



# **Shear Wave Elastography in Assessment of Liver Fibrosis**

Thesis

*Submitted for partial fulfillment of Master Degree in  
in Radiodiagnosis*

By

**Alaa Kanaan Abdulateef**

*M.B.B.Ch., College of medicine/ Baghdad University/ Iraq*

Under supervision of

**Prof. Dr. Sherif Abou Gamrah**

Professor of Diagnostic Radiology  
Faculty of Medicine - Ain Shams University

**Dr.Samar Ramzy Ragheb**

Lecturer of Diagnostic Radiology  
Faculty of Medicine - Ain Shams University

**Dr. Ayman Hassan Hassan Rezk**

Fellow of Diagnostic Radiology  
National Hepatology and tropical medicine research institute

*Faculty of Medicine  
Ain Shams University  
2020*

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

# قالوا

لَسْبَدَانِكَ لَا نَعْلَمُ لَنَا  
إِلَّا مَا عَلَّمْتَنَا إِنَّكَ أَنْتَ  
الْعَلِيمُ الْعَظِيمُ

صدق الله العظيم

سورة البقرة الآية: ٣٢



# Acknowledgeme

*First to all, I would like to thank **ALLAH** the almighty, for having made every thinking possible by giving me strength and courage to do this work .*

*It is a pleasure to me to express my deepest gratitude to **Prof. Dr. Sherif Abou Gamrah** Professor of Radiodiagnosis, Faculty of Medicine, Ain shams University, for his continuous scientific guidance, precious time and efforts.*

*Also, I'm deeply indebted and grateful to **Dr.Samar Ramzy Ragheb**, lecturer of Radiodiagnosis, Faculty of Medicine, Ain shams University, for her kind help, guidance and follow up throughout the whole work.*

*Also, thanks to **Dr. Ayman Hassan Hassan** Rezk Fellow of Radiology at National Hepatology and tropical medicine research institute, for his supervision, guidance and constant encouragement .*

*✍ **Alaa Kanaan Abdulateef***





This work is dedicated to:

My family; my father, my mother,  
my sister and my brother.

My lovely husband and my children  
(Ghaith and Taha).

Thanks to their love,  
encouragement, continuous help and  
support, I was always inspired to  
complete this work.



# List of Contents

Title	Page No.
List of Abbreviations .....	i
List of Tables .....	iv
List of Figures.....	v
Introduction .....	1
Aim of the Work.....	3
<b><u>Review of Literature</u></b>	
<b>Chapter (1):</b> Anatomy of the Liver .....	4
<b>Chapter (2):</b> Normal Ultrasound Appearance of Liver.....	24
<b>Chapter (3):</b> Pathology of Liver Fibrosis.....	34
<b>Chapter (4):</b> Non Invasive Assessment of Liver Fibrosis ..	64
Patients and Methods .....	69
Results .....	76
Illustrative Cases.....	89
Discussion.....	109
Summary.....	121
Conclusion .....	125
References .....	126
Arabic Summary.....	--

## List of Abbreviations

Abbr.	Full term
<b>1D</b>	Mono Dimensions
<b>2D</b>	Two Dimensions
<b>AICD</b>	An Implantable Cardioverter Defibrillator
<b>AILDs</b>	Autoimmune Liver Diseases
<b>ALD</b>	Alcoholic Liver Disease
<b>ALT</b>	Alanine Transaminase
<b>ARFI</b>	Acoustic Radiation Force Impulse
<b>AST</b>	Aspartate Aminotransferase
<b>AUC</b>	Area Under Curve
<b>AUROC</b>	Area under ROC curve
<b>BMI</b>	Body mass index
<b>CBD</b>	Common Bile Duct
<b>CLD</b>	Chronic Liver Disease
<b>EASL</b>	European Association for the Study of the Liver
<b>EGD</b>	Esophago gastro Dudenoscopy
<b>EGVB</b>	Esophageal and Gastric Variceal Bleeding
<b>EV</b>	Esophageal avarices
<b>FLLs</b>	Focal Liver Lesions
<b>FNH</b>	Focal Nodular Hyperplasia
<b>HA</b>	Hepatic Artery
<b>HB</b>	Hemoglobin
<b>HBV</b>	Hepatitis B Virus
<b>HCC</b>	Hepatocellular Carcinoma
<b>HCV</b>	Hepatitis A Virus

---

---

## List of Abbreviations

---

<b>HIV</b>	Human Immunodeficiency Viruses
<b>HPVG</b>	Hepatic Venous Pressure Gradient
<b>HV</b>	Hepatic Vein
<b>HZ</b>	Hertz
<b>INR</b>	International Normalized Ratio
<b>IQR</b>	Interquartile Range
<b>IQR/M</b>	Interquartile Range / median
<b>IVC</b>	Inferior Vena Cava
<b>KPa</b>	Kilopascal
<b>LHA</b>	Left Hepatic Artery
<b>LN</b>	Lymph Node
<b>LS</b>	Liver Stiffness
<b>LSE</b>	Liver Stiffness Evaluation
<b>LSM</b>	Liver Stiffness measurement
<b>LT</b>	Liver Transplantation
<b>MHz</b>	Mega hertz
<b>MRE</b>	Magnetic Resonance Elastography
<b>NAFLD</b>	Nonalcoholic Fatty Liver Disease
<b>NASH</b>	Nonalcoholic Steatohepatitis
<b>NPV</b>	Negative predictive value
<b>PCR</b>	Polymerase Chain Reaction
<b>PH</b>	Portal Hypertension
<b>PPV</b>	Positive predictive value
<b>PV</b>	Portal Vein
<b>RHA</b>	Right Hepatic Artery
<b>RNA</b>	Ribonucleic Acid
<b>ROC</b>	Receiver operator characteristic curve

---

---

## List of Abbreviations

---

<b>ROI</b>	Region Of Interest
<b>RTE</b>	Real-Time Elastography
<b>SCD</b>	Sub Cutaneous Density
<b>SD</b>	Standard deviation.
<b>SFL</b>	Simple Fatty Liver
<b>SMA</b>	Superior Mesenteric Artery
<b>SWE</b>	Shear-Wave Elastography
<b>TE</b>	Transient Elastography
<b>US</b>	Ultrasound
<b>USSS</b>	Ultrasonographic scoring system



## List of Tables

Table No.	Title	Page No.
<b>Table (1):</b>	Remarkable features on Diaphragmatic and visceral surfaces of the liver.....	7
<b>Table (2):</b>	Factors contributing to fibrosis progression in chronic hepatitis C.....	37
<b>Table (3):</b>	Metavir scoring system show liver fibrosis stages and Activity grades.....	38
<b>Table (4):</b>	Findings for the ultrasound features of the edge, surface and parenchymal texture of the liver.....	41
<b>Table (5):</b>	Child-Pugh classification.....	45
<b>Table (6):</b>	Salient features of technical aspects of liver elastography modalities.....	49
<b>Table (7):</b>	Clinical indications for TE.....	56
<b>Table (8):</b>	Conditions that affect accuracy of TE.....	57
<b>Table (9):</b>	Precautions and techniques of 2D-SWE.....	60
<b>Table (10):</b>	Demographic data of the studied patients.....	76
<b>Table (11):</b>	Laboratory investigation of the studied patients.....	78
<b>Table (12):</b>	US finding of the studied patients:.....	79
<b>Table (13):</b>	Liver US among the studied patients:.....	80
<b>Table (14):</b>	Liver fibrosis stage number and percentage by TE (Fibroscan) and SWE among the studied group. ....	82
<b>Table (15):</b>	Correlation and agreement between SWE and TE for grading of hepatic fibrosis in studied group shows highly significant with P-value $p < 0.001$ . ....	85
<b>Table (16):</b>	Correlation between TE and SWE among all the studied patients.....	86
<b>Table (17):</b>	Diagnostic accuracy of SWE in detection of TE results. ....	87
<b>Table (18):</b>	Receiver-operating characteristic (ROC) analysis for discrimination between F0-F1 and F2-F4 CHC patients using liver stiffness measured with SWE. ....	88
<b>Table (19):</b>	Relation of SWE with demographic data and anthropometric measures of the studied patients. ....	88

# List of Figures

Figure No.	Title	Page No.
<b>Figure (1):</b>	Liver and gallbladder, anterior view .....	4
<b>Figure (2):</b>	Diaphragmatic surface of liver .....	6
<b>Figure (3):</b>	Visceral surface of liver.....	7
<b>Figure (4):</b>	Left, Right, Caudate and Quadrate lobe of the liver .....	9
<b>Figure (5):</b>	The content of porta hepatis .....	11
<b>Figure (6):</b>	Segmental anatomy according to couinaud classification .....	12
<b>Figure (7):</b>	Clockwise numbering of liver segments.....	13
<b>Figure (8):</b>	Transverse image through the superior liver segments, that are divided by the right and middle hepatic veins and the falciform ligament .....	14
<b>Figure (9):</b>	At this level the left portal vein divides the left lobe into the superior segments (II and IVa) and the inferior segments (III and IVb).....	14
<b>Figure (10):</b>	At this level the right portal vein divides the right lobe of the liver into superior segments (VII and VIII) and the inferior segments (V and VI).....	15
<b>Figure (11):</b>	At the level of the splenic vein, which is below the level of the right portal vein, only the inferior segments are visible ....	15
<b>Figure (12):</b>	Normal portal venous circulation .....	18
<b>Figure (13):</b>	Common bile duct .....	20
<b>Figure (14):</b>	Liver ultrasound using convex probe on which the shearwave is implemented.....	25
<b>Figure (15):</b>	Normal appearance of the liver at US.....	27
<b>Figure (16):</b>	Transverse view of liver showing ligamentum venosum anterior to caudate lobe.....	28
<b>Figure (17):</b>	Main portal vein enters liver at hilum.....	29
<b>Figure (18):</b>	Three main Hepatic veins, left, middle and right can be traced into the IVC .....	30
<b>Figure (19):</b>	Normal waveform obtained from portal vein .....	32

---

## List of Figures

---

<b>Figure (20):</b> Hepatic a. flow demonstrates a low-resistance waveform.....	32
<b>Figure (21):</b> Normal sonographic appearance of common bile duct .....	33
<b>Figure (22):</b> Diagram of the comparison of the various staging systems for liver fibrosis .....	39
<b>Figure (23):</b> The ultrasound features of the liver edge .....	42
<b>Figure (24):</b> The ultrasound features of the liver surface.....	42
<b>Figure (25):</b> The ultrasound features of the liver parenchymal texture .....	43
<b>Figure (26):</b> Deformation of a soft solid under an external stress .....	48
<b>Figure (27):</b> Transient Elastography ( <b>Fibroscan</b> ) .....	50
<b>Figure (28):</b> Examples of liver stiffness measurements.....	52
<b>Figure (29):</b> An example of the TE technique .....	54
<b>Figure (30):</b> Liver stifness cut-offs in chronic liver diseases .....	55
<b>Figure (31):</b> Shear Wave elastography .....	59
<b>Figure (32):</b> Normal value of liver stiffness show by Philips share wave Elastography correlated with metavir score.....	62
<b>Figure (33):</b> Shear wave elastography could be displayed in color maps, developing real-time color-coded elasticity imaging .....	63
<b>Figure (34):</b> Shear-Wave elastography machine.....	71
<b>Figure (35):</b> Convex Prob (C5-1) which is the same prob used in abdominal U/S also used for SWE .....	72
<b>Figure (36):</b> Average stiffness by shearwave elastography. ....	74
<b>Figure (37):</b> Sex distribution among the studied cases were 13 males (43.3%) and were 17 females (56.7%). ....	77
<b>Figure (38):</b> Spleen size among the studied patients. ....	79
<b>Figure (39):</b> Ascites among the studied patients.....	80
<b>Figure (40):</b> Liver surface among the studied patients. ....	81
<b>Figure (41):</b> Liver texture among the studied patients.....	81
<b>Figure (42):</b> Grading of hepatic fibrosis using TE among the studied group.....	83
<b>Figure (43):</b> Percentage of non-significant liver fibrosis (F0-F1) and significant liver fibrosis (F2-F4) among studied group by TE. ....	83

---

## List of Figures

---

<b>Figure (44):</b> Grading and percentage of hepatic fibrosis stages using SWE among the studied group. ....	84
<b>Figure (45):</b> Percentage of non-significant liver fibrosis (F0-F1) and significant liver fibrosis (F2-F4) among studied group by SWE.....	84
<b>Figure (46):</b> The percentage of hepatic fibrosis grades in studied patients by SWE in comparative to TE.....	85
<b>Figure (47):</b> Correlation between TE and SWE among all the studied patients.....	86
<b>Figure (48):</b> Diagnostic accuracy of SWE in detection of TE results.....	87

## ABSTRACT

**Background:** Liver fibrosis is major medical issues in patients with chronic hepatitis C (CHC). It may lead to cirrhosis, hepatocellular carcinoma (HCC) and liver-related death. Therefore, assessing the degree of fibrosis in patients with chronic liver diseases, especially before the advanced stage, is clinically important to allow early care and prevent fatal liver disease.

**Objective:** The plan was to do shear-wave Elastography after fibroscan (TE) in order to assess the stiffness of the liver, detect the changes occurred in hepatitis C patients and measure diagnostic accuracy of 2D-SWE by using TE as reference standard.

**Methods:** A cross-section study included 30 persons with positive hepatitis C. They were referred to Radiology department at National Hepatology and tropical medicine research institute.

**Results:** Our study included (30) patients who have hepatitis C positive, their ages ranged from (18) years old to (60) years old with mean  $\pm$  SD of  $52.97 \pm 9.43$ . They were 17 females (56.7%) and 13 males (43.3%). Different liver fibrosis stages were observed by 2D-SWE as following: (F0) 4 patients (13.3%), (F1) 4 patients (13.3%), (F2) 9 patients (30.0%), (F3) 10 patients (33.3%), (F4) 3 patients (10.0%). While TE (fibroscan) shows (F0) 6 (20.0%), (F1) 3 patients (10.0%), (F2) 7 patients (23.3%), (F3) 8 patients (26.7%) (F4) 6 patients (20.0%). Our study showed that the relation between TE (fibroscan) and SWE finding had positive correlation of most patients with liver fibrosis with (p-value = 0.006 and r-value 0.487). Because the important of significant fibrosis for initiate antiviral protocol therapy, 30 patients classified into F0–F1 (non-significant liver fibrosis) versus F2–F4 (significant liver fibrosis). Our study show significant discrimination was found between no/mild fibrosis (F0-F1) and significant fibrosis (F2-F4), shows the sensitivity of SWE in detection of significant fibrosis results is 95.2% and the specificity is 77.8%, PPV 90.91%, NPV 87.5% and the accuracy 90.0% with cutoff value  $>5.7\text{kPa}$ .

**Conclusion:** SD-SWE is accurate in prediction significant fibrosis ( $\geq\text{F2}$ ), Thus is expected to overcome the limitation of TE as a reliable method to assess fibrosis induce by hepatitis.

**Keywords:** *Shear wave elastography, Liver fibrosis, Chronic Hepatitis C, Fibroscan (TE).*

## INTRODUCTION

**C**hronic liver disease is a substantial worldwide problem. Its major consequence is increasing deposition of fibrous tissue within the liver, leading to the development of cirrhosis with its consequences, portal hypertension, hepatic insufficiency, and hepatocellular carcinoma (HCC). As fibrosis progresses, there is increasing portal hypertension, loss of liver function, and higher risk of HCC (*Regev et al., 2002*).

The stage of liver fibrosis is important to determine prognosis and surveillance and to prioritize for treatment and potential for reversibility (*Marcellin et al., 2013*). The process of fibrosis is dynamic, and studies have shown that a regression of fibrosis is possible with treatment of the underlying condition (eg, antiviral therapy in viral hepatitis and immunosuppression in autoimmune hepatitis) (*Martinez et al., 2012*).

Previously, the only method of staging the degree of fibrosis was liver biopsy. Liver biopsy is considered the reference standard for fibrosis assessment and stage classification and also allows grading of steatosis, necrosis, and inflammatory activity (*Seeff et al., 2010*). However, biopsy is invasive, with potential complications that can be severe in up to 1% of cases (*Stotland and Lichtenstein, 1996*).

Further, tissue obtained via biopsy represents roughly only 1/50 000 of the liver volume, which may result in sampling error and is associated with considerable interobserver variability at microscopic evaluation. Therefore, noninvasive methods for liver fibrosis assessment have been an intense field of research, including elastographic methods (*Goodman, 2007*).

Elastography is a technique which has the ability to estimate hepatic fibrosis based on the assessment of tissue stiffness. Among the available armamentarium, transient elastography (TE), was the earliest and most extensively used (*Ferraioli et al., 2015*).

TE is difficult to perform in patients with obesity, ascites, shrunken liver, or those with narrow intercostal spaces (*Tatsumi et al., 2007*).

Further technological advances led to the emergence of a novel technique of Shear wave elastography (SWE) (*Friedrich-Rust et al., 2007*). This uses information of acoustically generated shear wave propagation speed through the liver to provide qualitative (stiffness-based color-coded maps) and quantitative assessment (average value in the region of interest in terms of the Young modulus, kilopascals) of liver fibrosis (*Li et al., 2016*).