Common Bile Duct Diameter Measurement by Magnetic Resonance Cholangiopancreatography

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ABSTRACT

The aim of this study is to compare the diameters of proximal and distal common bile duct (CBD) using magnetic resonance cholangiopancreatography (MRCP). The results may help in the daily MR interpretation of CBD and hepatobiliary disease.

From January to December 2006, a total of 153 subjects were recruited into our study. One hundred and twelve asymptomatic subjects who underwent health examinations including MRCP were recruited into the normal group. The remaining 41 patients were placed into the disease group, and their diagnosis included benign strictures (18), choledocholithiasis (14), gall stone with CBD dilation (3), cholecystectomy (4) and ampulla vater cancer (1). CBD measurements were performed using single shot thick slab MRCP projection. The CBD segment was divided into the proximal and distal parts. The largest diameters of both segments were recorded by two reviewers. Paired t-test was used to compare the difference between the proximal and distal CBD diameters, and regression analysis was used to analyze the difference between the normal and disease group.

Proximal CBD (11.7 ± 2.9 mm for reviewer A, 12.4 ± 3.3 mm for reviewer B) was significantly larger than distal CBD (8.3 ± 2.1 mm for reviewer A, 10.8 ± 2.3 mm for reviewer B) in the disease group (p < 0.001). Similar result was seen in the normal group, with the proximal CBD (4.4 ± 2.0 mm for reviewer A, 5.0 ± 2.1 mm for reviewer B) significantly larger than the distal CBD (3.9 ± 1.9 mm for reviewer A, 4.4 ± 2.0 mm for reviewer B) (p < 0.001). Despite the presence of confounding factors (age and sex), CBD diameters in the disease group are significantly larger than that of normal group in both proximal and distal CBD (p < 0.001).

MRCP measurement of CBD diameter is easy and non-invasive. The proximal part is significantly larger than the distal part in both normal and disease groups. Therefore measuring only the distal segments of CBD may underestimate the degree of obstruction.

The incidence of hepatolithiasis or intrahepatic calculi in East Asia is higher than Western countries [1]. With advances in medical imaging modalities, diagnosis of biliary tract disease is straightforward [2]. Abdominal ultrasound is the initial imaging of choice to demonstrate biliary tract disease [3, 4]. Ultrasound is a non-invasive imaging modality for screening and diagnosing obstructive biliary disease [3]. However, the major disadvantage of ultrasound is that artifacts from duodenal air or irregular respiratory rhythm may obscure the biliary tract and its lesion. Diagnosis of common bile duct stones is limited by its low sensitivity [5].

Endoscopic retrograde cholangiopancreatography (ERCP) is often regarded as the definitive diagnostic method and the gold standard in the evaluation of patient with suspected biliary tract disease [6]. It has the highest

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spatial resolution and diagnostic accuracy [7]. Moreover, physician could treat the abnormality at the same time. However ERCP is invasive, requires contrast medium injection and ionizing radiation, and is associated with a number of complications, such as pancreatitis, cholangitis, pancreatic sepsis, instrumental injury to the gastrointestinal tract, and drug reactions [8]. Therefore it has limited role as the first line examination [9].

Advances in magnetic resonance imaging (MRI) paved the way for development of magnetic resonance cholangiopancreatography (MRCP) in 1991 [10]. Using heavily T2-weighted magnetic resonance pulse sequence, bile and pancreatic duct fluid demonstrate high signal intensity, while the background tissues appear hypointense. As a result, the biliary tree, pancreatic ducts, and gallbladder are clearly depicted as bright signal structures on a background of dark tissues [11]. Nowadays MRCP is fast becoming a more popular non-invasive alternative to ERCP [8, 12].

However, MRCP is not without flaws. It is affected by the pulsation of the surrounding blood vessels [11, 13], and surgical clips and regional bowel peristalsis can also produce artifacts that may affect the diagnosis [8, 11]. Since fine details of CBD lesions are frequently obliterated by artifacts mentioned above, MRCP measurement of CBD diameter is important for the accurate diagnosis. For the same reason, MRCP cannot always depict the entire length of CBD in clarity and sometimes radiologists have to measure either the proximal or the distal segment.

There are a variety of normal ranges quoted for CBD diameters. The normal diameter for CBD was 4.1–6 mm which was suggested by ultrasound [14, 15], and 5.37 to 7.57 mm by multi-detector computed tomography (MDCT) [16]. To the best of our knowledge, there was no report about such measurement using MRCP. However, different measurement approached, different patient population, and different imaging modalities could affect the measured CBD diameters.

In this retrospective study, MRCP was performed for both the disease patients and the normal subjects. The disease group included the patients who suffered from a variety of hepatobiliary diseases, while the normal subjects were those who underwent health examinations. The purpose of this study is to evaluate the CBD diameter measurements using the MRCP for both proximal and distal segments in patient with hepatobiliary disease and healthy people. The results may help in the daily MR interpretation regarding CBD caliber and subsequent diagnosis hepatobiliary disease.

MATeRiALs And MeThodS

Subjects

The Institutional Review Board at our institute approved this retrospective study, and informed consent was waived. From January to December 2006, 292 consecutive subjects received MRCP, of which 213 were for health examinations, and 79 for disease diagnosis. The inclusion criteria of the normal subjects were, 1) the subjects had to receive a series of complete examinations including serum laboratory tests, X-ray examinations, abdominal ultrasound, non-contrast abdominal MR and MRCP, 2) they had to received the physical examinations by a variety of specialists including the internal medicine, 3) none of the participants had history of biliary disease, operation, abdomen pain or other subjective symptoms that may suggest biliary disease. Of the 213 subjects, 112 of them were included in our study. There were 71 males and 41 females (mean age, 51.2; range, 21-87). Among them, there were 13 participants older than 65 years. For the 79 patients who were referred by clinician to receive MRCP (not conventional abdominal MRI) for diagnosis of biliary disease, the inclusion criteria of the diseased subjects were: 1) they had to receive abdominal ultrasound, abdominal contrast enhanced MR and MRCP (some of them also received abdominal CT). 2) Diagnosis of hepatobiliary disease was made established by surgery and histopathologic analysis, or clinical diagnosis with follow-up studies for more than 6 months. Forty-one out of 79 patients were recruited into this study as the disease group. They were 17 males and 24 females, aged 46-84 years-old (mean age 66.5). Among them, 25 were 65 years and above. The disease group included benign strictures (19), choledocholithiasis(14), gall stone with CBD dilation (3), cholecystectomy (4), and ampulla vater cancer (1).

MRCP

Patients were required to fast for 8 hours prior to MR examination. All MRCPs were performed by a 1.5T MR machine (Philips Gyroscan ACS-NT, power tract 6000, The Netherlands) with 120 mT/m maximum gradient capability and phase array body coil. After localizing images, the coronal and axial abdominal images were obtained using T2-weighted pulse sequences. Axial images of the biliary and pancreatic ducts were obtained using T2-weighted fat suppressed pulse sequence.

Both groups’ MRCP included breath-hold thick slab single-shot turbo spin echo (ssTSE BH) sequence images. The parameters of the ssTSE BH sequence were as follows: TR, 8000 ms; effective TE, 850 ms; turbo factor, 128; flip angle, 90°; slice thickness, 30 to 40 mm; field of view, 250 mm; matrix, 256 × 205; acquisition time, 8 seconds. The entire pancreaticobiliary tree was included in all images. The same pulse sequence was repeated to acquire 4 to 6 projections of the pancreaticobiliary system from different angles.

For the disease group, additional 3D image including the raw data and maximum intensity projection (MIP) images, and contrast enhanced dynamic studies were also performed. The 3D MRCP images were obtained using...
T2-weighted fat suppressed, respiratory-triggered 3D turbo spin echo (3DTSE RT) sequence. The parameter were: TR, 2300 ms; effective TE, 750 ms; turbo factor, 102; flip angle, 90°; slice thickness of raw data, 2 mm with no gap; field of view, 270mm; matrix, 256 × 256 in coronal planes and 4 minutes and 10 seconds acquisition time. Fat saturation was used. Maximum intensity projection (MIP) projections of the pancreaticobiliary tree were reconstructed from the source images. The contrast enhanced abdominal MR studies were performed using T1-weighted fast field echo (FFE) sequence. The parameters were: TR, 175-210 ms; TE, 1.3-2.1; flip angle, 80° (before intravenous contrast administration) and 18-20 seconds (arterial-dominant phase), 50-55 seconds (portal venous phase), 5 minutes (delayed phase) after a manual intravenous administration of gadopentetate dimeglumine (Magnevists; Schering, Berlin, Germany; 0.1 mmol/kg body weight).

**Diameter Measurements**

Measurements of the CBD diameters were performed by two experienced radiological technologists (with two and 11 years experience of MR techniques, C.R.H., A.C.H.). Using coronal oblique image which could visualized the total CBD and pancreatic duct of single shot thick slab MRCP for both groups. The ruler function of the picture archiving and communication system (Centricity PACS, RA 600 v6.1, GE Medical Systems, Milwaukee, Wisconsin) was used for the measurement. The CBD was divided into two segments, proximal and distal, by the angulation of CBD depiction on coronal plane (near middle portion) noted in the thick slab MRCP coronal oblique image. The angulation was defined as the sharpest angle. The angle was measured at the intersection of imaginary lines drawn down the center of the bile duct [16]. All measurements were performed at a magnification factor of 2.0 to ensure precise delineation of the biliary duct borders. Both the widest diameter of the proximal and distal bile ducts were measured perpendicular to their long axis using electronic caliper.

**Statistics Analysis**

The statistics analysis was performed with Statistical Package for Social Science Software (SPSS version 15.0 Chicago, IL, USA). The data were presented as mean ± SD. To compare CBD diameter between the proximal and distal segments in disease or normal group, paired t-test was used. By controlling sex and age, linear regression was used in assessing proximal or distal bile duct between disease and normal group. The agreement between two reviewers in the measurement of CBD diameters at both proximal and distal part was evaluated by using the Pearson’s correlation. Student t-test was used for comparing the CBD diameters of the normal subjects that were below 65 years-old and those who were 65 years and above. The p value < 0.05 was considered statistically significant.

**RESULTS**

The measurement of CBD diameters are summarized in Table 1. For the disease group, the average diameter of the proximal CBD was 11.7 ± 2.9 mm (range: 5.7, 18.1) for reviewer A, 12.4 ± 3.3 mm (range: 6.5 mm, 21.8 mm) for reviewer B. The average diameter of the distal CBD was 8.3 ± 2.1 mm (range: 3.8, 12.3) for reviewer A, 10.8 ± 2.3 mm (range: 5.9 mm, 16.0 mm) for reviewer B (Fig. 1). The proximal segments were significantly larger than the distal ones (p < 0.001) in the disease group. For the normal group, the average proximal CBD caliber was 4.4 ± 2.0 mm (range: 1.6, 15.0) for reviewer A, 5.0 ± 2.1 mm (range: 2.2 mm, 17.5 mm) for reviewer B. While the distal CBD was 3.9 ±

<table>
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<tr>
<th>Reviewer</th>
<th>Proximal</th>
<th>Distal</th>
<th>p value†</th>
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<tr>
<td>Disease (41)</td>
<td></td>
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<tr>
<td>A*</td>
<td>11.7 ± 2.9 mm</td>
<td>8.3 ± 2.1 mm</td>
<td>&lt;0.001</td>
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<td></td>
<td>(5.7 mm, 18.1 mm)</td>
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<td>B</td>
<td>12.4 ± 3.3 mm</td>
<td>10.8 ± 2.3 mm</td>
<td>&lt;0.001</td>
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<td></td>
<td>(6.5 mm, 21.8 mm)</td>
<td>(5.9 mm, 16.0 mm)</td>
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<td>Normal (112)</td>
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<tr>
<td>A</td>
<td>4.4 ± 2.0 mm</td>
<td>3.9 ± 1.9 mm</td>
<td>&lt;0.001</td>
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<td></td>
<td>(1.6 mm, 15.0 mm)</td>
<td>(1.4 mm, 12.2 mm)</td>
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<tr>
<td>B</td>
<td>5.0 ± 2.1 mm</td>
<td>4.4 ± 2.0 mm</td>
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† data presented as the range (minimum, maximum).
* Pearson Correlation between reviewer A and B is 0.93 to 0.97.
CBD diameter measurement by MRCP

1.9 mm (range: 1.4, 12.2) for reviewer A and 4.4 ± 2.0 mm (range: 1.8 mm, 14.0 mm) for reviewer B (Fig. 2). Proximal segments were also significantly larger than the distal segments (p < 0.001) in the normal group.

There is no significant difference between two reviewers (p < 0.001). The Pearson’s correlation coefficient between two reviewers was 0.97 for proximal part of CBD and 0.93 for distal part of CBD with statistical significance (p < 0.001).

After controlling for confounding age and sex factors, proximal CBD diameter in the disease group seemed significantly larger than that of the normal group (p < 0.001). For the distal CBD, the disease group is also significantly larger than the normal group (p < 0.001).

**Figure 1.** A 71-year-old male who was pneumobilia with CBD and IHD dilatation. CBD diameter measurements were performed using MRCP. CBD diameter of the proximal segment is significantly larger than the distal segment for the disease group. The white arrow indicated the angle of CBD depiction on coronal plane (near middle portion), dividing the CBD into the proximal and the distal parts.

**Figure 2.** A 71-year-old male who underwent health examination. Using the MRCP, CBD diameter of the proximal segment is significantly larger than the distal segment for the normal group. The white arrow indicated the angle of CBD depiction on coronal plane (near middle portion), dividing the CBD into the proximal and the distal parts.
Linear regression analysis reveals that diameters of proximal and distal CBDs were not affected by the sex of patients (p > 0.05). However, they were significantly affected by the patients’ age (p < 0.001).

For the normal group, the average CBD diameter for the subjects that were 65 and above is significantly higher than the group below age of 65. The average diameter for the proximal CBD in normal subjects above age 65 is 6.6 mm for A reviewer (7.3 mm for B reviewer), for the distal CBD is 5.1 mm for A reviewer (5.7 mm for B reviewer). The average diameter for the proximal CBD in normal subjects below 65 is 4.2 mm for A reviewer (4.7 mm for B reviewer), for the distal CBD is 3.7 mm for A reviewer (4.3 mm for B reviewer).

**DISCUSSION**

Currently there are a variety of normal ranges quoted for CBD diameters. This inconsistency may be caused by different patient population in different studies with varying ages and pathologies, or different approaches in CBD measurement [15].

Sample et al measured the extrahepatic CBD diameters with ultrasound, and suggested that the normal diameter is average 6 mm [14]. As mentioned above, different measurement approaches and imaging modalities can affect the measured CBD diameters. Adibi measured CBD at two levels using ultrasound, one proximal and one distal. The proximal diameter was measured at the level of porta hepatitis, and the distal measurement was made at the level of pancreatic head. The results showed no significant difference between the proximal and distal CBD diameters.

Compared with other imaging modalities, ultrasound has a relatively small field of view and is usually limited to partial visualization of the CBD. As mentioned in the introduction, Adibi concludes that normal CBD has a constant diameter [17]. Our study uses MRCP for CBD measurement, and the results showed that the proximal segments of CBD are larger than the distal segments, which contradicts the results from above studies using ultrasound [14]. MRCP has less sampling error and more objective due to its ability to image the entire biliary tree, and therefore CBD diameter measurement with MRCP is more precise. With the superior imaging capability of MR, pancreaticobiliary tree can be visualized clearly and easily without invasive procedure such as ERCP [7]. An optimal MRCP allows the user to measure the caliber along any point in the CBD. However artifacts from surgical clips or bowel peristalsis can occasionally degrade the MR images and obscure parts of the biliary tree, leaving the physician with incomplete CBD assessment. Our results showed that the diameter of proximal CBD is larger than distal CBD in both disease and normal groups. Therefore in the diagnosis of hepatobiliary disease, we recommend that physicians measure the proximal CBD. If artifacts obscure the proximal segment, then physician should measure the distal CBD diameter while bearing in mind that the result is likely an underestimation its true maximal caliber.

The diameter of CBD was different in our study as compared with Park’s result. In Park’s study, CBD diameter measured at the angulation of CBD [16]. We measured CBD at both proximal and distal part which was separated by the angulation of CBD. Furthermore, the different imaging modalities used in ours and Park’s studies were the main reason for the different results. With the advancement of CT, contrast enhanced MDCT has excellent resolution because its high speed of imaging. Real time imaging could nearly fulfilled by CT scan, bowel peristalsis is minimal affected. The CBD diameter which measured by contrast enhanced MDCT is 5.37 to 7.57 mm in Park’s study [16]. The normal diameter of CBD was suggested 4.1–6 mm by using ultrasound [14,15]. In our result, CBD diameter for normal group is 4.4 ± 2.0 mm in proximal part and 3.9 ± 1.9 mm in distal part, which is smaller than the diameters measuring by MDCT. However, diameter measured by CT has several drawbacks, such as ionizing radiation and contrast enhanced risk. MRCP still provide the safe and good image quality.

The correlation between CBD diameter and patient age and sex were also analyzed in our study. Our results demonstrated that the CBD diameters in both the proximal and distal segments were correlated significantly with the patients’ age. On the other hand, the CBD diameters are not significantly affected by the patients’ sex. These results are in concordance with observations from previous studies using ultrasound [15, 17-20].

In conclusion, MRCP provide good depiction of the entire pancreaticobiliary trees. MRCP measurement of CBD diameters is both easy and precise. Proximal CBD is significantly larger than the distal segment. Measuring proximal CBD diameter provide a more accurate estimate of true CBD diameter than measurements taken distally. Physicians should be aware that when they measure only the distal CBD caliper they are likely underestimating the true diameter of the CBD.

**REFERENCES**

15. Bowie JD. What is the upper limit of normal for the common bile duct on ultrasound: how much do you want it to be? American Journal of Gastroenterology 2000; 95: 897-900