Prospective Assessment of Ultrasound Shear Wave Elastography for Discriminating Biliary Atresia from other Causes of Neonatal Cholestasis

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Objective To prospectively assess the diagnostic performance of ultrasound shear wave elastography (SWE) and hepatobiliary laboratory biomarkers for discriminating biliary atresia from other causes of neonatal cholestasis.

Study design Forty-one patients <3 months of age with neonatal cholestasis (direct bilirubin >2 mg/dL) and possible biliary atresia were prospectively enrolled. Both 2-dimensional (2D) and point ultrasound SWE were performed prior to knowing the final diagnosis. Median 2D (8) and point (10) shear wave speed measurements were calculated for each subject and used for analyses. The Mann-Whitney U test was used to compare shear wave speed and laboratory measurements between patients with and without biliary atresia. Receiver operating characteristic curve analyses and multivariable logistic regression were used to evaluate diagnostic performance.

Results Thirteen subjects (31.7%) were diagnosed with biliary atresia, and 28 subjects (68.3%) were diagnosed with other causes of neonatal cholestasis. Median age at the time of ultrasound SWE was 37 days. Median 2D (2.08 vs 1.49 m/s, $P = .0001$) and point (1.95 vs 1.21 m/s, $P = .0014$) ultrasound SWE measurements were significantly different between subjects with and without biliary atresia. Using a cut-off value of >1.84 m/s, 2D ultrasound SWE had a sensitivity = 92.3%, specificity = 78.6%, and area under the receiver operating characteristic curve (AuROC) of 0.89 ($P < .0001$). Using a cut-off value of >320 (U/L), gamma-glutamyl transferase (GGT) had a sensitivity = 100.0%, specificity = 77.8%, and AuROC of 0.85 ($P < .0001$). Multivariable logistic regression demonstrated an AuROC of 0.93 ($P < .0001$), with 2 significant covariates (2D ultrasound SWE [OR = 23.06, $P = .01$]; GGT [OR = 1.003, $P = .036$]).

Conclusions Ultrasound SWE and GGT can help discriminate biliary atresia from other causes of neonatal cholestasis. *(J Pediatr 2019;212:60-5)*.

Biliary atresia is a progressive obstructive fibroinflammatory cholangiopathy that presents as persistent jaundice in the neonatal period.[1] If not surgically palliated, biliary atresia results in cirrhosis and end-stage liver disease with almost certain death during the first 2 years of life. Conversely, if diagnosed before 45-90 days of age, surgical diversion of bile flow to the small intestine (Kasai portoenterostomy) can be performed with associated improved clinical outcomes, including delayed time to end-stage liver disease.[2] Despite recognition of the importance of early diagnosis and intervention, biliary atresia is the most common indication for pediatric liver transplantation.[3,4]

The evaluation of neonates with suspected biliary atresia varies, but typically includes a combination of more than one of the following: laboratory assessment (eg, bilirubin, alkaline phosphatase, gamma-glutamyl transferase [GGT], alanine aminotransferase [ALT]), conventional gray-scale ultrasound of the liver, gallbladder, and bile ducts, hepatobiliary scintigraphy, and liver biopsy. Patients deemed to be at high risk for biliary atresia after this work-up then commonly undergo intraoperative cholangiography, and histopathologic examination of the surgically excised extrahepatic biliary remnants allows for definitive diagnosis based on the typical fibrosing obstruction of the biliary tree.[5] Unfortunately, despite multiple diagnostic tools, timely diagnosis of biliary atresia can be challenging, with delayed diagnoses being relatively commonplace, in part because idiopathic neonatal hepatitis, Alagille syndrome, alpha-1 antitrypsin deficiency, parenteral nutrition associated liver disease, as well as other conditions can show similar clinical and diagnostic features.[6]

2D	2-dimensional
ALT	Alanine aminotransferase
AuROC	Area under the ROC curve
GGT	Gamma-glutamyl transferase
MMP-7	Matrix metalloproteinase-7
NPV	Negative predictive value
PPV	Positive predictive value
ROC	Receiver operating characteristic
SWE	Shear wave elastography

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A small number of studies have suggested that ultrasound shear wave elastography (SWE), based on the measuring the speed of shear waves generated within the liver, can help differentiate biliary atresia from other causes of neonatal cholestasis (ie, jaundice and conjugated hyperbilirubinemia in infants less than 3 months of age) with higher shear wave speeds suggesting the presence of biliary atresia. To date, ultrasound SWE has demonstrated sensitivities and specificities ranging from 81.4% to 100% and 66.7% to 100%, respectively, for identifying neonates with biliary atresia.[7-9] Further research is needed to further establish the diagnostic performance of ultrasound SWE for ruling in and ruling out the diagnosis of biliary atresia and to determine if additional clinical data (eg, age or laboratory markers) can improve its sensitivity and specificity. Liver shear wave speed measurements (in m/s) increase with increasing tissue stiffness (and increasing tissue fibrosis) and are related to the elasticity of a material (Young Modulus, or E, where $E = (\text{shear wave speed})^2 \times 3$, assuming a tissue density of 1 g/mL).[8]

The purpose of our study was to prospectively assess the diagnostic performance of two-dimensional (2D) and point ultrasound SWE for discriminating biliary atresia from other causes of neonatal cholestasis. We also sought to determine if the addition of clinical data could further improve predictive performance. We hypothesized that neonates with biliary atresia would demonstrate greater liver stiffness because of greater tissue fibrosis, and thus, increased liver shear wave speed measurements, when compared with neonates with other causes of cholestasis and that clinical data would further improve the diagnostic performance of ultrasound SWE for identifying biliary atresia.

Methods

This prospective study was approved by the local institutional review boards of the 4 participating children's hospitals (Cincinnati Children's Hospital Medical Center, C.S. Mott Children's Hospital, Nationwide Children's Hospital, and Lucile-Packard Children's Hospital) and was performed in a Health Insurance Portability and Accountability Act-compliant manner. Informed consent was obtained from a parent/guardian of all study participants. Grant support for this study was provided by Siemens Medical Solutions USA, Inc (Malvern, Pennsylvania).

At each participating institution, neonates (<3 months old) with cholestasis (conjugated bilirubin >2 mg/dL) and clinically suspected biliary atresia were identified between September 2016 and December 2018. Exclusion criteria included inability to undergo ultrasound imaging and known diagnosis/cause of neonatal cholestasis prior to research ultrasound imaging. Potential participants were identified by local pediatric gastroenterologists and pediatric radiologists.

Upon enrollment of a patient, research ultrasound 2D and point ultrasound SWE was performed either in the department of radiology or at the bedside in hospitalized patients. At all study sites, ultrasound SWE was performed using a similar ultrasound platform (Acuson S2000 or Acuson S3000 Ultrasound system; Siemens Medical Solutions USA, Inc, Malvern, Pennsylvania) and a 9L4 linear high-frequency transducer. Imaging was performed with patients free-breathing and using a right intercostal approach. By protocol, patients were nil per os for more than 1 hour. Research examinations were performed by dedicated pediatric sonographers, with all images reviewed centrally by a single investigator.

For 2D ultrasound SWE (Virtual Touch Imaging Quantification [VTIQ]), the elastogram field of view (size) was rectangular with a minimum dimension of 1.5 cm, and 2 elastograms were acquired from the central right hepatic lobe (including portions of liver segments V, VI, VII, and/or VIII). Four shear wave speed measurements were made on each elastogram, with 1 measurement placed in a representative area of greatest stiffness in each of the 4 elastogram quadrants while avoiding any areas of artifact (**Figure 1**). A total of eight 2D ultrasound SWE shear wave speed measurements were acquired from each subject. For point ultrasound SWE (Virtual Touch Quantification [VTQ]), 10 shear wave speed measurements were made from the central right hepatic lobe, with all measurements acquired from the same general location (**Figure 1**). All 2D and point ultrasound SWE measurements were obtained at least 1 cm deep to the liver capsule, avoiding vessels and areas of artifact.

Electronic medical records were subsequently reviewed for each patient at least 3 months after the research ultrasound SWE. Patient sex and age in days at the time of research ultrasound imaging were recorded. The following laboratory measurements were documented at the time of clinical presentation with neonatal jaundice: total bilirubin (mg/dL), direct (conjugated) bilirubin (mg/dL), ALT (U/L), GGT (U/L), and alkaline phosphatase (U/L).

Statistical Analyses

Median 2D (8 measurements) and point (10 measurements) shear wave speed measurements were calculated for each patient and used for analysis.

Continuous data were summarized as medians and IQRs, and categorical data were summarized as counts and percentages. The Mann-Whitney U test was used to assess for differences in continuous variables between subjects with and without biliary atresia (eg, age, laboratory measurements, ultrasound shear wave speed measurements). The Fisher exact test was used to assess for differences in categorical variables between subject groups (eg, sex).

Receiver operating characteristic (ROC) curve analyses were performed to assess the diagnostic performance of laboratory measurements and ultrasound shear wave speed measurements (both 2D and point) for discriminating patients with and without biliary atresia. The Youden J statistic was used to identify optimal laboratory measurement and ultrasound shear wave speed cut-off values that maximize sensitivity and specificity. Area under the ROC curve (AuROC), sensitivity, specificity, positive predictive value

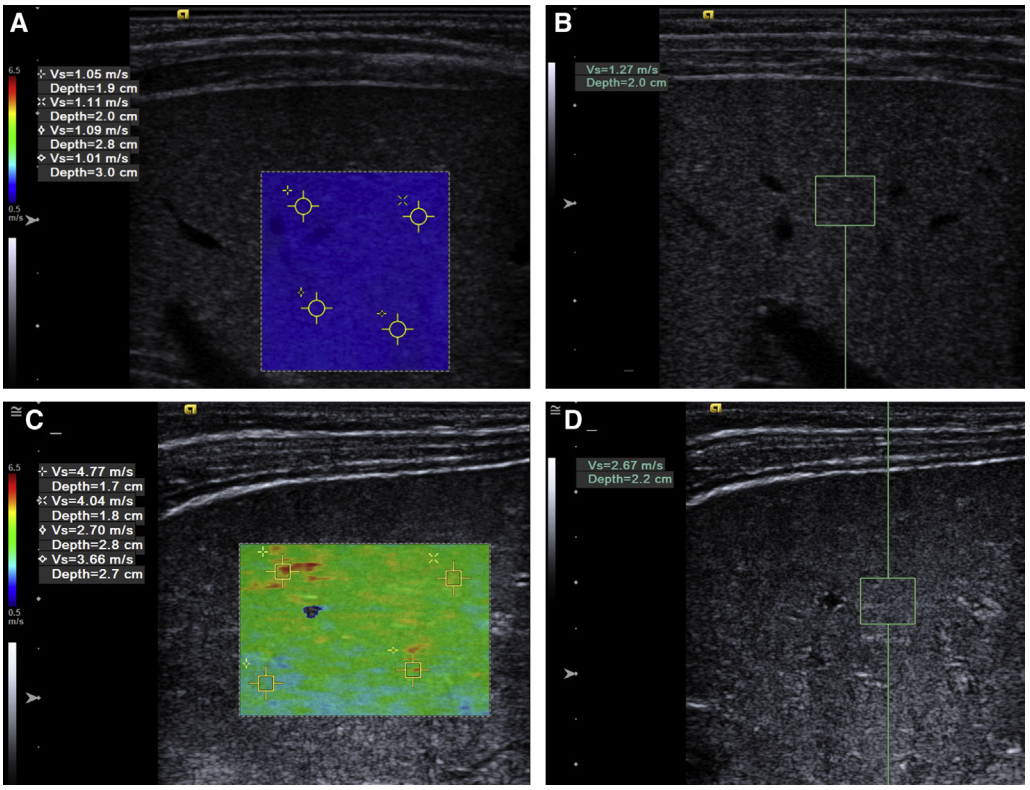

Figure 1. A 37-day-old boy with transient neonatal cholestasis attributed to neonatal hepatitis. **A,** 2D and **B,** point ultrasound SWE images show normal liver stiffness. Median shear wave speeds were 1.13 m/s and 1.14 m/s, respectively. **C,** 2D and **D,** point ultrasound SWE images from an 86-day-old boy with biliary atresia show marked liver stiffening. Median shear wave speeds were 3.48 m/s and 2.70 m/s, respectively.

(PPV), and negative predictive value (NPV) were calculated (with 95% CIs) as measures of diagnostic performance.

Multivariable logistic regression was used to further assess the discriminative abilities of 2D and point ultrasound SWE for identifying subjects with biliary atresia. Model building was performed using forward selection of independent variables (covariates), diagnosis of biliary atresia as our dependent variable (biliary atresia = "1"), and multiple independent variables (laboratory markers with a P value of less than .05 between subject groups, age, and ultrasound shear wave speed). A P value of $< .1$ was required for a variable to enter the model, and P value of $> .15$ was required for a variable to be removed from the model. Odds ratios and AuROC were determined for the final model (with 95% CIs). Separate models were created for 2D ultrasound SWE and point ultrasound SWE.

A P value of $< .05$ was considered statistically significant for all inference testing. Analyses were performed using MedCalc Statistical Software v 18.11.3 (MedCalc Software bvba, Ostend, Belgium; https://www.medcalc.org; 2019). Using 2D ultrasound SWE and based on data from Leschied et al, 36 subjects would be necessary to have 90% power to detect a mean difference in shear wave speed of 0.6 m/s between subjects with and without biliary atresia, assuming SDs of 0.7 m/s and 0.2 m/s for each group (unequal variance assumption) and alpha = 0.05.[8]

Results

Demographic and Laboratory Data

Forty-one patients were included in our study; 13 patients (31.7%) were diagnosed with biliary atresia, and 28 patients (68.3%) were diagnosed with nonbiliary atresia causes of neonatal cholestasis. Specific diagnoses are presented in **Table I** (available at www.jpeds.com).

Median age at the time of ultrasound elastography was 37 days (24-52 days). There was no difference in median age between patients with and without biliary atresia ($P = .19$); 29 patients were female. There was no difference in the proportion of female patients among those with and without biliary atresia ($P = 1.0$).

Median ALT and GGT measurements were significantly different between the biliary atresia and nonbiliary atresia groups ($P = .031$ and $P = .0009$, respectively), and there were no differences in total bilirubin, direct bilirubin, and alkaline phosphatase measurements (all P values of $> .05$). Demographic and laboratory data for patients with and without biliary atresia are presented in **Table II**.

Table II. Demographic, laboratory, and ultrasound shear wave speed data for patients with and without biliary atresia

Patient characteristics	Biliary atresia (n = 13)	Nonbiliary atresia (n = 28)	*P* value
Age (d)	37.0 (30.8-56.3)	31.5 (18.5-51.5)	.19
Sex (no. of male/female)	4/9	8/20	1.0
Total bilirubin (mg/dL)	7.8 (6.2-9.0)	7.7 (4.7-10.7)	.51
Direct bilirubin (mg/dL)	5.4 (4.8-6.4)	4.4 (3.3-6.7)	.31
ALT (U/L)	162 (88-208)	72 (42-138)	**.03**
GGT (U/L)	516 (473-758)	162 (111-301)	**.0008**
Alkaline phosphatase (U/L)	456 (324-653)	456 (394-539)	.90
2D shear wave speed (m/s)*	2.08 (1.90-2.50)	1.49 (1.34-1.80)	**.0001**
Point shear wave speed (m/s)†	1.95 (1.48-2.42)	1.21 (1.12-1.51)	**.0014**

Bold *P* values means statistically significant. Continuous data are presented as medians and IQRs.
*Median of 8 measurements for each subject.
†Median of 10 measurements for each subject.

Median 2D and point ultrasound SWE measurements also were significantly different between patients with and without biliary atresia, with patients with biliary atresia generally having stiffer livers with higher shear wave speeds ($P = .0001$ and $P = .0014$, respectively) (**Figure 1** and **Figure 2** [available at www.jpeds.com]). These results are presented in **Table II**.

Diagnostic Performance of Laboratory Markers and Ultrasound Elastography

Two laboratory tests (GGT and ALT, respectively) demonstrated better diagnostic performance than chance for distinguishing biliary atresia from nonbiliary atresia causes of neonatal cholestasis based on ROC curve analysis. Using a cut-off value of >320 U/L, GGT had a sensitivity of 100%, specificity of 77.8%, PPV of 64.7%, NPV of 100%, and AUROC of 0.85 ($P < .0001$) (**Figure 3** [available at www.jpeds.com] and **Table III**). Using a cut-off value of >115 U/L, ALT had a sensitivity of 69.2%, specificity of 75.0%, PPV of 56.2%, NPV of 84.0%, and AuROC of 0.71 ($P = .02$). Total bilirubin, conjugated bilirubin, and alkaline phosphatase showed no ability to discriminate patient groups.

Both 2D and point ultrasound SWE showed better diagnostic performance than chance for distinguishing biliary atresia from nonbiliary atresia causes of neonatal cholestasis based on ROC curve analysis. Using a cut-off value of >1.84 m/s, 2D ultrasound SWE had a sensitivity of 92.3%, specificity of 78.6%, PPV of 66.7%, NPV of 95.7%, and AuROC of 0.89 ($P < .0001$) (**Figure 4** [available at www.jpeds.com]). Using a cut-off value of >1.53 m/s, point ultrasound SWE had a sensitivity of 76.9%, specificity of 78.6%, PPV of 62.5%, NPV of 88.0%, and AuROC of 0.81 ($P < .0001$) (**Figure 4**).

Multivariable Logistic Regression

Using age, GGT, ALT, and 2D ultrasound SWE as possible independent variables, a highly significant model was identified for distinguishing patients with biliary atresia from patients without atresia with an AuROC of 0.93 ($P < .0001$). This model included 2 significant variables: 2D ultrasound SWE ($P = .013$) and GGT ($P = .036$). Model coefficients and ORs are presented in **Table IV** (available at www.jpeds.com).

Using age, GGT, ALT, and point ultrasound SWE as possible independent variables, a second highly significant model also was identified for distinguishing patients with and without biliary atresia with an AuROC of 0.89 ($P < .0001$). This model included 2 significant variables, including point ultrasound SWE ($P = .0097$) and GGT ($P = .011$). Model coefficients and ORs are presented in **Table V** (available at www.jpeds.com).

Discussion

Our study showed significant differences in ultrasound liver stiffness between neonates with biliary atresia vs other causes of neonatal cholestasis. Such differences were highly significant and were apparent using both 2D and point ultrasound

Table III. Diagnostic performance of laboratory tests and ultrasound shear wave speed for discriminating biliary atresia from other causes of neonatal cholestasis

Patient characteristics	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	AuROC	*P* value	Cut-off value
Total bilirubin (mg/dL)	100.0 (75.3-100.0)	32.1 (15.9-52.4)	40.6	100	0.57 (0.40-0.72)	.48	>5.0
Direct bilirubin (mg/dL)	84.6 (54.6-98.1)	50.0 (30.6-69.4)	44.0	87.5	0.60 (0.43-0.75)	.27	>4.0
ALT (U/L)	69.2 (38.6-90.9)	75.0 (55.1-89.3)	56.2	84.0	0.71 (0.55-0.84)	.02	>115
GGT (U/L)	100.0 (71.5-100.0)	77.8 (57.7-91.4)	64.7	100.0	0.85 (0.70-0.95)	<.0001	>320
Alkaline phosphatase (U/L)	46.2 (19.2-74.9)	77.8 (57.7-91.4)	50.0	75.0	0.51 (0.35-0.67)	.91	>391
2D shear wave speed (m/s)*	92.3 (64.0-99.8)	78.6 (59.0-91.7)	66.7	95.7	0.89 (0.75-0.96)	<.0001	>1.84
Point shear wave speed (m/s)†	76.9 (46.2-95.0)	78.6 (59.0-91.7)	62.5	88.0	0.81 (0.66-0.92)	<.0001	>1.53

95% CIs in parentheses.
*Median of 8 measurements for each subject.
†Median of 10 measurements for each subject.

SWE techniques. Similarly, serum GGT and ALT levels were significantly higher in subjects with biliary atresia. There were no significant differences between the groups in several other laboratory markers of cholestasis, including total and conjugated bilirubin as well as alkaline phosphatase.

When considering both laboratory markers and ultrasound SWE, the 2D ultrasound SWE technique demonstrated the best diagnostic performance for identifying subjects with biliary atresia, with an AuROC of 0.89. The observed sensitivity of 92.3% is slightly lower than that observed by Leschied et al (sensitivity of 100% in 11 subjects) and Wang et al (sensitivity of 97.6% in 86 subjects).[8,10] However, the sensitivity of 2D ultrasound SWE in our study was slightly higher than that demonstrated by Zhou et al (81.4% in 172 neonates with suspected biliary atresia).[9] The ability of 2D ultrasound SWE to correctly exclude biliary atresia in subjects that do not have biliary atresia was moderate, with a specificity of 78.6%. Like sensitivity, our observed specificity was lower than those observed by Leschied et al (specificity of 100%) and Wang et al (specificity of 100%).[8,10] Also, like sensitivity, the specificity demonstrated in our study was slightly higher than that shown by Zhou et al (specificity of 66.7%).[9]

GGT showed reasonable diagnostic performance for discriminating biliary atresia from other causes of neonatal cholestasis, with an AuROC of 0.85. This level of diagnostic performance was better than that observed for point ultrasound SWE (although 95% CIs overlap). When using forward selection to determine the best multivariable logistic regression, the combination of 2D ultrasound SWE and GGT resulted in an increase in AuROC when compared with either of these variables alone. The observed AuROC of 0.93 approaches that of a novel biomarker serum biomarker, matrix metalloproteinase-7 (MMP-7), which has recently been shown to have an AuROC of 0.97, sensitivity of 97%, and specificity of 91% for biliary atresia.[11] Although the MMP-7 biomarker likely performs slightly better than 2D ultrasound SWE, the combination of 2D ultrasound SWE and GGT are more readily available at the present time. It is also conceivable that the combination of MMP-7 and 2D ultrasound SWE (±GGT) will provide optimal diagnostic performance. Further study is needed to confirm this possibility.

Using an ROC analysis cut-off value of >1.84 m/s, 2D ultrasound SWE would have incorrectly identified 6 patients (of 28 subjects without biliary atresia) as having biliary atresia (false positives). Two of these 6 patients ultimately were diagnosed with transient cholestasis of unknown etiology, and 1 patient each had Alagille syndrome and total parenteral nutrition (TPN)-associated liver disease. The final 2 false positive subjects demonstrated both Cytomegalovirus (CMV) positivity and co-existent vascular abnormalities (Abernethy malformation and markedly elevated right heart pressure, respectively). These false positive instances are a reminder that ultrasound SWE measurements can be impacted by other co-existent medical conditions and, thus, should not be interpreted without considering available clinical data and potential confounders.[12] The cut-off shear wave speed value established by our study is similar to that observed in the study by Leschied et al where no patient without biliary atresia had a 2D ultrasound SWE liver shear wave speed above 1.87 m/s[8]. In their study, Wang et al established a 2D ultrasound SWE ROC analysis cut-off value of 8.68 kPa, or approximately 1.70 m/s, only slightly lower than our observed cut-off value.

Using the same 1.84 m/s cut-off value, 2D ultrasound SWE would have incorrectly identified only a single patient in our study (of 13 subjects with biliary atresia) as not having biliary atresia (false negative). This resulted in a NPV of nearly 96% and suggests this imaging technique has good diagnostic performance for ruling out the possibility of biliary atresia. Using an ROC analysis cut-off value of greater than 1.53 m/s, point ultrasound SWE incorrectly classified 9 of 41 (22%) patients (6 false positive instances similar to 2D ultrasound SWE but 3 false negative instances).

It should be noted that in our study, 2D ultrasound SWE values were systematically higher than point ultrasound SWE values with a corresponding higher shear wave speed cut-off value for 2D ultrasound SWE vs point ultrasound SWE for diagnosis of biliary atresia. Prior reports have shown a similar small difference in shear wave speed measurements between these 2 techniques using the same ultrasound system and a 9L4 linear transducer.[8,13] There are multiple possible explanations for this finding including differences inherent in the elastography algorithm and operator bias in 2D ultrasound SWE elastogram sampling. The specific cause of the discrepancy is not important for the clinical question at hand (diagnosis of biliary atresia) nor is the fact that a different shear wave speed provides optimal diagnostic performance depending on the technique used. What is important is recognition that the shear wave speed cut-off utilized may be technique, and likely vendor, dependent.[14]

Our study has limitations. First, most subjects (36 of 41) were recruited from 2 of the 4 participating institutions. Second, despite our study being prospective in design, our study cohort is composed of nonconsecutive patients, with the exact number of patients presenting with neonatal cholestasis at each institution during the study period unknown. Thus, our patient population has some features consistent with a convenience cohort.

Our study also has noteworthy strengths, including the use of similar ultrasound equipment to minimize shear wave speed measurement variability, use of a standardized imaging protocol, and a diversity of diagnoses in our nonbiliary atresia subject group. A final limitation is that we do not fully understand how well these imaging tests discriminate biliary atresia from other causes of neonatal cholestasis at the youngest ages (eg, 1-2 weeks of life). It is conceivable the ultrasound SWE will be less sensitive as biliary atresia is a progressive disease.

In conclusion, our study adds to a growing body of evidence that ultrasound SWE can help identify patients with

biliary atresia presenting with neonatal cholestasis. The 2D ultrasound SWE technique demonstrated better diagnostic performance than the point ultrasound SWE technique. Our results also suggest that the addition of laboratory data, such as GGT, can result in improved diagnostic performance compared with ultrasound alone. It is conceivable that a combination of noninvasive measurement of liver stiffness and serum markers may allow neonates presenting with suspected biliary atresia to potentially avoid delays in diagnosis related to achieve liver biopsy and/or hepatobiliary scintigraphy and proceed directly to intraoperative cholangiogram for a definite diagnosis and more timely surgical restoration of bile flow. ■

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Table I. Nonbiliary atresia causes of neonatal cholestasis (n = 28)

Diagnoses	Number of subjects
Transient cholestasis of unknown etiology (including neonatal hepatitis without identifiable cause)	11
Alagille syndrome/paucity of bile ducts	4
Parenteral nutrition associated liver disease	3
Alpha-1 anti-trypsin deficiency	2
ABO incompatible hemolytic anemia of the newborn	1
Choledochal cyst	1
CMV infection	1
CMV infection, Abernethy malformation (type II)	1
CMV infection, hepatic venous congestion from elevated right heart pressure	1
Glucose-6-phosphate dehydrogenase deficiency	1
Primary ciliary dyskinesia/ciliopathy	1
Rh disease	1

CMV, Cytomegalovirus.

Table IV. Final multivariable logistic regression model for predicting the diagnosis of biliary atresia using 2D ultrasound SWE

Variables	Coefficient	SE	OR	*P* value
Constant	−8.22	2.64	-	.002
GGT (U/L)	0.0034	0.0016	1.003 (1.000-1.007)	.036
2D shear wave speed (m/s)	3.14	1.26	23.06 (1.96-270.76)	.013

95% CIs in parentheses.
Model built using forward selection with $P < .1$ required for a variable to enter the model and $P > .15$ required for a variable to be removed from the model.
$P = .0001$ for overall model fit; AuROC = 0.93 (0.80-0.99).

Table V. Final multivariable logistic regression model for predicting the diagnosis of biliary atresia using point ultrasound SWE

Variables	Coefficient	SE	OR	*P* value
Constant	−6.99	2.16	-	.001
GGT (U/L)	0.0040	0.0016	1.004 (1.001-1.007)	.011
Point shear wave speed (m/s)	2.71	1.05	14.97 (1.93-116.46)	.0097

95% CIs in parentheses.
Model built using forward selection with $P < .1$ required for a variable to enter the model and $P > .15$ required for a variable to be removed from the model.
$P = .0001$ for overall model fit; AuROC = 0.89 (0.75-0.97).

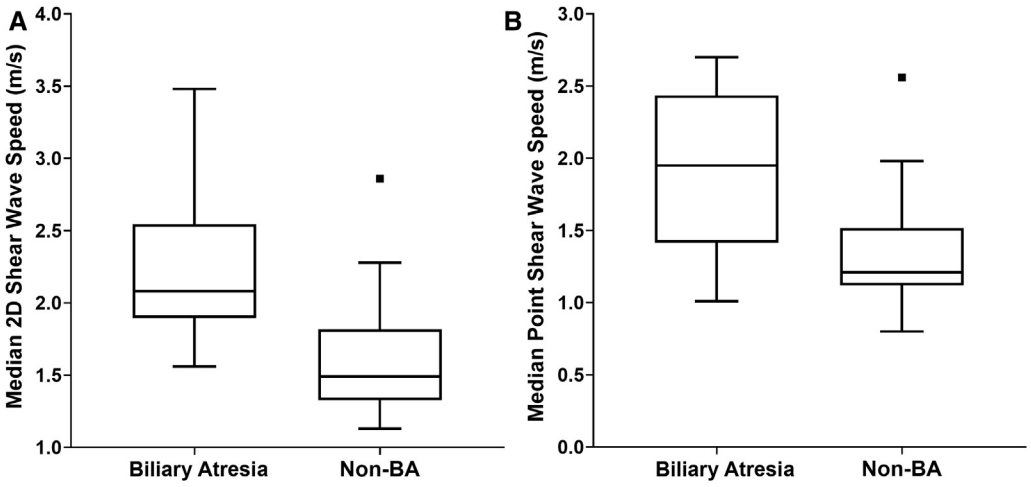

Figure 2. Tukey box plots showing **A,** 2D and **B,** point ultrasound SWE median shear wave speeds for patients with and without biliary atresia (P = .0001 and P = .0014, respectively). The patient shown as a black square is a statistical outlier.

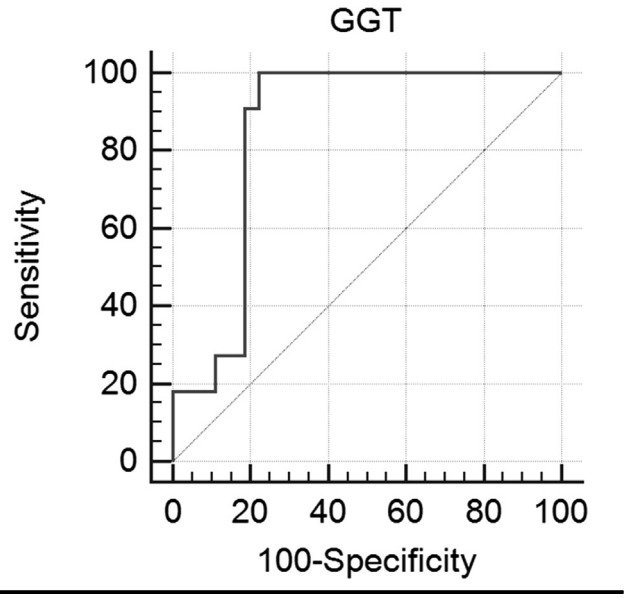

Figure 3. GGT ROC curve for discriminating patients with and without biliary atresia (AuROC = 0.85).

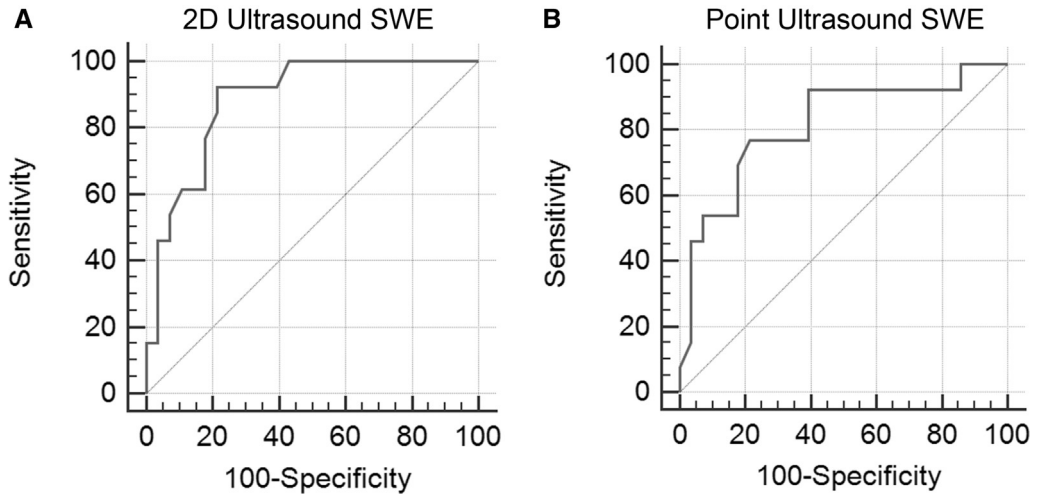

Figure 4. **A,** 2D ultrasound SWE ROC curve for discriminating patients with and without biliary atresia (area under the curve = 0.89). **B,** Point ultrasound SWE ROC curve for discriminating patients with and without biliary atresia (AuROC = 0.81).