

**Sudan University of Science and Technology**  
**College of Graduate Studies**

**Characterization of Benign and Malignant Liver  
lesions using Ultrasonography, and Texture Analysis**

توصيف اورام الكبد الحميده والخبيثه باستخدام الموجات فوق الصوتيه  
والتحليل النسيجي

**A thesis Submitted for Fulfillment of PhD Degree in  
Medical Diagnostic Ultrasound**

**By:**

**Abdelrafia Ballah Mohamed Saad**

**Supervisor:**

**Prof.Mohammed Elfadil**

**Co-Supervisor:**

**Dr. Asmaa Ibrahim Ahmed**

**2019**

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

① اللَّهُ لَا إِلَهَ إِلَّا هُوَ

الْحَيُّ الْقَيُّومُ لَا تَأْخُذُهُ سِنَّةٌ وَلَا نَوْمٌ لَهُ مَا فِي السَّمَوَاتِ

وَمَا فِي الْأَرْضِ مَنْ ذَا الَّذِي يَشْفَعُ عِنْدَهُ إِلَّا بِإِذْنِهِ يَعْلَمُ

مَا بَيْنَ أَيْدِيهِمْ وَمَا خَلْفَهُمْ وَلَا يُحِيطُونَ بِشَيْءٍ مِنْ عِلْمِهِ إِلَّا

بِمَا شَاءَ وَسِعَ كُرْسِيُّهُ السَّمَوَاتِ وَالْأَرْضَ وَلَا يَئُودُهُ حِفْظُهُمَا

وَهُوَ الْعَلِيُّ الْعَظِيمُ ②

# Dedication

Praise and love be to my family,

To Soul of my father

My respective mother

To my wife who have been my constant source of inspiration.

Lovely sisters and brother

My daughter

And to everyone who contribute to this work

## **Acknowledgement**

I would like to thank Prof. Mohammed Elfadil Mohammed, my Supervisor for his kind advice, true guidance, great help and valuable critics: I'm very grateful to Dr, Asma Ibrahim, my co- supervisor for her full advice, encouragement and great help.

I would like also to thank Dr. Ahmed Mustafa Abu Kuna, Dean of college of Medical Radiological Sciences for his help and good advice.

I would sincerely like to thank my both special friends ustaz, Abd Elrahman Hassan and Dr Babiker for their close support and thanks are also extended to Dr Osman Abdalwahab, Dr khawad and Dr Elsir Ali Saied for their help and support.

## المستخلص

هذه دراسته وصفية تحليلية لتوصيف آفات الكبد الحميدة والخبيثة باستخدام الموجات فوق الصوتية والتحليل النسيجي تهدف إلى توصيف آفات الكبد مثل الكيسات الكبدية المنقلة والانتشار والتمييز بينهما جنباً إلى جنب مع الكبد الطبيعي في الصور بالموجات فوق الصوتية عن طريق تحليل الملمس وطرق التصنيف باستخدام برنامج معالجة الصور ونظام لغة البيانات التفاعلية عن طريق إنشاء صور في شكل منسق لاستخدامها كمتغيرات لغة البيانات التفاعلية التي لها ثلاث ميزات من النظام البقائي من الدرجة الأولى والتي كانت تعني الانتروبيا والطاقة المتنازعة من دالة الكثافة من الصور وتم حساب جميع الصور باستخدام حجم نافذة  $3 \times 3$  والبيانات التي تم إعدادها من تحليل التمييز الخطي الحكيم والتحليل التمييزي الخطي. أجريت الدراسة خلال الفترة من 2016 إلى 2019 في مستشفى ابن سينا التعليمي وعيادة الدكتور عثمان عبد اشتملت الدراسة 260 مريضاً منهم 156 من الذكور و 104 الإناث الذين تتراوح الوهاب الخاصة أعمارهم بين 4 إلى 90 سنة ذوي حالات معروفة من آفات الكبد تم فحصهم بالموجات فوق الصوتية باستخدام نظام التشخيص بالموجات فوق الصوتية مع التحقيق منحنى خطي 3.5 ميغاهرتز. أظهرت النتائج أن أكثر آفات الكبد شيوعاً التي تم تشخيصها بواسطة الموجات فوق الصوتية كانت 112 (43%) من الحالات حيث أن النقايل تليها 49 (18.58%) من الحالات كسرطان كبدى 43 (16.5%) كورم دموي بينما الآخرون 22 (8.5%) ، 16 (6.2%) ، 12 (4.6%) ، 3 (1.2%) ، 2 (0.8%) و 1 (0.4%) من الحالات كأكياس. الخراجات. الخراجات المائية. سرطان الغدد الليمفاوية. الورم الحميد. وسرطان الاوعيه الصفراويه داخل الكبد علي التوالي . ظهرت معظم آفات الكبد ناقصة الصدى في الأنبيثات من قبل فرط الصدى في الورم الوعائي الدموي ، ونمط الصدى المتغاير في سرطان الخلية. لتحليل النسيج ، أسفرت الدراسة عن وجود تركيز جيد للميزات حول مركز الفصول الذي أعطى اختلافاً ملحوظاً بين الفصول مع دقة تصنيف كل فئة حيث تم تعديل 92.2% من الكبد الطبيعي بشكل صحيح و 75.6% و 81.4% و 100.0% و 100.0% من حساسية التصنيف لكيس الكبد وسرطان الكبدى والكيس المائي ونقايل الكبد على التوالي مع أعلى تصنيف عام للتنبؤ دقة 89.1%. وخلصت الدراسة إلى أن الموجات فوق الصوتية تعتبر الطريقة المثلي في تشخيص آفات الكبد. ثم أن نظام التشخيص بمساعدة الكمبيوتر زاد من دقة تصنيف آفات الكبد. ويستخدم التحليل الملمس كطريقة ثانية لأداء المزيد من خصائص الآفة. أوصت الدراسة أنه إذا كان هناك دلالة على اضطرابات في الكبد عن طريق الفحص بالموجات فوق الصوتية المريض وعند وضع الصورة علي برنامج

التحليل النسيجي بالاضافه الي التشخيص بالموجات فوق الصوتيه يؤديان الي درجه عاليه من الدقه في التشخيص .

## Abstract

This is a descriptive analytic study of characterization of benign and malignant liver lesion using ultrasonography and texture analysis, aimed to characterize liver lesions such as cysts, hydated cyst, hepatocellular carcinoma, and metastases using ultrasonography and to differentiate between them along with normal liver in ultrasound images by texture analysis and classification methods, using image processing program,( interactive data language IDL), by created an images in a tiff format in order to used as IDL variables. Three features from FOS which were mean, entropy and energy computed from the intensity function of the image and were calculated for each region of interest through all images using 3x3 window size and data prepared for SW-LD analysis, and linear discriminate analysis.

The study carried out during the period from 2016 to 2019 in (Ibn Siena Teaching Hospital and DR Osman Abdalwahab private clinic) in Khartoum, Sudan.

A total of 260 patients, 156 were male and 104 were females, whom aged between 4 to 90 years old known case of liver lesions were performed . All patients examined by ultrasound scanning using ultrasound machine Xario Diagnostic system with 3.5 MHz curve-linear probe. The result showed that the most common liver lesions diagnosed by ultrasound were 112(43%)cases as metastases ,followed by 49(18.85%)cases as HCC , 43(16.5%)cases as haemangioma. while the others were, 22(8.5%), 16 (6.2%) , 12(4.6%),3(1.2%),2(0.8%) and 1(0.4%)of cases as cyst, abscesses, hydated cyst, lymphoma, adenoma, and intrahepatic cholangiocarcinoma respectively. The majority of liver lesions were appear hypo echoic in metastases followed by hyper echoic in haemangioma, and heterogeneous echo pattern in hepatocellular carcinoma.

For texture analysis, the study showed resulted there was a well concentration of features around the classes centre which gave a remarkable difference among the

classes with classification accuracy of each classes in which 92.2% of normal liver was correctly classified and 75.6%, 81.4%, 100.0% and 100.0%, of classification sensitivity for liver cyst, HCC, Hydated Cyst, and Liver metastases respectively with highest predictive overall classification accuracy of 89.1%.

the study recommended that if there is indication of liver disorder by ultrasound screening ,the patents image must be analyzed by IDL program ,then the histopathology will be done only for confirmation , if it is not available, no need for it. Because the prediction of ultrasound and texture analysis tools together is very high

The study concluded that the ultrasound is considered as first line of liver lesions diagnosis.

In addition, the study concluded that the computer aided diagnostic system increased the accuracy of liver lesions classification. Texture analysis serves as second methods to perform more characterization of the lesion.



## List of content

<b>content</b>		<b>page</b>
Dedication		I
Acknowledgment		II
Arabic Abstract		V
English Abstract		VI-VIII
List of content		IX
List of tables		XIV
List of figures		XV
List of Abbreviations		XVII
<b>Chapter one</b>		
1-1	Introduction	1
1-2	Problem of the study	2
1-3	Objective	3
1-3-1	General objectives	3
1-3-2	Specific objectives	3
1-4	Significant of the study	4
1-5	Over view of the study	4
Chapter tow		
Theoretical background		
2-1	Anatomy	5
2-1-1	Surfaces of the liver	6
2-1-1-1	Superior surface	6
2-1-1-2	Anterior surface	7
2-1-1-3	Right surface	7
2-1-1-4	Posterior surface	7

2-1-1-5	Inferior surface	7
2-1-2	Gross anatomical lobe	8
2-1-2-1	Right lobe	8
2-1-2-2	Left lobe	8
2-1-2-3	Quadrangle lobe	8
2-1-2-4	Caudate lobe	9
2-1-3	Functional anatomy	9
2-1-4	Sectors and segments of the liver	10
2.1.4.1	Segment I	10
2.1.4.2	Segment II	10
2.1.4.3	Segment III	11
2.1.4.4	Segment IV	11
2.1.4.5	Segment V	11
2.1.4.6	Segment VI	11
2.1.4.7	Segment VII	12
2.1.4.8	Segment VIII	12
2.1.4.9	Segment IX	12
2-1-5	Fissures of the liver	13
2-1-5-1	Main portal fissure	13
2-1-5-2	Left portal fissure	13
2-1-5-3	Right portal fissure	13
2-1-5-4	Umbilical fissure	14
2-1-4-5	Venous fissure	14
2-1-5-6	Fissure of Gans	14
2-1-6 A	Vascular supply and lymphatic drainage	14
2-1-6-1	Hepatic artery	14

2-1-6-2	Veins	15
2-1-6-2-1	Portal vein	15
2-1-6-2-2	Hepatic veins:	15
2-1-6-3	Lymphatic's	16
2-2	Physiology	16
2-2-1	Carbohydrate metabolism	18
2-2-2	Amino acid metabolism	18
2-2-3	Lipid metabolism	19
2-2-4	Synthesis of plasma proteins	19
2-2-5	Formation of bilirubin	19
2-2-6	Phago cytosis by Kupffer cells	19
2-2-7	Storage	20
2-2-8	Detoxification	20
2-3	Over view of texture analysis methods	20
2-3-1	Gray level histogram	22
2-3-2	Co – Occurrence Matrices	23
2-3-3	Run Length Matrix	23
2-3-4	Gray Level Difference Matrix	24
2-3-5	Gradient Matrices	24
2-3-6	Texture Feature Coding Method	25
2-3-7	Autocorrelation Coefficients	25
2-3-8	Fractal Model (FM)	26
2-3-9	Discrete Wavelet Transform	26
2-3-10	Laws' Texture Energy measures	27
2-4	Liver lesions	28
2-4-1	Cystic liver lesions	28

2-4-1-1	Simple cysts	28
2-4-1-1-1	Simple hepatic cyst	28
2-4-1-1-2	Multiple Biliary hamartomas	29
2-4-1-1-3	Caroli disease	29
2-4-1-1-4	Adult polycystic liver disease (PCLD):	30
2-4-1-2	Infectious inflammatory conditions	30
2-4-1-2 -1	Hepatic abscesses	30
2-4-1-2 -2	Hepatic hydated cyst	31
2-4-1-3	Neoplastic cystic tumors	32
2-4-1-3-1	Biliary cyst adenoma	32
2-4-1-3-2	Biliary cyst adenocarcinomas	33
2-4-1-3 -3	Cystic hepatic metastases	33
2-4-2	Hyper vascular liver legions	34
2-4-3	Liver tumors	34
2-4-3-1	Secondary malignant liver lesions	34
2-4-3-1-1	Metastases (Mets)	34
2-4-3-2	Primary malignant tumors	35
2-4-3-2 -1	Hepatocellular carcinoma ( HCC)	35
2-4-3-2 -2	Cholangiocarcinoma	36
2-4-3-2-3	Primary lymphoma	36
2-4-3-2-4	Hepatoblastoma	36
2-4-3--3	Primary benign liver tumors	37
2-4-3-3-1	Haemangioma:	37
2-4-3-3-2	Hepatic adenoma	37
2-4-3-3-3	Focal nodular hyper plasia	38
2-5	Ultrasound Examination technique	39

2-5-1	Patient Preparation	39
2-5-2	Son graphic technique	39
2-6	previous studies	40-58
<b>Chapter three</b>		
<b>Methodology</b>		
3-1	MATERIAL	59
3-2	Design of the study	59
3-3	Population of the study	59
3-4	Sample size and type	59
3-5	Place and duration of the study	59
3-6	Variable of the study	59
3-7	Technique: (Imaging protocols)	59
3.8	Methods of data collection	60
3-9	Method of data analysis	60
3-10	Ethical approval	61
<b>Chapter four</b>		
	<b>Result</b>	62-88
<b>Chapter five</b>		
5-1	Discussion	89-96
5-2	Conclusion	97
5-3	Recommendations:	99
	Reference	100
	Appendices	109- 117

## List of tables

Table no	Subject	pagea
4-1	Sex distribution of liver lesion	49
4- 2	Age distribution of liver lesions	50
4- 3	Distribution of lesion diagnosed by ultrasound	51
4- 4	Relationship between Gender and Lesion type	51
4- 5	Lobar involvement of liver lesions	53
4- 6	Distribution of cases based on lesion size	53
4- 7	Relationship between gender and lesion size	53
4- 8	Relationship between lesion type and lesion size	54
4-9	Distribution of cases based on number of lesions	55
4- 10	Relationship between gender anl lesion size	55
4- 11	Relation ship between lesiontype and numbe	56
4-12	Chi-Square Tests	56
4-13	Distribution of cases based on shape of lesions	57
4- 14	Distribution of cases based on shape of lesions	58
4-14	Distribution of cases based on shape of lesions	59
4- 15	Distribution of cases based on shape of lesions	60
4- 15	Distribution of cases based on shape of lesions	60
4-16	Relationship between the gender and echogenicity	61
4-17	Distribution of cases based on echgenicity of lesions	62
4-18	Relationship between the lesion type and echogenicity	63
4- 19	Relationship between the lesions type and its echogenicity	64

4- 20	Distribution of cases based on vascularity of lesions	65
4- 21	Relationship between Lesion type and vascularity	66
4- 22	Distribution of lesions based on liver size table	67
4- 23	Relationship between gender and liver size	67
4-24	Relation between lesion type and liver size	68
4- 25	Relationship between gender and liver texture	69
4- 26	Relationship between lesion type and liver texture	71
4-27	Relationship between gender and Rt lobe angle	72
14- 28	Relationship between lesion type and Rt lobe angle	73
4-29	Relation between lesion site and Rt lobe angle	75
4- 30	Relationship between gender and Lt lobe angle	77
4- 31	Relationship between lesion type and Lt lobe angle	78
4-33	Relationship between lesion site and Lt lobe angle	79
4-34	Classification matrix of the original group and the predicted group using	81

## List of figures

Figure no	subject	Page no
2-1	The bed of the liver	5
2-2	Relations of the liver	5
2-3	Segments of the liver	7
2.4	The fissures and sectors of the liver	10
2-5	The main portal vein and its intra hepatic branches	13
4- 1	Gender distribution of liver lesion	49
4- 2	Relationship between Gender and Lesion type	52
4- 3	Distribution of cases based on shape of lesions	61
4-4	Distribution of cases based on echogenicity of lesions	62
4-5	Distribution of cases based on echogenicity of lesions	65
4-6	Relationship between gender and liver size	67
4- 7	Relationship between gender and liver size	69
4- 8	Relationship between gender and liver texture	70
4-9	Relationship between gender and Rt lobe angle	72
4-10	Relationship between lesion type and Rt lobe angle	74
4-11	Relation between lesion site and Rt lobe angle	76
4- 12	Relationship between gender and Lt lobe angle	77



4-13	Relationship between lesion type and Lt lobe angle	79
4-14	Relationship between lesion site and Lt lobe angle	80
4-15	Scatter plot of the classes using discriminant function	81
4-16	An error bar of 5 classes using the mean feature with the standard error	82
4-17	An error bar of 5 classes using the energy feature with the standard error	82
4-18	An error bar of 5 classes using the entropy feature	83

## List of abbreviations

FLL	Focal liver lesion
CRLM	Colorectal liver metastases
HCC	Hepatocellular carcinoma
US	Ultrasound
MET	Metastases
CAD	Computer-aided diagnostic
FNH	Focal nodular hyperplasia
RBCs	Red blood cells
TA	Texture analysis
ROI	Region of interest
GLH	Gray level histogram
COM	Co-Occurrence Matrices
RLM	Run length matrix
GLDM	Gray level Difference Matrices
GM	Gradient matrix
TFCM	Texture Feature Coding Method
TFN	Texture Feature Number
AC	Autocorrelation Coefficients

FM	Fractal Model
DWT	Discrete Wavelet Transform
LTE	Laws' Texture Energy
CT	Computerize Tomography
MRI	Magnetic Resonance Image
PCLD	Adult polycystic liver disease
ADPCKD	Autosomal dominant polycystic kidney disease
MBH	Multiple biliary hamartomas
HIV	Human immunodeficiency virus
AIDS	Acquired immune deficiency syndrome
HAE	Hepatic alveolar Echonococcus
PHL	Primary hepatic lymphoma
GI	Gastro Intestinal
TAUS	Trans abdominal ultrasound scanning
MHz	Megahertz
SVM	Support vector machine
CFS	Correlation-based feature selection
GLCM	Gray Level Co- occurrence Matrix
MATLAB	Matrix laboratory

GVF	Gradient vector flow
FNAC	Fine needle aspiration cytology
IROIs	Inside region of interest
SROIs	Surrounding region of interest
PCA	Principal component analysis
NN	Neural network
NNE	Neural network ensemble
B-Mode	Brightness
0AA	One against all
FOS	First order statistic
FPS	Fourier power spectrum
CAIA	Computer aided image analysis
HAEM	Haemangioma
SPSS	Statistical Package for Social Science
USSG	Ultrasound guided
FNAC	Fine needle aspiration cytology
(IDL	Interactive Data Language
0AA	One against all
DICOM	Digital Imaging and Communications in Medical