Volume-4, Issue-6, June-2015 • ISSN No 2277 - 8160

Research Paper | Technology

Estimation of Range of Hounsfield Unit on CT for Different Grades of Fatty Infiltration of Liver Categorized Using Ultrasound

Jumana Rahman	MSc Medical Imaging Technology, School of Allied Health Sciences, Manipal University, Manipal, Karnataka, India.
Sushil Yadav	Senior Scale Assistant Professor, Department of Medical Imaging Technology, School of Allied Health Sciences, Manipal University, Manipal, Karnataka, India.
Dr Prakashini K	Professor, Department of Radiodiagnosis and Imaging, Kasturba Medical College, Manipal University, Manipal, Karnataka, India.
***Rahul P. Kotian**	Senior Scale Assistant Professor, Department of Medical Imaging Technology School of Allied Health Sciences, Manipal University, Manipal Karnataka, India .*Corresponding Author

ABSTRACT

Introduction

Fatty liver disease describes the discrete accumulation of triglycerides within cytoplasmic vesicles of hepatocytes. Ultrasound is the first-line imaging technique for the diagnosing and grading of patients with fatty liver. The CT method employed realizes that the lower the mean liver attenuation or CT number in Hounsfield units (HU), the lower the tissue density and hence the greater the fat content. Therefore, liver density (attenuation in HUs) is inversely related to liver fat. . On unenhanced computed tomography (CT), liver density less than 40 Hounsfield units (HU) or a density difference of more than 10 HU between spleen and liver indicates fatty liver. To help prevent diagnostic errors and guide appropriate work-up and management, radiologists should be aware of the different patterns of fat accumulation in the liver, especially as they are depicted at ultrasonography or computed tomography.

Aim

Estimation of range of Hounsfield unit on CT for different grades of fatty infiltration of liver categorized on Ultrasound

Objective

To find out the relation between Hounsfield unit and fatty changes of the liver.

Materials and methods

The patients who were found to have fatty liver by ultrasound examination were included in this cross sectional study. From these, 30 patients were selected for each grading and the ultrasound results were compared with the HU measurements observed from CT. Kruskalwallis test was used to analyse the data, and the p value < 0.001 indicates statistically significant HU between grades of fatty liver .The HU of spleen and liver were also compared and it was found that there was a significant HU difference between them.

Results:

The mean age of the patients who had fatty liver was found to be 45. the median value of grade 1 was 37.48 HU and 25% of observations have value less than 36.22 HU(quartile 1) ,75 % of observations have value less than 38.98 HU. Grade 2 patients median value was 24.48 HU (quartile 3); after the statistical analysis it was found that the observation values of quartile 1 and quartile 3 lies between 22.68 HU and 26.68 HU. In grade 3 patients 5.15 HU was the median value and first quartile value was -5.155 HU and quartile 3 was 7.94 HU. After measuring the difference between HU of spleen and liver in grade one the median value was 12.6 HU; 25% of observation have value less than 7.79 HU and 75% of observation have value less than 15.26 HU. In grade 2 patients there was more difference of liver and spleen HU and the study stated that 22.54 HU was the median value ; quartile 1 and quartile 3 lies between 21.26 HU and 27.04 Honsfield unit. In grade 3 patients there was higher difference of liver and spleen HU and the median value was -40.83 HU, first quartile value was 38.24 HU and quartile 3 was 50.96 HU. The ROC analysis showed 25 was the cut off value with 0.97 sensitivity and 0.87 specificity. So with the above value of 25 HU , the vessel visualization is not possible.

Conclusion

Ultrasound was the first imaging technique for hepatic steatosis. However till date only maximum HU value was given to say the presence or absence of fatty liver. This is the first study to categorize the grades of fatty liver on CT in correlation with ultrasound. We conclude with the range of HU value in each grade of fatty liver.

KEYWORDS : Hounsfield unit, fatty infiltration of liver, ultrasound

INTRODUCTION

Fatty liver is the accumulation of lipid within hepatocytes. It is the commonest cause of elevated liver enzymes. Some patients will have excess alcohol intake as the underlying cause but there are a significant and growing number of patients with non-alcohol-related fatty liver. This condition has an association with obesity, type 2 diabetes and hyperlipidemia. In humans, adipose tissue is an important "energy bank" in which excess energy is stored and then released to meet the energy needs of the body. In the fed state and during periods of excess calorie intake, the excess energy is stored within adipose tissue as triglycerides. In the fasting state and during starvation, triglycerides within adipose tissue can be rapidly broken down by hormone sensitive lipase to generate fatty acids. Oxidation of fatty acids releases more energy than that of carbohydrate, protein or triglycerides. Fatty acids are thus the most efficient "fuel" to meet the body's energy needs. Discrete accumulation of triglycerides within cytoplasmic vesicles of hepatocytes by steatosis (abnormal retention of lipid within a cell) called fatty liver disease. Fatty liver disease comprises a spectrum of conditions (simple hepatic steatosis, steato hepatitis with inflammatory changes, and end-stage liver disease with fibrosis and cirrhosis). Hepatic steatosis is often associated with diabetes and obesity and may be secondary to alcohol and druguse, toxins, viral infections, and metabolic diseases.Detection and quantification of liver fat have many clinical applications, and early recognition is crucial to institute appropriate management and prevent progression (14)

The epidemics of Obesity, metabolic syndrome, type 2 diabetes, and atherosclerosis are increasing worldwide (1). Nonalcoholic fatty liver disease (NAFLD), for a long time unnoted in the metabolic field, is becoming recognized as a condition possibly involved in the pathogenesis of these diseases. Support for this hypothesis emerges from studies revealing that NAFLD precedes the manifestation of the metabolic derangements (2). Today, with a prevalence of about 34% in the United States among adults (3), NAFLD is the most common cause of chronic liver disease, constituting a major risk factor for progression to liver failure, cirrhosis, and hepatocellular carcinoma (4-5). Particularly alarming are the data showing that NAFLD has become the most common cause of liver disease in children (6).

Hepatic steatosis appears as a diffuse increase in echogenicity (bright liver) and a number of sonographic alterations in the liver [9,10]. The sensitivity of US to detect steatosis decreases with a degree of fat infiltration less than 30% [15].mainly steatosis have three stages which is called as grade 1 , grade 2 , and grade 3.with the help of ultrasound echogenicity categorized these three stages of echogenicity. In mild stage minimal diffuse increase in hepatic echogenicity and normal visualization of diaphragm and intra hepatic vessel border will be there. When deposition of fat increases in the liver , it leads to moderate stage which is called as grade 2 fatty liver.in this stage there is moderate diffuse increase in hepatic echogenicity and slightly impaired visualization of intrahepatic vessels and diaphragm .Where more deposition leads to severe stage which is called as grade 3. There is a marked increase in echogenicity and poor visualization of hepatic vessels and diaphragm.

To develop a protocol for measurement of liver fat using computed tomography (CT), Banerji et al. and Goto et al in 1995 was first described the identification of liver fat by CT as a predictor of health risk. The CT method employed realizes that the lower the mean liver attenuation or CT number in Hounsfield units (HU), the lower the tissue density and hence the greater the fat content. Therefore, liver density (e.g., attenuation in HUs) is inversely related to liver fat .calculate the mean HU value for liver and we can categorize in each grade. Steatosis results in a reduction in the attenuation of the liver, which can be measured in Hounsfieldunits(HU) and appears as hypodense liver parenchyma(12,13).Unenhanced CT is considered

Aim:
Estimation of range of Hounsfield unit on CT for different grades of fatty infiltration of liver categorized using ultrasound.

Objective:
To correlate between Hounsfield unit and fatty changes of the liver.

MATERIALS AND METHODS:
A cross sectional study was carried out on 90 patients referred for Ultrasound and CTscan to the Department of Radio-diagnosis, Kasturba Hospital,Manipal.

Study Criteria:
Inclusion criteria:
All patients with fatty liver who underwent CT scan with ultrasound report.

Exclusion criteria:
- Patient who did not have fatty liver on their ultrasound report.
- All patients with fatty liver who underwent CT scan without ultrasound report.
- Patient with fatty liver having other liver pathologies.

The liver was examined with a real time ultrasound equipment after 6 hours fasting so that bowel gas was minimal and gall bladder and pancreas could be optimally evaluated in the same settings.

Supine and right anterior oblique views were obtained and the patients were evaluated in various positions in order to grade the severity of fatty infiltration and renal parenchyma was compared with liver parenchyma. The second step done was CT examination in these patients by using 64 slice MDCT in the department. Non-contrast upper abdomen CT was done. Five measurements of the Hounsfield units were measured in the right and left lobe of the liver and correlated with ultrasound results. Hounsfield unit of liver was compared with the spleen and the grading of fatty liver was done on the basis of the difference between the both. The vessels were observed in each grading of stenosis.Hounsfield measurements were taken from the axial section which is showing porta hepatic clearly. This slice was taken as a reference image for accuracy and measurement of the pre and post two slices from the reference image. Right and left lobe were measured by five separate ROI's. Average value of these ROI's were taken as grand mean value for both the liver and the spleen.

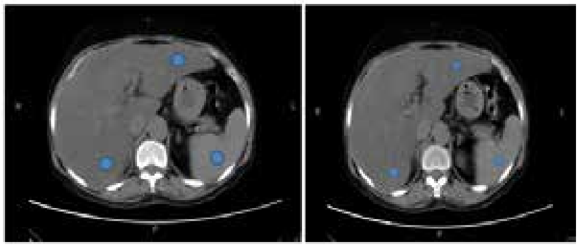


Fig:A and B: Image A and B are the two slices above the reference image, HU measured from Right and left lobe of the liver.HU of spleen also measured.

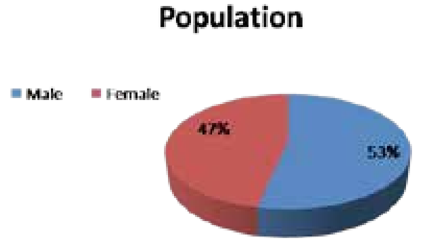
Statistical Analysis method: Median and inter quartile range was used to summarize the value of HU in each grading. Kruskalwallis-ANOVA wasused to test the median difference in HU between three grades. P value less than 0.001suggests that there is significant difference of HU between each gradings.

RESULTS
Present study was performed on 90 patients. We have included 30 patients in all three grading. The selected 90 patients were diagnosed for fatty liver with the help of ultrasound report and graded by observation by usingDescriptive analysis.

Current study can estimate the range of Hounsfield unit on CT for different grades of fatty infiltration of liver with reference of ultrasound results. By statistical analysis it was found that the study does not come under normal distribution, the observations follow kruskulwallis test. The total population taken is 90, among which the frequency of male is48 and females is 42.So 53 % of the total population were males and 47 % were females. The highest incidence of hepatic steatosis was found in the age group of 44.96 +12.7 in males and 46.95 + 12.5 in females.

Frequency and percentage of population

Population	Frequency	Percentage
Male	48	53
Female	42	47



Mean age of population

Population	Mean age	Stand. Deviation
Male	44.96	12.7
Female	46.95	12.5

Table 1: The following table showsminimum and maximum values of HU in each grades

Grade	Mean of HU in liver	Std. Deviation	Minimum HU	Maximum HU
1	37.7489	3.37327	27.75	47.11
2	24.1647	3.32480	14.75	29.51
3	0.7589	11.42480	-36.79	11.69

Grand mean ranges

By descriptive analysis we have found that 27.75 is the minimum value of grade 1 and it extends till 47.11. So 28-47 HU indicates presents of grade 1 steatosis. Then 14.75 is the minimum value of grade 2 and it extends till 29.51 under current observations. So we can conclude that 15-30 HU shows grade 2 steatosis. Sograde 3 category minimum value found is -36.79 and 11.69 is the highest HU. So severe steatosis cases HU changes from -37 to 12.

By using the same analysis it was found that the difference between liver and spleen changes with respect to each grading is shown in the following table 2.

Table 2

Grade	Mean HU of Spleen	Mean HU of Liver	Difference of Spleen and Liver	Standard Deviation
1	49.46	37.7489	11.71	5.38878
2	47.59	24.1647	23.4253	5.52588
3	46.27	0.7589	45.51	11.48166

For healthy liver patients there will be 10 HU changes between liver and spleen. Since deposition of fat increases there will be more difference between the two. Under this Selected 30 patient mean HU of spleen is 49.46 and mean HU of liver is 37.74. and difference between these two 11.71 HU.But in grade 2 patients there is a more difference between spleen and liver HU .It shows around 23.4 HU.In Grade 3 patients there is a high difference between spleen and liver HU,the mean difference is 45.5 HU .The above table concluded that when fat deposition increases, difference of HU between Spleen and liver also increases.

Table 3

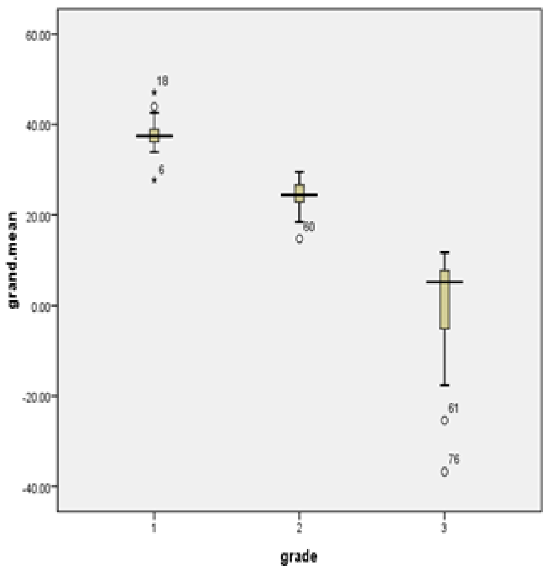
Grade	Median	Q1	Q3
Grade 1	37.48	36.22	38.98
Grade 2	24.48	22.68	26.68
Grade 3	5.15	-5.155	7.94

Descriptive statistics shows p value less than 0.001, so it shows a significant difference of HU between each group. Since it doesnot follow normal distribution, the median and quartile of each group was calculated. Table 3 shows37.48 is the median value of grade 1 and 25 % of observation have value less than 36.22HU ,75 % of observation have value less than 38.98HU.Grade 2 patients median value is 24.48 HU ; 25 % of observation have value less than 22.68 HU and 75% of observation have value less than 26.68 HU.in grade 3 patients 5.15 is the median value and 25 % of observation have value less than -5.155 HU and 75% of observation have value less than 7.94 HU.

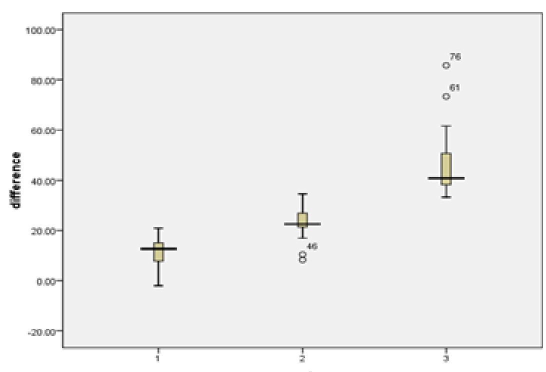
Table 4
Difference between HU of spleen and liver in each grades of steatosis

Grades	Median	Q1	Q2
Grade1	12.6	7.79	15.26
Grade2	22.54	21.26	27.04
Grade3	-40.83	38.24	50.96

Table 4shows describes that ,12.6 HU is the median of difference of liver and spleen in grade 1 ;25% of observation have value less than 7.79 and 75% of observation have value less than 15.26.in grade 2 patients there is more difference between liver and spleen HU .The table concluded that 22.54 is the median of grade 2 ;25%of observation follows values which is less than 21.26 and 75% of observation have value less than 27.04.in grade three patients there is high difference of HU between liver and spleen .median value is -40.83 and 25% of observation follows value less than 38.24 and 75 % of observation have value less than 50.96.



Box plot 1:



Box plot: 2

Box plot 1 represents the table 1 and 3.it shows quartile range of each grade and median value .box plot showing the out layers value of each grades.in grade 3 , 76th and 61th position observations are considered as out layers ,out layers have 1.5 times lesser value than minimum value of HU .its showing -36.79 HU and -25.43 HU for76th and 61th observation.in box plot had mentioned about a star,which is represent that values 3 times lesser than the minimum value,so it considered as out layer value.

Box plot 2 reprents the table 2 and 4.it shows quartile range of difference between spleen and liver HU.Here have plotted the median value , minimum HU , maximum HU and out layers.in grade 3 , 61th and 76th position observations are 73 HU AND 85.9 HU respectively .those values are 1.5 times greater than maximum value.

When the severity of fatty infiltration increases Hounsfield value decreases.CT scan of normal liver has poor visualization of vessels comparing to steatosis cases.by using ROC curve the cut off value of vessel visualization in steatosis cases was found. The descriptive statistics show 25 is the cut off value with 0.97 sensitivity and 0.87 specificity. So above the value of 25 HU, the vessel visualization is not possible.

DISCUSSION

The imaging appearance of different grades of hepatic steatosis in CT have not yet been evaluated in our country. There are many studies which have proved that in general HU decreases when fatty infiltration increases.Fatty liver, or hepatosteatosis, is characterized histologically by triglyceride accumulation within the cytoplasm of hepatocytes [11] and refers to fat accumulation in the liver exceeding 5%–10% by weight [12]. macrovesicular fatty accumulation is the most common cause of steatosiscan occur because of alcoholic and non-alcoholic.

Ultrasound is reasonably sensitive for detecting fatty liver (sensitivity70–85% and specificity of 80–90%) and is a useful screening test. Typicallythis shows increased echogenicityas the only abnormal feature.In the presence of risk factorsfor fatty liver, the diagnosis is difficult if milder degree of fatty infiltration, then theultrasound will be normal. Abdominal CTscan is a potentially useful test although accurate diagnosis dependson sensitive calibration of densityscores. Fatdistribution in the liveris often 'uneven' and can give theappearance of a focal lesion (focalfatty sparing). Often the site of thelesion is helpful (i.e. focal fatty sparingmore common in certain areas of the liver) but sometimes imaging with both ultrasound and CT scan is required to make the diagnosis.

Norbert Stefan, KonstantinosKantartzis, performed study on causes and consequences of fatty liver in2008 (16), authors included mechanisminvolved in the pathogenesis of hepatic fat accumulation, particularlythe role of body fat distribution, nutrition, exercise, genetics,and gene-environment interaction.

Literature shows obesity and excess alcohol intake is the most common causes of steatosis .Sonography of steatosis can be focal or diffused. Diffused steatosis can be divided into mild, moderate and severe. In grade I,diffuse increase in hepatic echogenicity, more than kidney and normalvisualization of diaphragm and portal vein wall, grade II, moderate diffuse increase in hepatic echogenicity;and non-visualization of portal vein wall. In grade III, increase in echogenicity leading to non-visualization of diaphragm. Current study have included only diffuse fatty infiltration.To estimate the range of Hounsfield in CT current study have taken ultrasound grading as a reference standard.

J. E. Jacobs et al performed study on diagnosticcriteria for fatty infiltration of the liver on contrast- enhanced helical CT," authors concluded that non contrast abdomen scan is more helpful for the detection of steatosis[18].Current study included only non-contrast abdomen scan .Present study included 90 patients which are categorized into three depending on the severity based on ultrasound and underwent unenhanced CT. Yoshihisa Kodama et al performed study on comparison of CT Methods for Determining the Fat Content of the Liver. The purpose of this study was to assess which of a number of methods of measuring attenuation on CT scans is best for prediction of hepatic fat content. Here investigators have divided the liver based on three hepatic vein and measured Hounsfield unit from twelve region of interest. And ROI measured $1.0 \pm 0.1 cm2$[17],present study also has used multiple ROIfrom the right and left lobe of the liver and division of lobes based on portal vein average was calculated.

Cody J. Boyce ,et al performed study on Hepatic steatosis in asymptomatic adults identified by unenhanced low-dose CT. Authors concluded that liver attenuation less than or equal to 40 HU shows steatosis. also found out that how the HU value is varying in each grades of fatty liver.so almost all patients had less than 40 HU .study observed that for each grading ,there was a significant range of HU values.

Current study proved that ther was significant difference between HU value in grade I (37.48 HU is the median value) to grade III steatosis (median value 5.15 HU).

Detection of milder grade of fatty liver can be missed on USG and also there is a difficulty in clearly defining the difference between grade 1 and grade II .In certain cases chances of under or over estimation of these two grades can happen. By measuring HU on the CT,it helps to predict the actual grade of fatty liver.Incaseof certain liver disease like hepatitis , liver echogenicity will reduce thus there is a chance of mis-interpretation of fatty liver in USG .But with the help of HU value we can predict the amount of fatty liver.

In alcoholics hepatic steatosis is well known complication which leads to cirrhosis. But more important is non-alcoholic hepatic steatosis. Studies have proved that it is well known risk factor for steatohepatitis and cirrhosis. Thus these patients should be followed up regularly for the progression of fatty liver. So in these cases actual measurement of HU value is one of the option for relative quantification of steatosis. Already there are many studies going on MRI estimation of hepatic steatosis.So in our study we have estimated a cut off value of HU for different grades of fatty liver, which can be taken as basement for further studies in absolute quantification of fatty infiltration of liver thus in future CT can match with MRI studies.

Cody j Boyce et al concluded thatliver attenuation less than or equal to spleen attenuation minus 10 HU also characterizeS steatosis. So in the current study we measured Hounsfield unit of spleen to get more accuracy of results. We have observed how the difference of spleen and liver HU vary in each stage of hepatosteatosis.In grade I patients, there was11.7 HU median difference of spleen and liver. The fat deposition increases when the difference between spleen and liver increases. The median difference of grade II patientswas 23.5 HU and it was found thatwhen the severity increases, there was higher median difference value between spleen and liver. In grade III the value was 45.5 HU, so grading of fatty infiltration of liver can be done with the help of spleen and liver HU measurements. There was significant difference between spleen and liver in each stage of steatosis, so this method also helps to categorize the hepatic steatosis. But we cannot apply this criteria in some patients who had splenectomy or any other splenic diseases. So the actual HU value measurement from liver parenchyma itself is more helpful for deciding the stage of hepatosteatosis.

Usually vessels are not visualized in non-contrast study and we have noted whether vessel visualization present or not in each case. The current study also derivedthe cut off.HUvalue at which vessel visualization is made. Using ROC analysis we have found that 25 HU was the cut off value with 0.97 sensitivity and 0.87 specificity.Vessel visualization is not possible for the values above25 HU. This cut off value comes under grade II steatosis. So by looking at this criterion of vessel visualization we can conclude that stage of fatty liver is definitely more than grade I.

CONCLUSION

Ultrasound was the first imaging technique for hepatic steatosis. However till date only maximum HU value was given to say the presence or absence of fatty liver. This is the first study to categorize the grades of fatty liver on CT in correlation with ultrasound. We conclude that significant range of HU value in each grade of fatty liver.

REFERENCES

1: Hu FB, Willett WC, Li T, Stampfer MJ, Colditz GA, Manson JE 2004 Adiposity as compared with physical activity in predicting mortality among women. N Engl J Med 351:2694–2703 | 2 Shibata M, Kihara Y, Taguchi M, Tashiro M, Otsuki M2007 Nonalcoholic fatty liver disease is a risk factor for type 2 diabetesin middle-aged Japanese men. Diabetes Care 30:2940–2944 | 3. Browning JD, Szczepaniak LS, Dobbins R, Nuremberg P, Horton JD, Cohen JC, Grundy SM, Hobbs HH 2004 Prevalence of hepatic steatosis in an urban population in the United States: impact of ethnicity. Hepatology 40:1387–1395 | 4: Angulo P2002 Nonalcoholic fatty liver disease. N Engl J Med 346:1221–1231 | 5:Caldwell SH, Oelsner DH, Iezzoni JC, Hespenheide EE, Battle EH, Driscoll CJ1999 Cryptogenic cirrhosis: clinical characterization | and risk factors for underlying disease. Hepatology 29: 664 – 669 | 6: Lavine JE, Schwimmer JB2004 Nonalcoholic fatty liver disease in the pediatric population. Clin Liver Dis 8:549 –555ix | 7: HaagaJ.R.Lanzieri C.F .SartorisD.J,et al text book of computed tomography and magnetic resonance imaging of the whole body.vol.1 , 3rd edition 1994:896-939 | 8:B D Chaurasia : human anatomy ,volume 2 | | 9: World J Gastroenterol2008 June 14; 14(22): 3476-3483 World Journal of Gastroenterology ISSN 1007-9327.14.3476 © 2008 The WJG Press. :Non-invasive means of measuring hepatic fat content bySanjeev R Mehta, E Louise Thomas, Jimmy D Bell, Desmond G Johnston, Simon D Taylor-Robinson | | 10: Strauss S, Gavish E, Gottlieb P, Katsnelson L. Interobserver and intraobserver variability in the sonographic assessment of fattyliver. AJR Am J Roentgenol 2007;189:W320–W323. | | 11:Hamaguchi M, Kojima T, Itoh Y, Harano Y, Fujii K, Nakajima T, et al. The severity of ultrasonographic findings in nonalcoholic fatty liver disease reflects the metabolic syndrome and visceral fat accumulation. Am J Gastroenterol 2007;102:2708–2715. | | 12: Ricci C, Longo R, Gioulis E, Bosco M, Pollesello P, MasuttiF,Croce LS, et al. Noninvasivein vivo quantitative assessment of fatcontent in human liver. J Hepatol1997; 27: 108-113. | | 13:Nishino M, Hayakawa K, Nakamura Y, Morimoto T, Mukaihara S. Effects of tamoxifen on hepatic fat content and the developmentof hepatic steatosis in patients with breast cancer: high frequencyof involvement and rapid reversal after completion oftamoxifen therapy. AJR AmJ Roentgenol2003; 180: 129-134. | 14: Imaging-based Quantification of Hepatic Fat:Methods and ClinicalApplications:RadioGraphics 2009; | 15C. K. Ryan, L. A. Johnson, B. I. Germin, and A. Marcos, "One hundred consecutive hepatic biopsies in the workup of living donors for right lobe liver transplantation," LiverTransplantation, vol. 8, no. 12, pp. 1114–1122, 2002. | 16. Rumackcm , Wilson S. R Charbonneau j.w text book of diagnostic ultrasound . vol. 1 .third edition,2005:77-139. | 17. Yoshihisa Kodama ,Chaan S. Ng ,Tsung T. Wu:Comparison of CT Methods for Determining the Fat Content of the Liver;AJR 2007; 188:1307–1312. | 18. : J. E. Jacobs, B. A. Birnbaum, M. A. Shapiro et al., "Diagnostic criteria for fatty infiltration of the liver on contrast- enhanced helical CT," American Journal of Roentgenology, vol. 171, no.3, pp. 659–664, 1998 |