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Research Article

PROSPECTIVE EVALUATION OF HEPATIC SHEAR WAVE ELASTOGRAPHY FOR ASSESSING LIVER FIBROSIS IN BILIARY ATRESIA: CORRELATION WITH HISTOPATHOLOGY AND SURGICAL OUTCOMES

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ABSTRACT

Background: Biliary atresia (BA) is a severe pediatric liver disorder that requires early diagnosis and surgical intervention via Kasai portoenterostomy (KPE) to optimize outcomes. This study evaluates the role of shear wave elastography (SWE) and liver biopsy in assessing preoperative liver status and predicting postoperative outcomes in BA patients. Methods: Of 40 patients evaluated for suspected BA, 32 met the inclusion criteria. Preoperative SWE values, liver biopsy scores, and clinical parameters were analyzed for correlations and predictive utility. Postoperative outcomes, including bile flow restoration, elastography trends, and biochemical markers, were assessed at 3 and 6 months. Results: The median age at surgery was 72 days, with a mean preoperative SWE value of 13.49 ± 3.81 kPa. Preoperative elastography and liver biopsy scores were significantly correlated (rho = 0.61, p = 0.003). At 3 months post-surgery, 47% of patients achieved patent bilioenteric drainage. SWE values and biopsy scores were significantly lower in the patent group compared to the non-patent group (SWE: 13.97 ± 3.12 vs. 15.92 ± 3.94 kPa, p = 0.059; biopsy: 9.0 ± 1.54 vs. 10.83 ± 0.98, p < 0.05). The patent group showed a gradual decrease in SWE values over time, while the non-patent group exhibited a sharp increase. Total bilirubin and gamma-glutamyltransferase (GGT) levels were significantly lower in the patent group at 3 months (bilirubin: 3.92 ± 1.61 vs. 12.08 ± 2.08 mg/dL, p = 0.001; GGT: 517.25 ± 205.15 vs. 941.50 ± 363.86 IU/L, p = 0.002). Discussion and Conclusion:SWE and liver biopsy provide complementary insights into preoperative liver status and postoperative prognosis in BA patients. SWE trends and histopathological findings highlight their potential as valuable tools for early diagnosis, surgical decision-making, and postoperative monitoring. Early intervention and meticulous follow-up are critical for improving outcomes in BA.

Keywords :- Biliary Atresia, Shear Wave Elastography, Liver Biopsy, Kasai Portoenterostomy, Liver Fibrosis, Cholestasis, Postoperative Outcomes.

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INTRODUCTION

Biliary atresia (BA) is a rare but severe pediatric liver disorder characterized by progressive obliteration of the extrahepatic bile ducts, leading to cholestasis, fibrosis, and eventually cirrhosis if untreated. It is the most common indication for liver transplantation in children. Early diagnosis and surgical intervention through Kasai portoenterostomy (KPE) are critical to restoring bile flow and preventing irreversible liver damage.

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However, outcomes following KPE vary significantly, influenced by factors such as the extent of liver fibrosis, cholestasis, and the timing of surgery.

Accurate assessment of liver pathology is essential for guiding management and predicting postoperative outcomes in BA. Liver biopsy remains the gold standard for evaluating hepatic architecture, including fibrosis, bile duct proliferation, and inflammation. However, it is invasive and associated with procedural risks. In contrast, shear wave elastography (SWE) is a non-invasive imaging modality that quantifies liver stiffness, offering a promising alternative for assessing fibrosis and monitoring disease progression.

This study aims to evaluate the correlation between preoperative SWE values and liver biopsy findings in patients undergoing KPE for BA and to explore their predictive value for postoperative outcomes. Additionally, we analyze the biochemical and elastographic trends over time to understand their role in monitoring disease progression and recovery. By integrating these findings, we seek to refine preoperative assessment and postoperative care strategies for BA patients.

MATERIAL AND METHODS

Study Type and Setting

This prospective observational cohort study was conducted at a tertiary care center from January 2020 to October 2020 at Sri Lakshmi Narayana Institute of Medical Sciences, Puducherry. The study aimed to evaluate hepatic shear wave elastography (SWE) for assessing liver fibrosis in biliary atresia (BA) and its correlation with histopathology and surgical outcomes. Approval was obtained from the institutional ethics board before initiating the study.

Sample Size Calculation

The sample size was determined based on the prevalence of BA and the expected correlation between SWE values and liver histopathology findings. The calculation accounted for a significance level of 0.05 and a power of 80%, ensuring adequate representation for statistical analysis.

Participants and Recruitment Process

Patients with neonatal cholestasis suspected of BA who underwent a standard preoperative investigation protocol were recruited. Inclusion and exclusion criteria were as follows:

Inclusion Criteria:

- Neonates with suspected BA undergoing standard investigations, including liver function tests (LFTs), ultrasonography (USG), hepatobiliaryiminodiacetic acid (HIDA) scan, and SWE.
- Patients confirmed with BA through intraoperative cholangiogram (IOC) who underwent Kasai portoenterostomy (KPE).

Exclusion Criteria:

- Advanced-stage cirrhosis precluding KPE.
- Syndromic BA cases.
- Patients lost to follow-up or who did not survive 3 months postoperatively.

Participants underwent standard extended KPE, during which a liver wedge biopsy was taken for histopathological analysis.

Tools Used in the Study

1. **Two-Dimensional Shear Wave Elastography (SWE):**
   - Performed using the Aixplorermultiwave SIG2320 system (HologicSuperSonic Imagine, France).
   - Transducers: High-frequency linear (4–15 MHz) and low-frequency convex abdominal (1–6 MHz).
   - Performed in segments II, IVA, and VIII of the liver.
2. **Histopathological Analysis:**
   - Biopsy evaluated using the METAVIR scoring system (F0–F4).
   - Graded based on cholestasis, hepatocellular damage, bile duct proliferation, portal edema, and portal inflammation [9].

Data Collection

- **Preoperative Data:**
  - LFTs, SWE values, and IOC findings were recorded.
  - SWE measurements were taken with three readings per segment, averaged to calculate a single SWE value in kilopascals (kPa).
- **Postoperative Data:**
  - Patients were followed weekly for 3 weeks, monthly for 3 months, and then every 3 months for a year.
  - At 3 months post-KPE, patients underwent repeat HIDA scans, LFTs, and SWE evaluations [10].
- **Outcome Categorization:**
  - Patients were classified into HIDA-patent (bilioenteric drainage established) and non-patent (bilioenteric drainage absent) groups based on HIDA scan results.
  - SWE values were compared between groups to assess postoperative outcomes.

Statistical Analysis

Data were analyzed using statistical software.

- Continuous variables were expressed as mean ± standard deviation (SD) and compared using t-tests or Mann-Whitney U tests as appropriate.
- Categorical variables were analyzed using chi-square tests.
- Correlations between SWE values and histopathological parameters were assessed using Spearman's correlation coefficient.
- A p-value < 0.05 was considered statistically significant.

Ethics for the Study

The study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the institutional review board before the study's initiation. Informed consent was obtained from the parents or legal guardians of all participants. Confidentiality of patient data was maintained throughout the study.

RESULTS

Patient Inclusion and Characteristics

Of the 40 patients evaluated for suspected biliary atresia (BA), 8 were excluded:

- **2 syndromic patients** with unconfirmed diagnoses,
- **4 with distal patency** confirmed on intraoperative cholangiography (IOC),
- **1 patient** with advanced liver cirrhosis, where Kasai portoenterostomy (KPE) was abandoned,
- **1 patient** lost to follow-up.

This left 32 patients (12 females) meeting the inclusion criteria. The median age at surgery was 72 days, and the mean preoperative elastography value was **13.49 ± 3.81 kPa**.

Histopathological Findings

A liver biopsy scoring system was used to evaluate cholestasis, hepatocellular damage, bile duct proliferation, portal edema, and portal inflammation (Table 1).

The mean liver biopsy score was 9.76 ± 1.50 out of 19. Preoperative elastography and liver biopsy scores showed a strong positive correlation (rho = 0.61, p = 0.003).

Portal Fibrosis and SWE Values

- F2 portal fibrosis was observed in 14 patients (47.6%) with a mean SWE value of 17.28 kPa.
- F3 portal fibrosis was observed in 11 patients (52.4%) with a mean SWE value of 14.49 kPa.
- A significant difference was noted between groups using the Wilcoxon and Mann-Whitney U tests (W = 2.000, p < 0.001).

Postoperative Outcomes

At three months post-surgery:

- 15 patients (47%) achieved patent bilioenteric drainage confirmed by hepatobiliaryiminodiacetic acid (HIDA) scan.
- 9 patients (28%) were non-patent.
- 5 patients (16%) died, including:
  - 2 at home due to unknown causes likely related to underlying conditions,
  - 1 in-hospital death from sepsis and severe cholangitis with liver failure.

Interpretation of SWE and Liver Biopsy Results

- The mean preoperative elastography values were significantly different between patent (13.97 ± 3.12 kPa) and non-patent (15.92 ± 3.94 kPa) groups (p = 0.059).
- The patent group had a lower mean liver biopsy score (9.0 ± 1.54) compared to the non-patent group (10.83 ± 0.98, p < 0.05).

Three-Month Follow-Up

- Mean SWE at three months was 15.8 ± 4.28 kPa in the patent group versus 19.3 ± 3.28 kPa in the non-patent group (p = 0.001).
- Total bilirubin was significantly reduced in the patent group (3.92 ± 1.61 mg/dL) compared to the non-patent group (12.08 ± 2.08 mg/dL, p = 0.001).

At the time of surgery, the nonpatentgroup's mean age (days) was 89.5±10.13, whereas the patent group's was 81±14.76. In the patent group, the mean preoperative SWE was 13.97±3.12 kPa, whereas in the non-patent group, it was 15.92±3.94 kPa. There was a statistically significant difference (W¼15.600, p¼0.059). Also, the patent group (n = 12) had a mean preoperative liver biopsy score of 9.0±1.54 out of 15, whereas the non-patent group (n = 6) had a mean score of 10.83±0.98. At three months, the mean SWE for the patent group was 15.8±4.28 kPa, whereas the nonpatent group's was 19.3±3.28 kPa.A statistically significant difference was observed (p¼0.001).

The mean preoperative total bilirubin was 10.25 mg/dL(±2.95); among the patent group, it was 10.65 mg/dL ± 2.77), while in the nonpatent group, it was 10.70 mg/dL (±3.50) with a p-value of 0.892. The mean total bilirubin at 3 months post-KPE in the patent group was 3.92 mg/dL (±1.61), and in the nonpatent group, it was 12.08 mg/dL (±2.08) with a p-value of 0.001. At 3months, the GGTvalue in the patent group (n¼12) was 517.25±205.15 IU/L, whereas in the nonpatent group

(n¼6), it was 941.50_363.86 with a p-value of 0.002. At 6 months, the GGT value in the patentgroup (n¼10) was 433.3 IU/L.

Out of 12 patients in the HIDA patent group at 3 months, 10 underwent elastography 6months postsurgery. The other two patients were lost to follow-up. The mean± SD elastography in these patients was 13.97±3.12 kPa preoperatively, 14.80±2.28 kPa at 3 months postoperatively, and 13.23±2.25 kPa at 6 months postoperatively. It showed a slow but continuous rise in elastography values over time in the HIDA patent group.

On the other hand, in the HIDA nonpatent group, the mean elastography score was 15.92 kPa preoperatively and 19.3 at 3 months; this rise was significantly higher and sharp compared with the patent group. None of the patients in the nonpatent group underwent elastography at 6months, either because of mortality, lost to follow-up, or referred for a liver transplant.

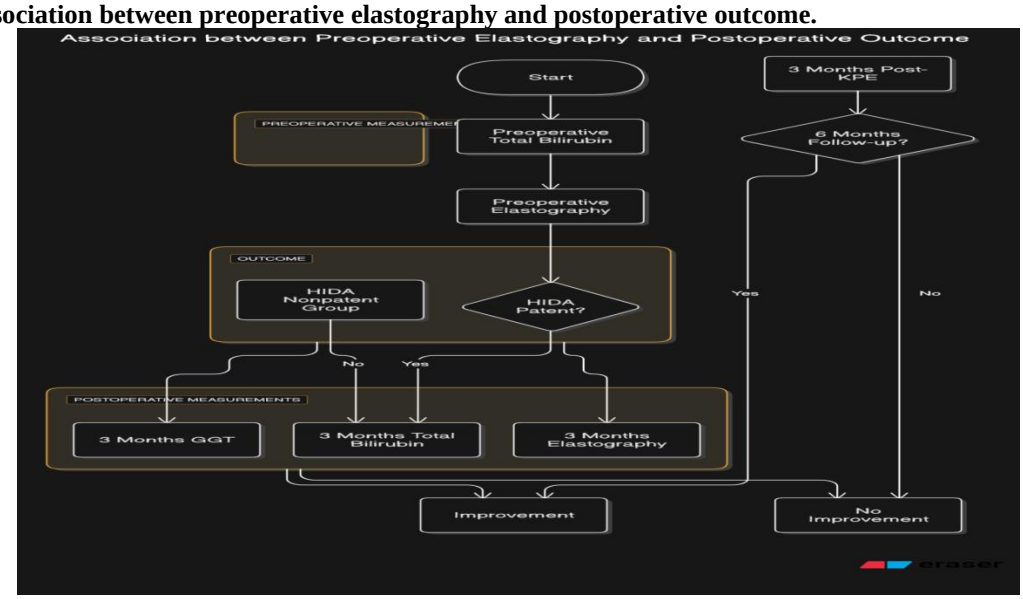
Table 1:

Histopathological Parameter	Scoring Levels
Cholestasis	Canalicular (1), Hepatocytes (2), Centrilobular (3)
Hepatocellular Damage	Ballooning (1), Feathery degeneration (2), Necrosis (3)
Bile Duct Proliferation	Mild (1), Moderate (2), Severe (3)
Portal Edema	Mild (1), Moderate (2), Severe (3)
Portal Inflammation	Mild (1), Moderate (2), Severe (3)

Table 2: Preoperative demographics and clinical characteristics of children

S.no	Parameter	Value
1	Age (d) mean±SD	81.86±38.13
2	Weight (kg)	4.82
3	M:F, N (%)	14:9
4	Bilirubin (mg/dL), mean	10.25±2.95
5	AST (IU/L), mean_±SD	241.15±4.95
6	ALT (IU/L), mean±_SD	178±132.2
7	GGT (IU/L), mean±SD	604.86±385.74
8	ALP (IU/L), mean_±SD	619.90±215.15
9	Preoperative SWE (kPa), mean±_SD	12.49±2.81
10	Portal fibrosis grading:F2/F3	10/11
11	Liver biopsy scoring,mean±_SD	9.52±1.5

Figure 1: Association between preoperative elastography and postoperative outcome.



DISCUSSION:

1. **Patient Characteristics and Timing of Surgery:** The median age of surgery (72 days) observed in this study aligns with Davenport et al. (2020) [12], who emphasized early surgical intervention as a critical determinant of improved biliary atresia outcomes. Delays in diagnosis and treatment have been associated with increased fibrosis and worse outcomes, as corroborated by Bezerra et al. (2020) [13].
2. **Preoperative SWE and Liver Biopsy Correlation:** The significant correlation between preoperative SWE values and liver biopsy findings (rho = 0.61) highlights the utility of SWE as a non-invasive alternative for fibrosis assessment. Sundaram et al. (2020) [14] similarly reported a strong correlation between elastography findings and histopathological grades of fibrosis, supporting its clinical relevance. However, the elevated SWE values in non-patent patients suggest the need for further refinement of elastographic thresholds to predict outcomes accurately.
3. **Histopathological Insights:** Higher biopsy scores in the non-patent group (10.83 ± 0.98 vs. 9.0 ± 1.54, $p < 0.05$) are consistent with the findings of Sokol et al. (2006) [15], who identified advanced histopathological changes such as bile duct proliferation and portal inflammation as predictors of poor recovery. These findings reinforce the importance of liver biopsy in evaluating the severity of liver damage preoperatively[16].
4. **Postoperative SWE Trends:** The gradual decline in SWE values in the patent group, reflecting fibrosis regression and liver recovery, aligns with Kim et al. (2019) [17], who demonstrated similar trends in elastography post-KPE. The contrasting rise in SWE values in the non-patent group suggests ongoing liver damage, supporting SWE's role in longitudinal monitoring.
5. **Bilirubin and GGT Trends:** The significant reduction in bilirubin and GGT levels in the patent group mirrors findings by Davenport (2017) [16], where successful bile flow restoration was associated with improved biochemical markers. These parameters serve as reliable indicators of postoperative biliary drainage and liver function.
6. **Portal Fibrosis and SWE Discrepancy:** The study notes discrepancies between portal fibrosis staging and SWE values, which may be influenced by additional factors like inflammation and edema. Similar observations were made by Bezerra et al. (2020) [13], who emphasized the multifactorial nature of liver stiffness beyond fibrosis alone.
7. **Mortality and Morbidity:** The observed mortality rate (16%) highlights the severity of BA, especially in non-patent cases, corroborating Sokol et al. (2006) [15]. Non-patent patients often experience complications like cholangitis and sepsis, necessitating liver transplant referrals, consistent with reports by Kim et al. (2019) [17-20].

Implications:

While this study validates the utility of SWE and biopsy in BA evaluation, its limitations, including the small sample size and variability in follow-up, call for larger-scale studies. Future research could refine SWE thresholds and explore adjunct therapies to optimize BA management.

CONCLUSION

SWE and liver biopsy provide complementary insights into preoperative liver status and postoperative prognosis in BA patients. Early diagnosis, timely surgical intervention, and postoperative monitoring are pivotal for improving survival and quality of life in this vulnerable population.

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