Normograms for the extrahepatic bile duct diameter in children

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Abstract

Objective: The normal diameter of the extrahepatic bile duct (EHD) in children has been poorly studied. Prior studies have enrolled small subject numbers, have studied only specific pediatric age groups or have potential bias due to loosely defined exclusion criteria. We sought to establish parameters for the normal diameter of the EHD in children from birth to late adolescence, including premature infants.

Methods: A 12½ month IRB-approved, HIPAA-compliant, retrospective chart review of all transabdominal ultrasounds performed on children (<18 years old) was conducted at a single pediatric tertiary referral center. Exclusion criteria included a past medical history of any pancreaticobiliary or hepatology disorder. New abnormal findings related to the liver, biliary system or pancreas were also excluded. Recorded EHD measurements from review of the radiology reports were compiled. Estimated mean and ninety-five percent prediction intervals of EHD were calculated and reported for six non-overlapping pediatric age groups.

Results: A total of 1016 ultrasounds on unique patients were included within the study. Estimated mean values and calculated ninety-five percent prediction intervals (in parentheses) for the diameter of the EHD were: prematurity, 0.7 (0.3-1.7) mm; 0-2 months, 1.0 (0.4-2.3) mm; 3-11 month, 1.2 (0.5-2.9) mm; 1-4 years, 1.4 (0.6-3.3) mm; 5-12 years, 1.9 (0.8-4.3) mm; 13-17 years, 2.3 (1.0-5.2) mm.

Conclusion: Our derived data of normal predicted parameters of the EHD diameter in children of all age groups will help guide clinicians in identifying those patients outside the norm that may benefit from additional testing.
**Key words:** common bile duct; pediatric

**What is known**

- Adequate data is available on the diameter of the normal adult-sized extrahepatic bile duct.
- Limited data exists on the normal diameter of the extrahepatic bile duct in children.
- Reliable diameter norms in children are important to help identify abnormally sized ducts that may benefit from additional diagnostic evaluation to rule out disease pathology.

**What is new**

- Newly derived estimated mean diameter and 95% prediction intervals of the normal extrahepatic bile duct in children.
Introduction

Ultrasonography is a ubiquitous, non-invasive method of assessing the morphology of the biliary tree including the size and diameter of the extrahepatic bile duct (EHD). In children, this imaging modality has the added benefit of the avoidance of ionized radiation exposure and can be readily performed without the need for sedation.

Abnormal dilatation of the biliary tree can be influenced by an obstructive process such as choledocholithiasis or other biliary tract pathology including congenital anomalies. Recognizing when biliary dilation is within the limits of normal anatomical variation versus a pathologic enlargement is invaluable in the clinical setting especially in children who may be incapable of fully articulating their symptoms and can have atypical, insidious presentations.

In the adult population, the diameter of the normal EHD has been well-studied including studies correlating a gradual diameter increase for age in older healthy adults. In contrast, children have been studied to a much lesser extent, with prior studies being limited by small sample sizes and variable exclusion criteria. Several studies have also limited the age assessment to young adolescents while others have failed to include the youngest of age groups, specifically newborns and infants.

Given the limitations in previously published pediatric studies, we sought to establish reliable childhood normative diameter measurements of the EHD by sonography in a large pediatric cohort.

Methods

Methods are available online as Supplemental Digital Content 1 (http://links.lww.com/MPG/A757).
Exclusion criteria flow chart is accessible via online Supplemental Digital Content 2 (http://links.lww.com/MPG/A758).

Results

A total of 2303 transabdominal ultrasounds on 2180 unique children were performed during the designated study period. Study indications were variable, but included though not limited to an evaluation for abdominal pain, organomegaly, abdominal distention, biochemical abnormalities suggestive of abdominal pathology and/or blunt trauma. Based on the defined exclusion criteria, 1287 studies were excluded from the review, leaving a remaining 1016 scans included within the study. Eighty-nine study reports were reread due to being identified as not having a clearly documented EHD size measurement. The distribution of patients into each age category were as follows: prematurity, 16; 0-2 months, 60; 3-11 month, 52; 1-4 years, 184; 5-12 years, 317; 13-17 years, 387. Based on the collective data, the estimated means and the corresponding 95% prediction limits were calculated and are presented in tabular and graphical format (Table 1 and Figure 1, respectively). There were no significant gender differences identified in size of the EHD in any of the age categories (data not shown). Quantile regression coefficients were used to develop quantile plots; scatter graph representing the study data points is shown mapped over the quantile plots (Figure 2). Twelve patients reported to have a history of premature birth but without a designation of their gestational age were excluded from quantile plot derivation.

Discussion

Our study represents the largest patient series to date for the purpose of developing normative size measurements of the pediatric EHD diameter across the complete spectrum of ages from
newborns to late adolescence. Through broadly defined exclusion criteria that encompasses a comprehensive list of hepatobiliary and pancreatic disorders, our pediatric study cohort has attempted to reflect a representative segment of the healthy pediatric population as it relates to the pancreatico/hepatobiliary systems. In doing so, our benchmark data will allow clinicians to identify children who may benefit from additional diagnostic assessment as a result of their measured EHD diameter fitting outside the expected normal parameters.

Identifying accurate and reliable size parameters of the normal pediatric EHD is important for being able to recognize potentially significant disease states versus normal size variation found in the general population. Adult studies have characterized the normal size of the EHD with several authors demonstrating a direct relationship between patient age and the size of the EHD \(^1\)\(^-\)\(^3\). By contrast, the available pediatric studies that have attempted to establish normal measurements of the EHD are limited in number, with the majority of these studies restricted by their small sample sizes, limited defined exclusion criteria or inconsistencies in measurement protocol \(^4\)\(^-\)\(^9\).

For newborns and young infants, our data of a 95% upper prediction limit measurement of 2.3 mm (age category 0-2 months) is similar to that reported by Carroll et al where a measurement of more than 2 mm during the first three months of life was considered abnormal and suggestive of biliary obstruction \(^8\). In this age group (including premature patients), it is most important to identify an abnormally enlarged bile duct size specifically to discern those whom may possess a congenital choledochal cyst.

The study from Carroll et al \(^8\) is the only study to date that has attempted to evaluate the normal size of the EHD in the neonatal age group. Though these authors did report the gestational age of their study cohort, it is unclear as to the CGA of the premature infants including the number of...
subjects with a CGA of less than zero at the time of their ultrasound. We evaluated premature infants (defined as a gestation age <37 weeks and with a CGA <0 weeks at the time of their sonogram) separately from infants born premature but with a CGA of ≥0 weeks (who were reported within the age category reflective of their CGA). Though our premature age category included only a small number of infants (16), we did identify a 95% prediction interval that differed from infants 0-2 months of age (0.3-1.7 mm compared to 0.4-2.3 mm). The validity of our 95% prediction interval for premature infants would be best supported by a study including a larger cohort of infants with a similar exclusion criteria used in our current study.

Notably, the study by Carroll et al was reported in 1982, and advances in ultrasound technology used in our study lend to higher resolution imaging and a more exquisite depiction of the EHD and its size.

While several studies have failed to present their measurements of the EHD with corresponding reference ranges, Zhang et al did include this in their data. Their study of 343 Chinese children from birth to 14 years of age reported the 95% reference ranges in different age groups similar to our age distribution categories. We found comparable measurements, however, key differences are important to highlight between our data and that from Zhang et al. More than half of their patient cohort (222) was less than 4 years of age with only 100 subjects between the ages of 4-14 years old (4-7 years: 57; 7-14 years: 43). By categorizing pubertal children with a pre-pubertal age group (7-14 years old), the authors included a rapid growth age segment with a group of children with a slower growth rate that would also likely reflect variable biliary tree growth rates. As such, their normal EHD diameter for this age group of ≤4.10 mm is subject to either over or under bias depending upon the age distribution. Our data separated children in this age group into 5-12 years and 13-17 years with sample sizes of 317 and 387 children, respectively, which
we believe appropriately factors in pubertal growth and more effectively reflects the general patient population. Moreover, as Zhang et al described, the size of the EHD may be influenced by patient ethnicity, whereby their patient population was exclusive to Chinese children and our cohort reflects a more diverse ethnic population representative of the central United States. Given that our data analysis did not assess for a possible difference in the EHD size based on patient ethnicity, the existence of such a variation remains unknown.

As would be expected, our data shows that the diameter of the EHD increases in size with the age of the child, a finding that was also demonstrated by prior pediatric studies. We identified a gradual increase in EHD diameter corresponding with increasing age of the child from an estimated mean measurement of 1.0 mm in the youngest of infants to 2.3 mm in the adolescent. We also found a wider variance of normal from newborn to adolescence as reflected in the 95% prediction intervals.

The generally accepted normal EHD diameter cutoff in adults is 6 mm. Our data found the upper prediction interval limit in normal children ages 13 thru 17 years to be 5.2 mm. It has been shown that the cessation of growth, specifically linear growth, does not end with late adolescence, but in fact continues substantially beyond 18 years of age and well into the third decade of life. This continuation of growth beyond adolescence likely reflects the measurement differences from our late adolescence data compared to prior adult measurement data of the EHD.

A strength of our study is the standardized sonographic measurement of the EHD. Our sonographic method consistently recorded the largest measured transverse diameter of the EHD. The diameter of the EHD has previously been shown to vary depending on the location along the length of the duct the measurement is taken and also on the measured axis.
showed that sonographically the EHD is not uniformly circular but rather oval in cross-section with an anterior-posterior (AP) diameter that is shorter than the transverse diameter measurement. Not only is a standard plane of measurement (i.e. AP versus transverse) important, of equal significance is the location of measurement along the length of the main extrahepatic bile duct with both Wu and Horrow identifying variation when the duct is measured at the hilum, the suprapancreatic or the intrapancreatic segment.  

Our study is retrospective in nature and is subject to the associated limitations of such a review. However, our large sample size of over 1000 study subjects mitigates this effect. Our broad and comprehensive exclusion criteria significantly improves the validity of our data, and greatly diminishes the likelihood of an unrecognized disease process confounding our results. No prior study has employed as extensive of an exclusion list of disease processes in the study subjects that might adversely influence the size and morphology of the biliary tree. We further excluded any new sonographic finding involving the liver/biliary tree/pancreas that would represent a previously undiagnosed condition (e.g. steatohepatitis) regardless of how remotely the condition might influence the EHD size. By employing such rigorous, all-inclusive exclusion criteria, our study cohort in essence reflects as closely as possible a healthy pediatric population.

An additional limitation of our study consists of the study subjects having undergone an ultrasound for a particular symptom or medical indication, and thus arguably not considered entirely healthy. Our extensive exclusion criteria was employed to overcome this limitation and aimed to segregate patients with medical conditions that could influence the bile duct diameter. A prospective study alternative would be evaluating a cohort of asymptomatic patients with no past medical history. Unfortunately, such a study would be impractical and cost prohibitive, and unlikely to attain as large of a cohort of children as our study.
Because our data collection was based on the EHD measurements made at the original reading of the sonogram by a group of radiologists (with only 89 studies needing to be reread due to the absence of a documented measurement), there does exist the potential for intra- and interobserver variability in the documented size of the EHD. The diminutive size of the EHD introduces an additional margin for measurement error. Invariably, these types of errors are inherent to a large retrospective study, but may be reduced though not eliminated by the adherence to specific guidelines or protocols in the reading of sonogram studies. Conclusion: Our study is the largest cohort of children including premature infants to be assessed for the purpose of identifying the normal EHD diameter of all pediatric age groups. We have identified 95% prediction intervals for specific age categories. We found a slow, yet progressive increase in EHD diameter with age in children from birth up to 18 years of age.
References


Table 1. Estimated means with corresponding 95% prediction intervals.

<table>
<thead>
<tr>
<th>Age (n=1016)</th>
<th>Estimated mean (mm)</th>
<th>95% prediction interval (mm)</th>
</tr>
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<tbody>
<tr>
<td>Premature (n=16)</td>
<td>0.7</td>
<td>0.3 – 1.7</td>
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<tr>
<td>0-2 months (n=60)</td>
<td>1.0</td>
<td>0.4 – 2.3</td>
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<tr>
<td>3-11 months (n=52)</td>
<td>1.2</td>
<td>0.5 – 2.9</td>
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<tr>
<td>1-4 years (n=184)</td>
<td>1.4</td>
<td>0.6 – 3.3</td>
</tr>
<tr>
<td>5-12 years (n=317)</td>
<td>1.9</td>
<td>0.8 – 4.3</td>
</tr>
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<td>13-17 years (n=387)</td>
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</tbody>
</table>
Figure 1. Estimated means with corresponding 95% prediction intervals.
Figure 2. Scatter graph with quantile plots of EHD diameter by age.