DESCRIPTIVE STATISTICS OF INVESTIGATED METHODS

METHODS	EBD diameter				N
	X	Minimum	Maximum	SD	
US	3.17	1.10	6.30	1.32	132
TSE	3.14	2.00	7.00	1.18	158
HASTE	3.26	2.00	6.00	1.03	141
True FISP	3.30	1.00	7.00	1.16	81
TOTAL	3.20	1.00	7.00	1.10	512

US – ultrasound, TSE – thick slab rapid acquisition with relaxation enhancement, HASTE – thin section single-shot TSE, True FISP – fully rewound gradient echo

Mean diameter of EBD for all measurements was 3.2±1.1, descriptive statistics for each method is given in Table 3.

Investigation showed that there was a trend of increase in the diameter of EBD with age, i.e. 0.0155 mm per year, significant at p=0.0954 (Figure 2). The EBD diameter was slightly larger in patients aged more than 45 years.

Measurement of EBD diameter was positive highly significantly correlated for each MR sequence with US (Table 4).

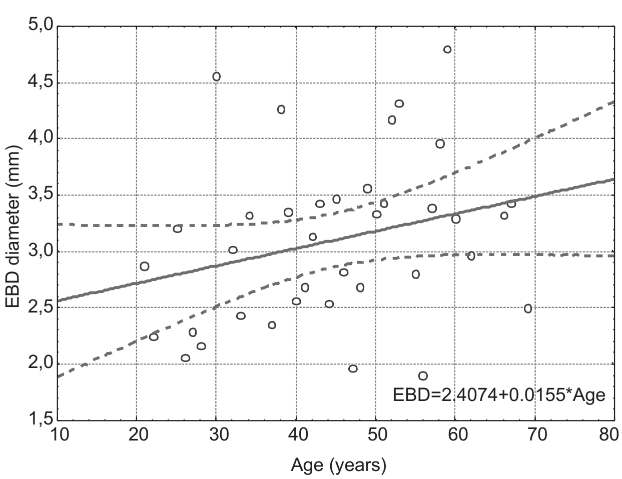

Fig. 2. Scatterdiagram shows the age-related change in the average extrahepatic bile duct diameter of 76 patients, ranged in age from 21 to 69 years, with regression line and 95% confidence interval, EBD – extrahepatic bile duct

Discussion

In our study size of EBD in healthy individuals measured by US correlated well with size measured by MR irrespective of sequence used. There was no significant difference in size of EBD comparing US to any MR sequence used or between MR sequences. All measurements by MR were within normal range and all measurements of EBD in our population were within accepted normal limits, irrespective of method used. Mean diameter of EBD was 3.2±1.1 mm which is in the range of referenced studies[3,8,9].

TABLE 4
CORRELATIONS BETWEEN MR SEQUENCES AND US MEASUREMENTS OF EBD DIAMETER

	US	TSE	HASTE	True FISP
US	1	0.58	0.64	0.61
TSE	0.58	1	0.70	0.67
HASTE	0.64	0.70	1	0.56
True FISP	0.61	0.67	0.56	1

All correlations are significant at p<0.050, N=76, US – ultrasound, TSE – thick slab rapid acquisition with relaxation enhancement, HASTE – thin section single-shot TSE, True FISP – fully rewound gradient echo

In 1987 Spitzer et al. reported that, if visualized by MR, normal size of EBD is 6.4±2.1 mm, range 4.5-10.0 mm on T1 weighted sequences and 7.8±1.9 mm, range 4.4-11.8 mm on T2 weighted sequences[10]. Reasons for obvious bile duct maximization authors find in blurring due to respiratory movement during few minutes acquisition time of spin echo sequences and signal averaging in borderline voxels. In almost twenty years MR imaging standards improved and modern hardware and software allows much detailed analysis of bile ducts routinely. Bile has varying signal by MR depending on fasting state of the individual and pulse sequence used. While on T1 weighted sequence signal of bile can appear booth high or low, on T2 weighted sequences it is constantly of high signal intensity. MRCP consists of heavy weighted T2 sequences where stationary or slow moving fluids (bile) appears hyperintense and background tissue (liver, pancreas, blood vessels, fat and connective tissues) is of very low signal intensity. This results in high contrast and excellent depiction of biliary structures. MRCP sequences can be performed with thick or thin section, usually in coronal and oblique coronal planes. MRCP is comparable to ERC in the diagnosis of bile duct pathology. MRCP have some advantages over ERC: it is noninvasive with no morbidity or mortality, no contrast media is needed, and there is no ionizing radiation. MRCP is capable of high quality images of biliary tree even in the presence of biliary-enteric communication or stenosis of bile ducts where ERC is of limited value[6]. MRCP is not affected by meteorism as US often is. MRCP is much more accurate in detecting bile ducts stones than US[7]. Furthermore, MR images are obtained in few seconds requiring little or no patient cooperation.

Although recent standard MR textbook state that common bile duct should not exceed 7 mm[6] there are no supporting published data concerning normal size of EBD measured by MR, or MR comparing to US as primary tool for evaluation of biliary tree.

For more than two decades US measurements of bile ducts is accepted as simple and accurate procedure but it is not as straightforward as it seems. There are many points in measurement process that are source of potential error. Also there are various reasons for discrepancy in EBD size measured by US and by conventional radiographic methods so one might expect similar problems comparing US and MR.

Common hepatic duct and part of common bile duct are usually easily depicted by US as anechoic tubular structure in porta hepatis anterior to the portal vein and hepatic artery crossing between, while distal pancreatic section of common bile duct generally cannot bee visualized by US. Standard anatomic relationships are present in 75-85% of population[11,12]. Due to different anatomic relationships occasionally during US examination EBD can be mistaken for cystic duct and hepatic artery[13], or even portal vein[14]. In rare cases it is impossible to distinguish anomalous cystic duct from common duct by US. Color Doppler can be used to identify blood vessels but this is not routine in standard examination of biliary tree. Also visualization of porta hepatis is sometimes not adequate due to meteorism. In our study in four patients other structures were misinterpreted as EBD. In all cases meteorism interfered with adequate visualization of porta hepatis. In three cases right hepatic duct was misidentified as EBD as confirmed later by comparing US and MRCP images. In fourth case supposed EBD measured by US was twice the size measured by MRCP. Reviewing US images reveled that only one tubular structure, almost certainly portal vein, was visualized and measured. This error could be avoided using color Doppler. The other possible reason for observed discrepancy might be daily variation of bile duct size. While some published data indicate that meal can affect duct size[15] other data do not support this view[16,12]. In our study the time between examinations was as short as possible and no food in this period was consumed. Misidentification of EBD by MRCP is almost impossible, only high amount of liquid gastric and bowel content or ascites can interfere with adequate visualization of EBD.

Various sites for measuring EBD were proposed[8,18]. Measuring EBD in different sites is one of the reasons for size discrepancy between US and radiographic methods[4]. Measuring EBD at its widest point, as in our study, is preferred because it discriminates best between normal and dilated bile ducts. EBD is usually widest in its pancreatic part witch is depicted by radiographic methods and MR but not by US. Usually it is not possible to distinguish common hepatic duct from common bile duct by US so this makes measurement on precise anatomic part of EBD impossible. In order to compare accurately methods in present study widest part of EBD in porta hepatis was measured both by US and MR.

It is well documented and understood that size of bile ducts measured by US differs from size measured by radiographic methods[4,5,14]. Normal size of EBD measured by IVB is 8mm, by ERCP and by PTC is 11mm[4,5], all markedly wider compared to US measurements. The reasons for this difference are minimization of bile ducts by US and maximization by radiographic methods. First in vitro US measurements showed minimization of duct size due to reverberation artifacts from the wall of the duct of 1.5 to 2 mm[4]. Later, improved equipment and optimization of gain settings reduced this error to 0.5 mm[19]. On the other hand there is maximization of duct size measured by radiographic methods due to radiographic projection and choleretic effect of contrast media by all methods and increased pressure in bile ducts due to injection of contrast media by ERCP and PTC[4,19]. These factors do not affect size of bile ducts obtained by MR, there is no magnification by MR images and no contrast media is used for MRCP.

Different measurement plain used by US compared to other methods is claimed as possible source of EBD size discrepancy[19]. Measurement plain is transversal by US and coronal by IVB, ERCP and PTC and if cross section of bile ducts is oval rather than circular measuring in various plains can lead to discrepancy in their size. Although by means of MRCP EBD were depicted and measured in coronal planes it did not affect our result. The correlation between measurements in transverse (US) and coronal plains (MRC) were good. Such results are in accordance with other published data stating that oval cross section is rare in normal sized bile ducts[20]. Finally possible reason for size discrepancy of EBD is respiratory variation[21]. In our study it was avoided by imaging EBD in inspiration booth by US and MR.

Our study demonstrated slight but significant widening of EBD with age not dependent on imaging method used. It is widely accepted that in healthy individual normal EBD measured by US is up to 6 or 7 mm wide[2,3] but there are exemptions to that rule. Obstructed bile ducts can measure 6 mm or less[18]. EBD up to 10 mm wide can be normal in elderly[16,22] and after cholecystectomy[23,24], but some studies do not confirm with this view[25,26]. The controversy concerning widening of bile ducts with age is long lasting. Morphological changes during life are surely subject to multiple factors besides age. It is stated that chronological and morphological age is not the same[27] and there is not likely to be a single pattern of »normal human aging«[28]. Therefore simple linear models describing age related changes are not suitable, more complex analysis and transdisciplinary research is needed to fully understand this problem[28].

The results of this study validate use of MR in quantitative assessment of EBD and establish MR as an accurate measuring tool, comparable to widely spread used US. Regarding this study there was no difference in size of EBD measured by US and MR, booth methods are objective with negligible or no errors incorporated. There is potential source of error in identifying EBD by US, MR being safer in this respect and useful when US is of limited value.

There are some limitations in this study. One obvious drawback was probable identification of portal vein as EBD by US in one patient. It could be avoided including color Doppler identification of blood vessels but this is not usual procedure in US biliary examination. One highly experienced radiologist doing all the measurements would probably afford greater degree of standardization but this would also differ from routine work. As measurements of bile ducts are performed on day to day basis in various circumstances and by various experienced radiologists we feel that routine procedures were more appropriate and our study was designed accordingly. Number of individuals included in our study was low due to limited time and access to MR unit.

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USPOREDBA ŠIRINE EKSTRAHEPATALNOG ŽUČNOG VODA MJERENOG MAGNETNOM REZONANCIJOM I ULTRAZVUKOM U ZDRAVIH ISPITANIKA

SAŽETAK

Širina žučnih vodova je važan dijagnostički znak, proširenje žučnih vodova može biti znak opstruktivne žutice. Svrha naše studije bila je odrediti razlike u širini ekstrahepatalnog žučnog voda mjerenog magnetnom rezonancijom i ultrazvukom kao i promjene u širini voda vezane uz dob. Širina ekstrahepatalnog žučnog voda mjerena je u 76 nasumično izabranih zdravih ispitanika. Tri radiologa su neovisno izmjerili širinu žučnih vodova na ultrazvuku (US) i tri T2 sekvence magnetne rezonance (MR). Učinjena je statistička obrada podataka korelacijom i linearnom regresijom. Prosječna širina ekstrahepatalno žučnog voda mjerena ultrazvukom bila je 3.17 mm, a magnetnom rezonancijom 3.14 mm na na thick slab rapid acquisition with relaxation enhancement sekvenci (TSE), 3.26 mm thin section single-shot sekvenci (HASTE) i 3.30 mm na coronal fully rewound gradient echo sekvenci (True FISP). Između ultrazvuka i tri sekvence magnetne rezonancije nije bilo statistički značajne razlike u širini žučnih vodova ($p<0.05$), a nađen je porast širine ekstrahepatalnog žučnog voda s dobi ispitanika (0.0155mm/god. $p=0.0954$). Rezultati pokazuju visoku korelaciju izmjerene širine žučnih vodova svakom pojedinom sekvencom magnetne rezonancije u usporedbi sa širinom izmjerenom ultrazvukom. Svim metodama prikazan je porast širine ekstrahepatalnog žučnog voda povezan s dobi. Dobiveni rezultati pokazuju da je magnetna rezonancija pouzdana metoda u određivanju širine žučnog voda.