Research paper

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Two-dimensional shear wave elastography for assessing liver, spleen, and kidneys in healthy newborns

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spleen elasticity;
kidney elasticity

Abstract

Aim: The aim of the study was to obtain two-dimensional shear wave elastography measurements of the liver, spleen and kidneys in healthy full-term newborns, as well as to assess its feasibility in this age group. **Materials and methods:** We performed two-dimensional shear wave elastography of the liver, spleen and kidneys using a linear transducer at least 60 minutes after food intake in a group of 58 healthy, full-term, spontaneously breathing newborns. A series of 5 measurements using 5-mm-diameter regions of interest were performed, with the results expressed in m/s and kPa. Exam feasibility was assessed using the IQR/Median ratio as ≤30% for kPa, and ≤15% for m/s. Descriptive statistics, Shapiro-Wilk W, Levene's, Mann-Whitney U tests and Spearman correlation analysis were used for statistical assessment. **Results:** The feasibility of the exam was 68.97% for the right liver lobe, 67.24% for the left lobe, 91.07% for the spleen, 89.29% for the right kidney, 85.71% for the left kidney. Mean results: right liver lobe: 1.43 m/s, SD ±0.11, 6.04 kPa, SD ±0.97, left liver lobe: 1.41 m/s, SD ±0.12, 5.86 kPa, SD ±1.02, spleen: 2.36 m/s, SD ±0.21, 16.99 kPa, SD ±3.21, right kidney: 1.92 m/s, SD ±0.18, 11.34 kPa, SD ±3.21, left kidney: 1.88 m/s, SD ±0.16, 10.81 kPa, SD ±1.80. The splenic-hepatic elastography index for m/s and kPa results was as follows: mean 1.65, SD ±0.20, mean 2.82, SD ±0.73, respectively. No differences were found between the right vs left lobe of the liver, or the right vs left kidney; there was no correlation between the measurements and gender or food intake interval >60 minutes. A positive correlation was found between the results for the right and left lobe of the liver and age, and the results for the left lobe of the liver and body weight. **Conclusions:** Two-dimensional shear wave elastography of the liver, spleen and kidneys can be successfully performed in healthy neonates. We obtained reliable mean shear wave elastography values for the examined organs.

Introduction

Two-dimensional shear wave elastography (2D-SWE) is a dynamic, quantitative shear wave imaging (SWI) method for non-invasive assessment of mechanical properties of organs, including the liver, spleen and kidneys[1,2]. Measurements are performed in real time, in a two-dimensional view[3]. During the examination, a color-coded map of the tissue is created corresponding to its elasticity (elastogram), where each color is coded according to a scale specified in the device, in meters per second (m/s) or kilopascals (kPa)[4]. The elastogram shows the range of tissue stiffness. It covers a much larger area of the examined tissue than in other SWI methods, such as transient elastography (TE) or point shear wave elastography (pSWE)[1,5]. It also allows for setting up to several regions of interest (ROI) to obtain quantitative measurements[5]. The values are expressed in units defining the shear wave velocity in m/s (actual measurement), as well as in kPa, which is a measurement calculated from the following formula: E = 3G (E – Young's modulus, G – shear modulus)[6]. In the 2D-SWE technique, the superposition of the anatomical B-mode ultrasound image and the elastogram allows for greater accuracy in placing the ROI in the selected area and increases the reliability of the shear wave velocity measurement[4]. In contrast to pSWE, the size of a circular ROI can be adjusted within a specified range[7]. Rapid data acquisition makes the result independent

of involuntary movements of the patient or operator, which allows for examining uncooperative patients and reliable measurements during spontaneous breathing[4]. The recommended quality criteria for all ultrasound SWE techniques include the number of required acquisitions (for children under 5 years of age), spontaneous breathing, five ROI measurements, and the ratio of interquartile range/median (IQR/M), which is ≤30% for kPa measurements and ≤15% for m/s measurements of the liver and spleen[2,8,9].

SWE is used for noninvasive diagnosis and treatment monitoring in chronic fibrotic liver diseases, as well as to limit the number of unnecessary diagnostic biopsies[2,9]. In neonates, SWE has been shown to be useful in differentiating congenital biliary atresia from other causes of cholestasis, in monitoring liver fibrosis in the course of short bowel syndrome and after Fontan procedure for single-ventricular heart[10–12]. SWE has been shown to be useful for liver evaluation in premature infants with intrauterine growth restriction[13].

Splenic SWE for the diagnosis of significant portal hypertension has shown greater sensitivity in assessing the risk of bleeding from esophageal varices in adult and pediatric patients[8,14,15]. The splenic-hepatic elastography index can be used in patients with portal hypertension of unknown origin to help differentiate between causes of cirrhosis and absence of cirrhosis[2]. This index may be an acceptable tool for predicting the severity of hepatic pathology leading to fibrosis or cirrhosis[16]. Assessment of splenic stiffness is useful in selecting children with biliary atresia after Kasai's operation for liver transplantation and in the case of congenital kidney disease (autosomal recessive polycystic kidney disease, ARPKD) for detection and quantitative assessment of liver fibrosis and portal hypertension[17,18]. There are currently no recommendations for hepatic or splenic assessment in neonates and young children, and the existing ones only refer to adult patients[2].

Renal SWE is used in children for the diagnosis of renal hypoplasia and dysplasia[2]. It is useful in assessing renal parenchymal stiffness in severe hydronephrosis; however, studies have shown that the results are not unambiguous[19,20]. SWE used for the diagnosis of glomerulonephritis in children shows some superiority over conventional US in predicting the course of the disease and allowing for its earlier detection[21]. So far, no recommendations have been developed to specify the principles and techniques for renal examinations using SWE imaging, which, as emphasized, results from the complex, anisotropic structure of this organ[22,23]. However, there is a need for research in patients with chronic kidney diseases to determine what factors actually affect renal SWE measurements, as well as to assess the role of renal elastography and the indications for its use in clinical practice[24].

The main objective of the study was to obtain SWE measurements, mean shear wave velocity and elasticity in 2D-SWE of the liver, spleen and kidneys in a population of healthy, full-term, spontaneously breathing neonates, using a linear transducer, as well as to assess the feasibility of 2D-SWE in this age group. Additional objectives included assessing the relationship between SWE findings and the site of liver elasticity measurement (right vs left lobe), differences between the right vs left kidney, determining the correlation between SWE findings and gender, age (days of life), body weight, food intake intervals >60 minutes, and estimating the splenic-hepatic elastography index (right lobe) in healthy newborns.

Materials and methods

The study was approved by the Bioethics Committee of the Nicolaus Copernicus University in Toruń, Medical College in Bydgoszcz (KB 379/2019). It was conducted in a group of healthy, full-term newborns, with a birth weight corresponding to ≥10th percentile for gestational age according to WHO, with a calendar age ranging from the 2 to 28 days of life, with no pre- or perinatal history of risk factors for liver, spleen and kidney diseases or systemic conditions, congenital defects and metabolic diseases, and no hepatic, splenic and renal pathology in pre- or postnatal ultrasound. The characteristics of the group are presented in Tab. 1.

Hepatic, splenic and renal elasticity was measured using the 2D-SWE method during an ultrasound examination (the same device and transducer used for B-mode US), with Canon Aplio i600 system, a14L5 linear transducer (10 MHz), neonatological preset, in spontaneously breathing newborns. A minimum food intake interval of 60 minutes was required. The liver and spleen were assessed with the newborn in the supine position. The right hepatic lobe was assessed under the right costal arch or in the right intercostal space, the left hepatic lobe was assessed in the midline, under the costal arch, achieving optimal transducer placement. The spleen was examined in the left intercostal space or under the left costal arch, achieving optimal transducer placement. The kidneys were assessed in the prone position, from the dorsal side, in the middle part of the kidney, in the view transverse to the long axis. The transducer was placed perpendicularly to the surface of the examined organs, avoiding additional pressure with the transducer. Before taking measurements, a color-coded uniform area of the measurement map (elastogram) was determined using the wave propagation map (option available in the device). The measurements were done below the organ capsule, with the ROI placed within the elastogram so that it was filled with a uniform color, and with wave lines arranged in parallel, equally spaced on the propagation map. The above steps were repeated to obtain a series of 5 measurements (ROI). The ROI size was 5 mm for the right and left lobes of the liver, spleen and

Tab. 1. Characteristics of the group of newborns

Number (girls/boys)	58 (36/22)
Gestational age (weeks)	38–41
Apgar score (scores)	9–10
Calendar age (days) min–max / mean (median)	2–28 / 10 (4)
Birth weight (g) min–max/mean (median)	2720–5250 / 3656 (3628)
Body weight at examination (g) min–max/mean (median)	2530–5240 / 3697 (3690)
Body length at birth (cm) min–max/ mean(median)	48–65 / 55 (55)
Body length at examination (cm) min–max/ mean (median)	48–67 / 55 (55)
BMI at birth min–max/mean (median)	10.23–16.1 / 12.18 (12.06)
BMI at examination min–max/mean (median)	9.57–15.41 / 12.25 (12.04)
Feeding break (minutes) min–max/mean (median)	60–300 / 114 (105)

BMI – body mass index

kidneys. Examples of 2D-SWE examinations of the right and left lobes of the liver, spleen and kidney are illustrated in Fig. 1, Fig. 2, Fig. 3, Fig. 4. In the kidney examination, the ROI included the renal parenchyma (cortex and pyramid) in such a way that the position of the pyramid (long axis) was parallel to the US beam, excluding the lumens of the calyces and the renal pelvis. The results for each organ were obtained based on the calculation performed by the application installed by the manufacturer in the US device, based on a series of 5 measurements.

Newborns with reliable measurements for the right and left liver lobe, spleen, as well as the right and left kidney were qualified for calculations and statistical analysis. The IQR/M index, which was ≤30% for kPa measurements and/or ≤15% for m/s measurements, was used as a reliability parameter. In the case of US abnormalities found in a given organ and/or an unreliable result from a series of SWE measurements, the measurement was not included in the statistical analysis. SWE feasibility for the liver, spleen and kidney was assessed based on the reliability parameter, by calculating the per-

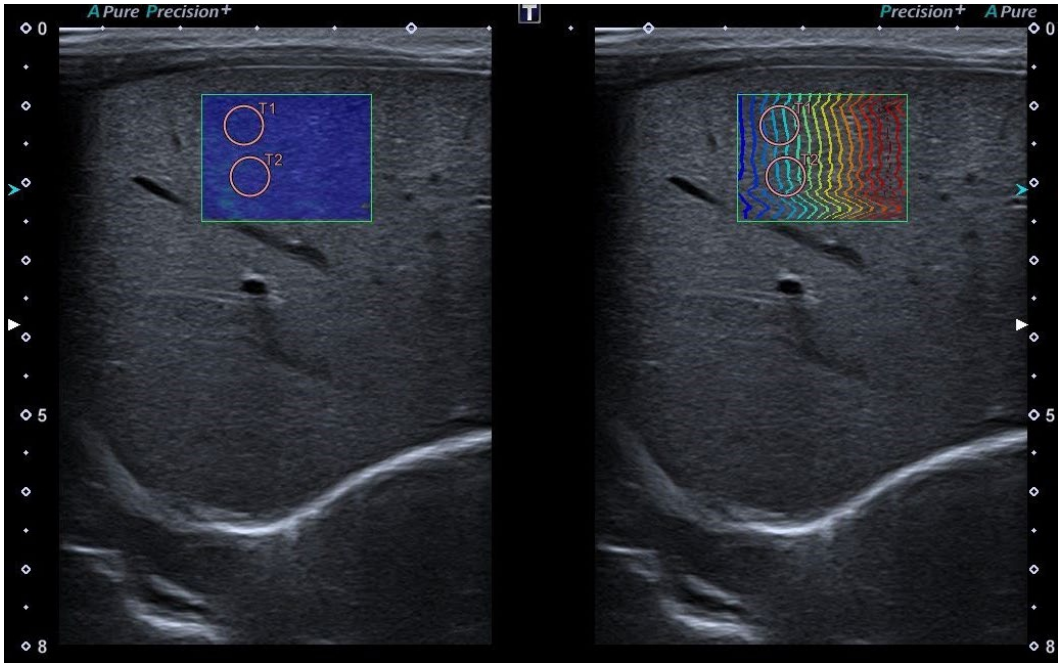

Fig. 1. *An exemplary SWE measurement of the right liver lobe with a color-coded map and a wave propagation map, two ROIs are marked*

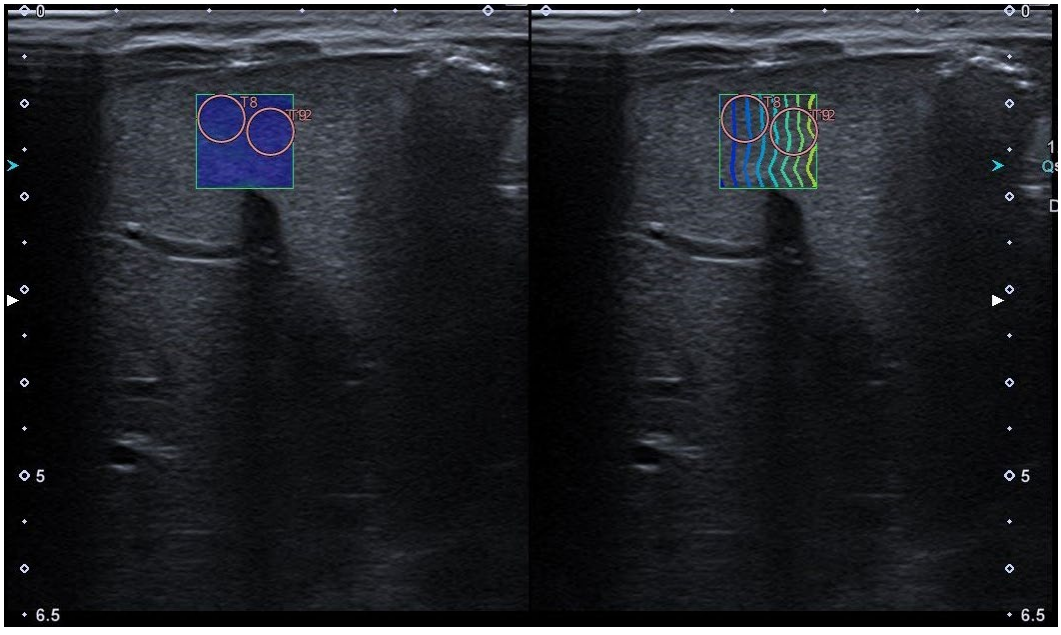

Fig. 2. *An exemplary SWE measurement of the left liver lobe with a color-coded map and a wave propagation map, two ROIs are marked*

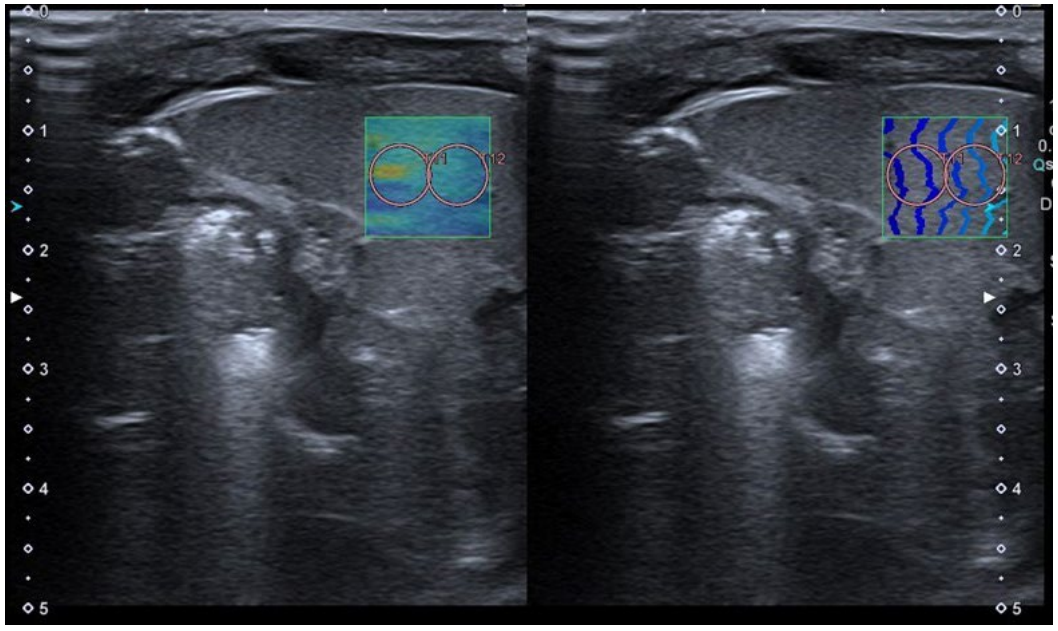

Fig. 3. *An exemplary spleen elasticity measurement, with a color-coded and a wave propagation map, two ROIs are marked*

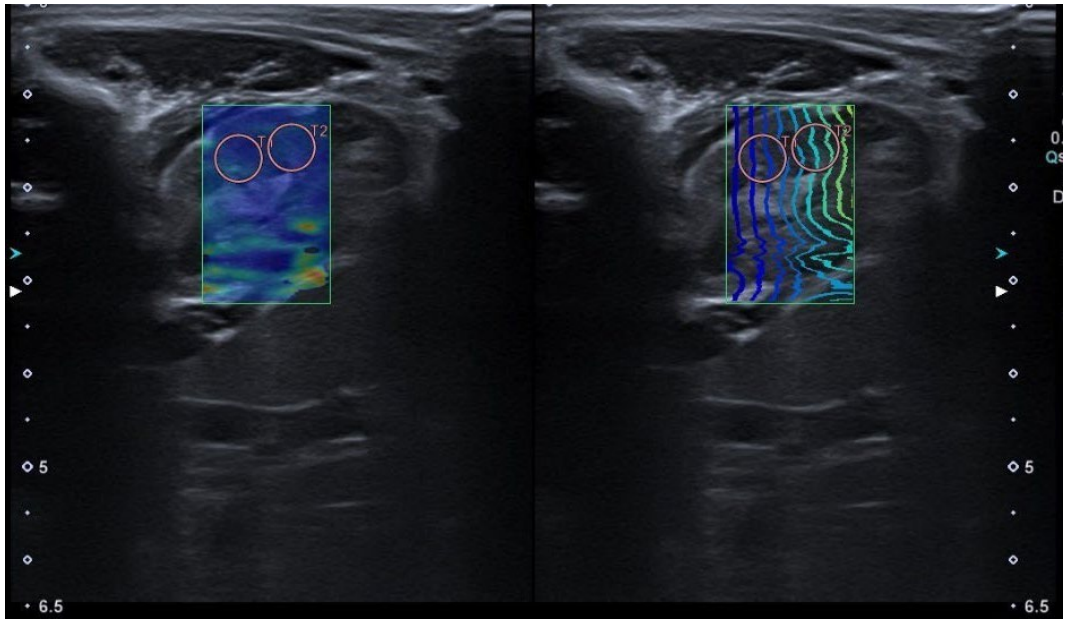

Fig. 4. *An exemplary right kidney elasticity measurement. ROI covering renal parenchyma (cortex and pyramid), excluding calyceal and renal pelvic lumens*

centage ratio of reliable measurements to the total number of measurements performed for individual organs. The splenic-hepatic index was calculated by selecting reliable measurements for the right liver lobe and spleen, obtained simultaneously in the same patient.

2D-SWE findings that met the study criteria were processed using statistical methods. The following descriptive statistics were used: mean, confidence interval (95%), median, minimum, maximum, lower quartile, upper quartile, percentiles, standard deviation and standard error. The Shapiro-Wilk W test and visual inspection of histograms were used to verify the assumption of normality of the distribution of the values of the analyzed variables. Levene's test was used to assess the homogeneity of variance. The Mann-Whitney U test was used to assess intergroup comparisons. The Spearman rank correlation test was used to assess the monotonic relationship between the analyzed variables. The significance level was set at $\alpha = 0.05$ for all analyses. Statistical analysis was performed using Statistica 13.3. (StatSoft).

Results

The hepatic, splenic and renal sizes assessed in the group of 58 newborns were within the accepted norms in conventional US exam.

US assessment of hepatic parenchyma found no pathological lesions in either of the lobes. Splenic US excluded 2 newborns (one due to the presence of a subcapsular cyst, the other one due to crying preventing splenic measurements). Renal US excluded 2 neonates with Tamm-Horsfall phenomenon. Based on classical abdominal US, 58 neonates were qualified for hepatic, 56 for splenic, and 56 for renal 2D-SWE.

Reliable results (Tab. 2) were used to calculate the feasibility of 2D-SWE.

Reliable SWE results for both liver lobes, spleen, both kidneys and the splenic-hepatic index in healthy full-term, spontaneously breathing newborns, obtained with a linear transducer, are presented in Tab. 3 (m/s) and Tab. 4 (kPa).

The mean SWE results of both liver lobes, spleen and kidneys did not depend on gender. The measurement site for the liver (right/left lobe) and kidneys (right/left) did not affect the results (Fig. 5, Fig. 6, Fig. 7, Fig. 8). The correlations between mean SWE results and food intake interval >60 minutes, body weight, and age are presented in Tab. 5, Tab. 6 and Tab. 7, respectively.

Discussion

The reliability of SWE of the liver, spleen and kidneys depends on multiple factors associated with the technique itself, the method used, the number of measurements repeated in a series, the type of the transducer used, the age group of the examined patients, patient cooperation (holding the breath), an appropriately long interval between meals, as well as factors dependent on the operator's experience in working with infants, and there are SWE reliability criteria for children[25]. Elastography measurements are influenced by ascites, significant obesity, increased venous pressure, acutely inflamed liver, consumed meal and the type of transducer used[26]. Greater respiratory mobility, motor restlessness caused by crying or discomfort, difficulty in achieving a several-hour food intake interval, especially in newborns and infants, are factors that reduce measurement accuracy in children under 24 months of age[2]. Also, there are anatomical differences in the organs of neonates and infants that should be taken into account[2]. Some SWE principles and quality criteria used in young children have been adopted from the guidelines for adults[2]. We used a linear transducer, which is recommended for patients under 2 years of age, in our study[27]. The principles of hepatic and splenic SWE in adults and differences in young children and infants are presented in Fig. 9[8,28,29].

Tab. 2. Feasibility results for shear wave elastography of the liver, spleen and kidneys

Organ	Number of examined neonates	Number of reliable results (measurements)	Number of unreliable results (measurements)	Rate of (%) reliable measurements feasibility	Rate of (%) unreliable measurements
Right liver lobe	58	40 (200)	18 (90)	68.97	31.03
Left liver lobe	58	39 (195)	19 (95)	67.24	32.76
Spleen	56	51 (255)	5 (25)	91.07	8.93
Right kidney	56	50 (250)	6 (30)	89.29	10.71
Left kidney	56	48 (240)	8 (40)	85.71	14.29

Tab. 3. Reliable SWE measurements of the liver, spleen, kidneys and splenic-hepatic elastography index (m/s)

	Right liver lobe	Left liver lobe	Spleen	Right kidney	Left kidney	Splenic-hepatic elastography index
Reliable measurements (No.)	40	39	51	50	48	33
Mean	1.43	1.41	2.36	1.92	1.88	1.65
Confidence interval (–95.00%)	1.39	1.37	2.30	1.87	1.83	1.58
Confidence interval (+95.00%)	1.46	1.44	2.42	1.97	1.92	1.72
Median	1.41	1.40	2.33	1.92	1.88	1.61
Minimum	1.19	1.17	2.00	1.52	1.54	1.31
Maximum	1.66	1.64	3.10	2.31	2.20	2.25
Lower quartile	1.36	1.31	2.22	1.79	1.78	1.54
Upper quartile	1.51	1.50	2.48	2.03	2.00	1.74
10th percentile	1.31	1.25	2.13	1.74	1.64	1.42
90th percentile	1.59	1.58	2.58	2.12	2.09	1.90
Standard deviation (SD)	0.11	0.12	0.21	0.18	0.16	0.20
Standard error	0.02	0.02	0.03	0.02	0,02	0.04

Tab. 4. Reliable SWE measurements of the liver, spleen, kidneys and splenic-hepatic elastography index (kPA)

	Right liver lobe	Left liver lobe	Spleen	Right kidney	Left kidney	Splenic-hepatic elastography index
Reliable measurements (No.)	40	39	51	50	48	33
Mean	6.04	5.86	16.99	11.34	10.81	2.82
Confidence interval (–95.00%)	5.73	5.52	16.09	10.75	10.29	2.56
Confidence interval (+95.00%)	6.35	6.19	17.89	11.93	11.33	3.08
Median	5.85	5.70	16.40	11.25	10.75	2.63
Minimum	4.10	3.90	12.10	7.00	7.40	1.75
Maximum	8.10	7.90	29.60	16.20	14.60	5.19
Lower quartile	5.40	5.00	15.00	9.80	9.50	2.44
Upper quartile	6.70	6.70	18.80	12.50	12.15	3.11
10th percentile	5.00	4.60	13.70	9.20	8.20	2.07
90th percentile	7.50	7.40	20.00	13.65	13.40	3.76
Standard deviation (SD)	0.97	1.02	3.21	2.08	1.80	0.73
Standard error	0.15	0.16	0.45	0.29	0.26	0.13

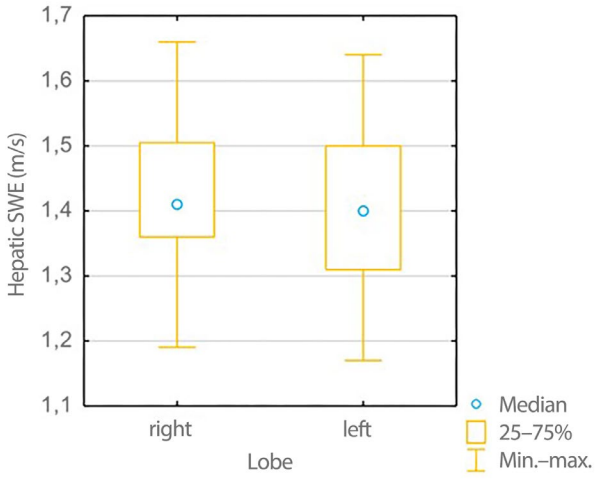

Fig. 5. Liver. Comparison of SWE measurements for the right vs left lobe (m/s), $p = 0.48$

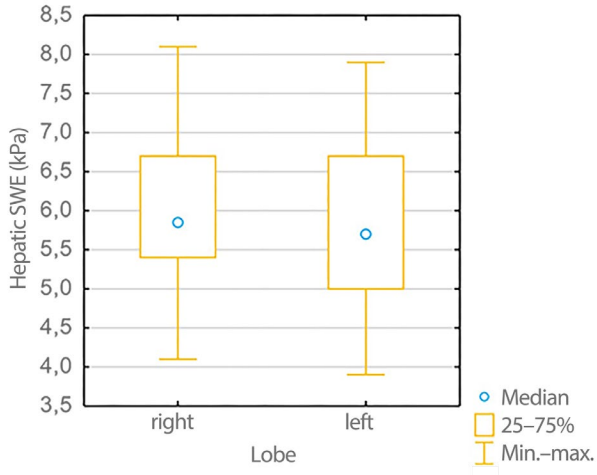

Fig. 6. Liver. Comparison of SWE measurements for the right vs left lobe (kPa), $p = 0.44$

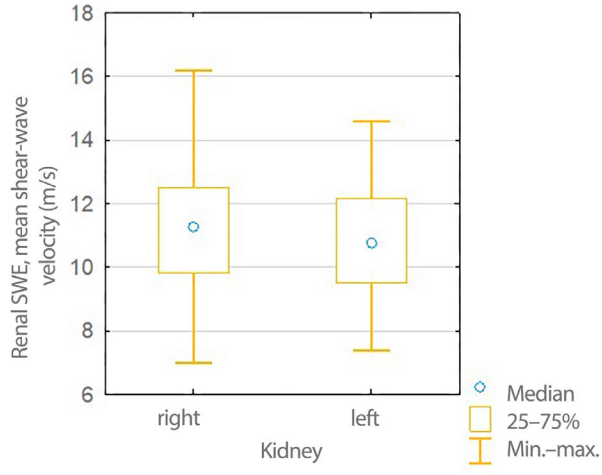

Fig. 7. Comparison of SWE measurements for the right vs left kidney (m/s), $p = 0.22$

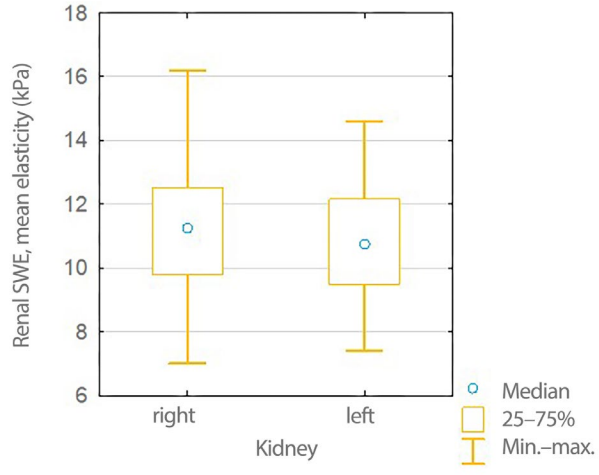

Fig. 8. Comparison of SWE measurements for the right vs left kidney (kPa), $p = 0.26$

Tab. 5. Correlation between the obtained SWE results for the right and left liver lobes and age, body weight and food intake interval

Pair of variables	Significant (No.)	Spearman's Rho	t (N-2)	*p*
Body weight at examination (g) / mean SWE for the right liver lobe (m/s)	40	0.27	1.72	0.09
Body weight at examination (g) / mean SWE for the right liver lobe (kPa)	40	0.27	1.72	0.09
Age (days of life) / mean SWE for the right liver lobe (m/s)	40	0.57	4.27	0.0001
Age (days of life) / mean SWE for the right liver lobe (kPa)	40	0.57	4.23	0.0001
Food intake interval (minutes) / mean SWE for the right liver lobe (m/s)	40	–0.13	–0.81	0.42
Food intake interval (minutes) / mean SWE for the right liver lobe (kPa)	40	–0.13	–0.80	0.43
Body weight at examination (g) / mean SWE for the left liver lobe (m/s)	39	0.61	4.74	0.00003
Body weight at examination (g) / mean SWE for the left liver lobe (kPa)	39	0.62	4.78	0.00003
Age (days of life) / mean SWE for the left liver lobe (m/s)	39	0.68	5.63	0.000002
Age (days of life) / mean SWE for the left liver lobe (kPa)	39	0.68	5.64	0.000002
Food intake interval (minutes) / mean SWE for the left liver lobe (m/s)	39	–0.09	–0.55	0.58
Food intake interval (minutes) / mean SWE for the left liver lobe (kPa)	39	–0.08	–0.49	0.62

SWE – shear wave elastography

Tab. 6. Correlation between the obtained SWE results for the spleen and age, body weight and food intake interval

Pair of variables	Significant (No.)	Spearman's Rho	t (N-2)	*p*
Body weight at examination (g) / mean SWE for spleen (m/s)	51	–0.14	–0.96	0.34
Body weight at examination (g) / mean SWE for spleen (kPa)	51	–0.13	–0.89	0.38
Age (days of life) / mean SWE for spleen (m/s)	51	–0.23	–1.67	0.10
Age (days of life) / mean SWE for spleen (kPa)	51	–0.22	–1.56	0.12
Food intake interval (minutes) / mean SWE for spleen (m/s)	51	–0.01	–0.07	0.94
Food intake interval (minutes) / mean SWE for spleen (kPa)	51	–0.02	–0.12	0.90

SWE – shear wave elastography

Tab. 7. Correlation between the obtained SWE results for the right/left kidney and age, body weight and food intake interval

Pair of variables	Significant (No.)	Spearman's Rho	t (N-2)	*p*
Body weight at examination (g) / mean SWE for right kidney (m/s)	50	0,02	0,12	0,90
Body weight at examination (g) / mean SWE for right kidney (kPa)	50	0,03	0,18	0,86
Age (days of life) / mean SWE for right kidney (m/s)	50	0,09	0,60	0,55
Age (days of life) / mean SWE for right kidney (kPa)	50	0,10	0,67	0,51
Food intake interval (minutes) / mean SWE for right kidney (m/s)	50	0,01	0,06	0,95
Food intake interval (minutes) / mean SWE for right kidney (kPa)	50	0,03	0,20	0,84
Body weight at examination (g)/ mean SWE for left kidney (m/s	48	0,03	0,17	0,86
Body weight at examination (g) / mean SWE for left kidney (kPa)	48	0,04	0,24	0,81
Age (days of life) / mean SWE for left kidney (m/s)	48	0,01	0,08	0,93
Age (days of life) / mean SWE for left kidney (kPa)	48	0,00	–0,01	0,99
Food intake interval (minutes) / mean SWE for left kidney (m/s)	48	–0,10	–0,69	0,49
Food intake interval (minutes) / mean SWE for left kidney (kPa)	48	–0,12	–0,79	0,43

SWE – shear wave elastography

The lack of SWE standards and the limited research in newborns may have an impact on the assessment of the obtained results[9]. The use of a series of 5 measurements to obtain reliable results for the examined organs was in accordance with the recommendations for children under 5 years of age, as it improves the quality of measurements in the opinion of experts[9,29,30]. Results expressed in m/s and kPa can be compared with data published in scientific literature in different centers. A comparison of our findings with those published by other authors is presented in Tab. 8, Tab. 9 and Tab. 10.

Appropriately long feeding interval is one of the most important factors affecting the accuracy and quality of the examination. Some studies in newborns and infants used a 3–4-hour feeding interval (as in adult patients) to maintain the standard of correct hepatic and/or splenic SWE, which is not in accordance with expert opinions[2]. Food intake has been shown to significantly affect the obtained measurements due to increased portal blood flow[39,40]. Kao *et al.*, who assessed the effect of food intake on portal blood flow in newborns, suggested at least 60-minute interval between food intakes[41]. In our study, no effect of feeding break ≥60 minutes on hepatic or splenic SWE measurement was demonstrated. The IQR/M index adopted in the study is consistent with literature data and was the basis for calculating the SWE feasibility index[7–9].

Conclusions

2D-SWE of the liver, spleen and kidneys is a method that can be successfully utilized in healthy, spontaneously breathing newborns. Reliable measurements obtained with this approach can be used in further research to establish reference values in healthy newborns and to develop cut-off points for SWE values for selected hepatic, splenic and renal conditions with a neonatal onset. The adopted minimum feeding break of 60 minutes in newborns is sufficient to obtain reliable SWE measurements. The clinical utility of the obtained hepatic, splenic and renal SWE measurements in healthy newborns and the splenic-hepatic index require further research in specific clinical entities in full-term newborns, infants and premature infants.

Conflict of interest

The authors do not report any financial or personal connections with other persons or organizations which might negatively affect the contents of this publication and/or claim authorship rights to this publication.

General principles for hepatic SWE

- Food intake interval of at least 2–3 hours;
- 10–20-minute rest before the exam;
- Prone position;
- Right arm raised;
- Holding breath for a few seconds in a neutral position;
- The transducer placed perpendicularly to the liver capsule, in the right intercostal space;
- Measurements within the right lobe of the liver;
- Measurement at least 1 cm below the organ capsule.

General principles for splenic SWE

- At lest 3-hour feeding break;
- A 10-minute rest before the exam;
- Prone position;
- Left arm raised;
- Holding breath for a few seconds in a neutral position;
- The transducer placed perpendicular to the splenic capsule, in the left intercostal space;
- Measurement at least 1 cm below the organ capsule.

Differences in SWE protocol for children

- Exam performed between meals in small children and infants;
- Holding breath impossible, spontaneous breathing;
- Comfortable supine position, ensuring child's calmness during the exam;
- Anatomical differences, the liver is located lower in the abdominal cavity in infants and small children;
- The transducer is placed under the costal arch or in the intercostal space;
- The use of a linear transducer in infants.

Fig. 9. Principles for hepatic and splenic SWE, including the differences in the pediatric population

Tab. 8. Comparison of mean hepatic SWE measurements in neonates and infants

Author	Hepatic SWE measurements, mean (±SD)				Method, age group
	Right lobe		Left lobe		
	m/s	kPa	m/s	kPa	
Our research	1.43 (0.11)	6.04 (0.57)	1.41 (0.12)	5.86 (1.02)	2D-SWE, neonates
Palabiyik *et al.*[31]	1.70 (0.24)				2D-SWE, neonates
Franchi-Abella *et al.*[32]		5.65 (1.42)			SSWE, infant subgroup
Fontanilla *et al.*[33]	1.02 (0.13)		1.12 (0.11)		ARFI (pSWE), neonate subgroup
Galina *et al.*[34]		4.63 (0.6)			2D-SWE, neonates, infants and children <2 years
Allison *et al.*[14]		6.23 (1.98)			SSI, Preterm AGA infants without cholestasis
Zhou *et al.*[35]		5.3 (1.0)			SSWE, infants <60 days of life

ARFI – acoustic radiation force impulse; AGA – appropriate for gestational age; 2D-SWE – two dimensional shear wave elastography; pSWE – point shear wave elastography; SD – standard deviation; SSI – supersonic shear imaging; SSWE – supersonic shear wave elastography; SWE – shear wave elastography

Tab. 9. Comparison of splenic SWE measurements

Author	Splenic SWE measurements, mean (±SD)		Method, age group, comments
	m/s	kPa	
Our research	2.36 (0.21)	16.99 (3.21)	2D-SWE, neonates
Palabiyik *et al.*[31]	2.03 (0.27)		2D-SWE, neonates
Lee *et al.*[36]	2.02 (0.037)		ARFI, a subgroup of children <5 years
Pawluś *et al.*[37]		16.6 (2.5)	SSI, adults, convex transducer

ARFI – acoustic radiation force impulse; 2D-SWE – two dimensional shear wave elastography; SD – standard deviation; SSI – supersonic shear imaging; SWE – shear wave elastography

Tab. 10. Comparison of renal SWE measurements

Author	Renal SWE measurements, mean (±SD)				Method, age group, comments
	Right kidney		Left kidney		
	m/s	kPa	m/s	kPa	
Our research	1.92 (0.18)	11.34 (3.21)	1.88 (0.16)	10.81 (1.80)	2D-SWE, neonates
Palabiyik *et al.*[31]	1.69 (0.33)		1.70 (0.31)		2D-SWE, neonates
Sohn *et al.*[20]	1.80 (median)		1.83 (median)		ARFI, children <2 years
Grass *et al.*[38]	1.60 (0.47) 1.97 (0.28)		1.56 (0.48) 1.94 (0.31)		pSWE, VTQ, children pSWE, VTQI, children

ARFI – acoustic radiation force impulse; 2D-SWE – two dimensional shear wave elastography; pSWE – point shear wave elastography; SD – standard deviation; SWE – shear wave elastography; VTIQ – virtual touch imaging quantification; VTQ –virtual touch quantification

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Author contributions

Original concept of study: GP. Writing of manuscript: GP. Analysis and interpretation of data: GP, PZ, ISK. Final acceptation of manuscript: GP, PZ, ISK. Collection, recording and/or compilation of data: GP. Critical review of manuscript: GP, PZ, ISK.

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