Scholars Journal of Applied Medical Sciences (SJAMS) **ISSN 2320-6691 (Online)**
Sch. J. App. Med. Sci., 2017; 5(6D):2320-2329 **ISSN 2347-954X (Print)**
©Scholars Academic and Scientific Publisher
(An International Publisher for Academic and Scientific Resources)
www.saspublishers.com DOI: 10.36347/sjams.2017.v05i06.052

Review Article

Review on pancreatic steatosis detection by imaging modalities

Alaa Ibrahim[1], Caroline Edward[2], Ahlam Asiri[1], H. Osman[1], K. Sherrif[1], Ali Yasen[3]
[1]Taif University College of applied medical science P O box 2425 Post code21944, KSA Taif
[2]Sudan University of Science and Technology College of medical radiological Science Khartoum Sudan
[3]Taif University, Faculty of Medicine, post code 21944

***Corresponding author**
Alaa Ibrahim
Email: hamidsssan@yahoo.com

Abstract: The accumulation of fat in the pancreas has been referred to as fatty infiltration, fatty pancreas, fat non-alcoholic pancreatic disease and pancreatic steatosis. Pancreatic steatosis is the best description of fat accumulation in the pancreatic gland without fat replacement, and this term also describes the possibility that the fat accumulation is a reversible process. Pancreatic steatosis is an increasing problem due to the increasing incidence of obesity and aging this review study aimed to review article is to summarize the author's articles about the pancreatic steatosis. And to review the clinical significance of pancreatic steatosis by using various imaging modalities .Authors discussed and illustrated the various radiological modalities that had been used to study quantification of pancreatic fat. Such as ultrasound, computed tomography and magnetic resonance imaging. Several studies suggested that the association of fat accumulation in the pancreas with obesity, diabetes and metabolic syndrome. The study concluded that axial CT scan is considered as an appreciable radiological method for measuring the pancreas size and characterizing its structure using CT number (Hounsfield). The study also revealed that the pancreas size and CT number had significant relations with age and other body habits us.
Keywords: RVIEW, MDCT, MRI, pancreatic Steatosis.

INTRODUCTION

Pancreatic steatosis (PS) is the fatty replacement of pancreatic parenchyma, being often associated with obesity and aging. Similar to this condition in pancreas, any excessive lipidic deposition in the liver tissue are referred to as nonalcoholic fatty liver disease (NAFLD) [1].

The accumulation of fat in the pancreatic gland has been referred to different terminologies, such as pancreatic lipomatosis, fatty replacement, fatty infiltration, fatty pancreas, lipomatous pseudo hypertrophy, non-alcoholic fatty pancreatic disease and pancreatic steatosis. According to the well-quality paper of Smits et al [2].

Authors believe that pancreatic steatosis is the best description of fat accumulation in the pancreatic gland without fat replacement, and this synoums also describes the possibility that fat accumulation is a reversible process. Accumulation of fat in the pancreas is increasingly recognized as a cause of pancreatic dysfunction and of the death of non adiposities through lip apoptosis, ultimately leading to diabetes [3, 8].

Fatty infiltration of the pancreas is generally a diffuse process; however, it may be unevenly distributed in the pancreas. Focal fatty infiltration of the pancreas is usually most prominent in the anterior aspect of the head of the pancreas and seen as a region of decreased attenuation on computed tomography and may simulate pancreatic neoplasm [9].

Focal fatty infiltration can mimic a hypoattenuating mass on CT examinations [10]. The morphology of the pancreas was qualitatively evaluated and categorized into four patterns: normal pancreas, atrophy of the pancreas without fatty replacement, partial fatty replacement of the pancreas, and subtotal or complete replacement of the pancreas by hypertrophic fatty tissue. the pattern of pancreatic fatty replacement was further visually evaluated at four pancreatic regions (head , neck, body, and tail)into Grade0corresponded to a normal appearance of a given pancreatic region, without fatty replacement (Fiq1);grade1corresponded to fatty replacement that involved less than 25% of a given pancreatic region ,grade2 corresponded to fatty replacement that involved 25-50% of a given pancreatic region(Fig2); grade3 corresponded to fatty replacement that involved 50-70% of a given pancreatic regions; and grade 4 corresponded to fatty replacement that involved more than 75% of a given pancreatic region (Fig3).The degree of fatty replacement of the pancreas was correlated with the functional status of the pancreas[11].

Fatty infiltration of the pancreas has been also reported in advanced cases of cystic fibrosis [11].

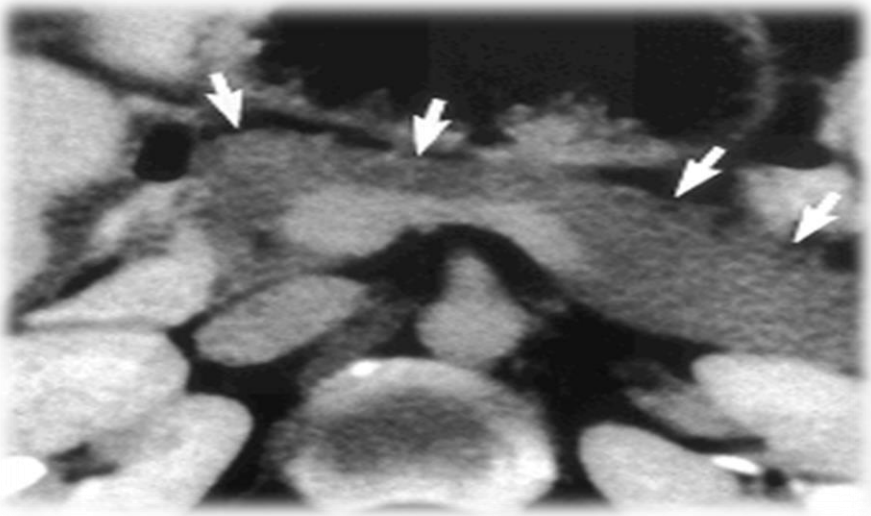

Fig-1 :a 28year old man. CT scan shows a normal sized pancreas without fatty replacement (Grade 0 for the four pancreatic regions) [11].

Fig-2: Cystic Fibrosis in a 16-year-old male adolescent .CT scan shows partial fatty replacement of the pancreas, residual glandular pancreatic tissue (arrows)is seen (grade2 for the neck and body of the pancreas ,which are seen at this level),patient had type 1 diabetes mellitus[11].

Fig-3: Cystic Fibrosis in a 25 year-old woman .CT scan shows subtotal fatty replacement of the pancreas ,tiny areas of residual glandular pancreatic tissue (arrows)are seen (grade 4for the neck and body of the pancreas ,which are seen at this level) patient had type 1 diabetes mellitus[11].

The fatty infiltration of the pancreas was first described in 1993 by Ogilvie that reported 17% pancreatic fat storage for obese cadavers as compared with 9% for lean ones. Pancreatic steatosis (PS) is the best description for fat accumulation in the pancreatic gland without fat replacement [12].The PS is a fatty replacement of pancreatic parenchyma, being often associated with obesity and aging [13].

The PS is generally a diffuse process occurring uniformly, but may be unevenly distributed in the pancreas and can be confined to region of the pancreas (focal fatty infiltration), being classified as: type 1a: preferential fatty replacement of head; type 1b: preferential fatty replacement of head, neck and body; type 2a: preferential fatty replacement of head and uncinate process; type 2b: fatty replacement of most of pancreas regions except the peribiliary region. Focal PS is a disorder without clinical significance. However, this condition may simulate a mass-like lesion [14].Various imaging modalities including ultra sonography (US) [15, 16]. Or magnetic resonance (MR) imaging [7, 8, 17, 18] have been used to study quantification of pancreatic fat. However, US examination can be of limited value in the evaluation of the entire pancreas due to the location of the pancreas behind the stomach or colon [19]. In addition, US do not provide reliable quantitative information [20].

Even though MR imaging (including MR spectroscopy) has the potential to allow quantification of fat content, fat quantification of the pancreas is far more challenging than that for the liver [8, 21, 18] The pancreas is prone to MR chemical shift artifacts because of its relatively small size, irregular morphology, and location in the middle of the abdomen surrounded by visceral fat [8, 15, 16]. Thus, computed tomography (CT) may be a more practical, noninvasive imaging modality for the pancreas because it is widely available and is performed with a short acquisition time [19].

In ultrasound The PS was diagnosed when there was an increase in echogenicity of the pancreas compared with the kidney. As the pancreas echogenicity could not be compared directly with the kidney in the same window, the examiner compared the difference between pancreatic echogenicity and the renal echogenicity in different window, and between hepatic and pancreatic echogenicity, to obtain an objective pancreato-renal echo contrast (Fig4)[1].

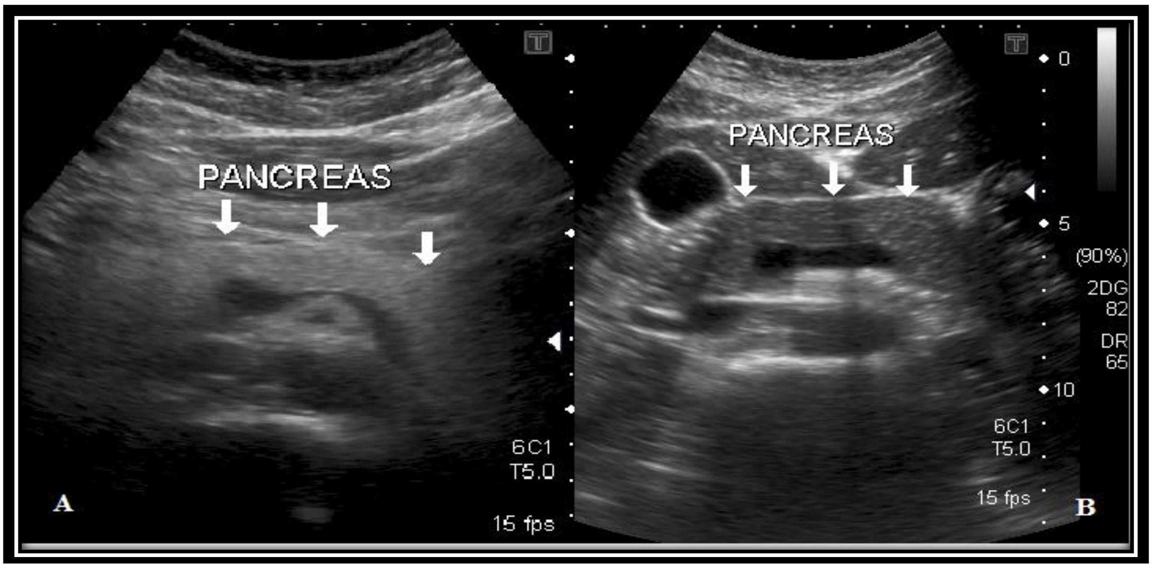

Fig-4: A: difuse steatosis pancreatic and B:normal pancreas using ultrasound scan[1].

The NAFLD diagnostic criteria included characteristic echo patterns of hepato-renal echo contrast, bright liver, deep attenuation, and vascular blurring (Fig5). The Grading of NAFLD was classified as: grade I (mild): increased hepatic echogenicity with visible periportal and diaphragmatic echogenicity; grade II (moderate): increased hepatic echogenicity with imperceptible periportal echogenicity, without obscuration of diaphragm; grade III (severe): increased hepatic echogenicity with imperceptible periportal echogenicity and obscuration [22].

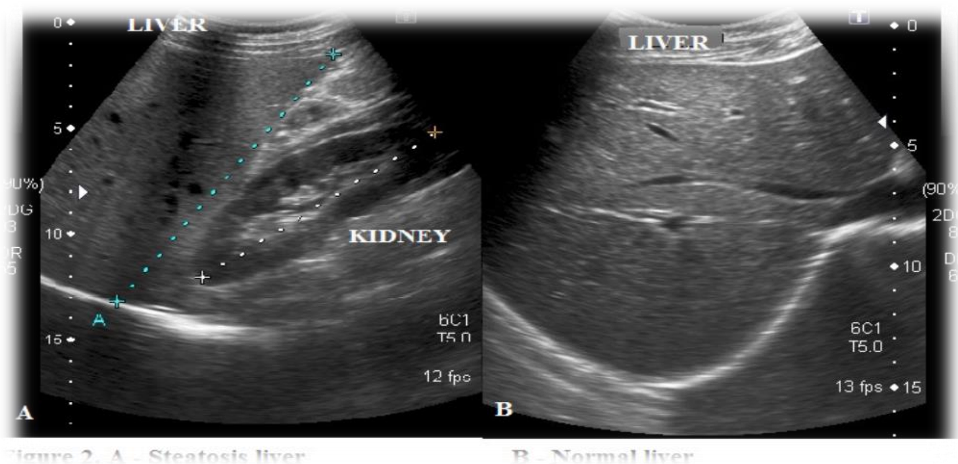

Fig-5: A: steatosis liver and B: normal liver using ultrasound scan[1] .

Fat accumulation in pancreas is significantly correlated to NAFLD. With the following characteristics: mild PS and mild NAFLD, moderate PS and moderate and severe NAFLD (P and between severe PS and moderate and severe NAFLD [1].

The PS can be classified as diffuse or as focal fatty infiltration, this latter was classified as: type1a: preferential fatty replacement of head; type 1b: preferential fatty replacement of head, neck and body; type 2a: preferential fatty replacement of head and uncinate process; type 2b: fatty replacement of most of pancreas except peribiliary region [14].

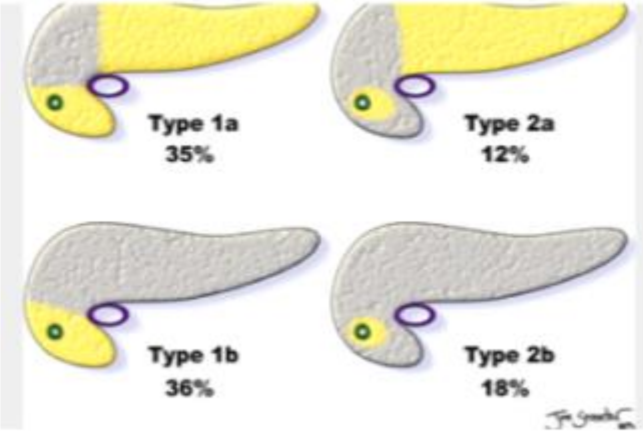

Fig-6: Uneven fatty replacement of the pancreas. Drawings illustrate the four different patterns of fatty replacement of the pancreas (gray areas). The percentage of cases of uneven pancreatic lipomatosis represented by each type is also indicated [14].

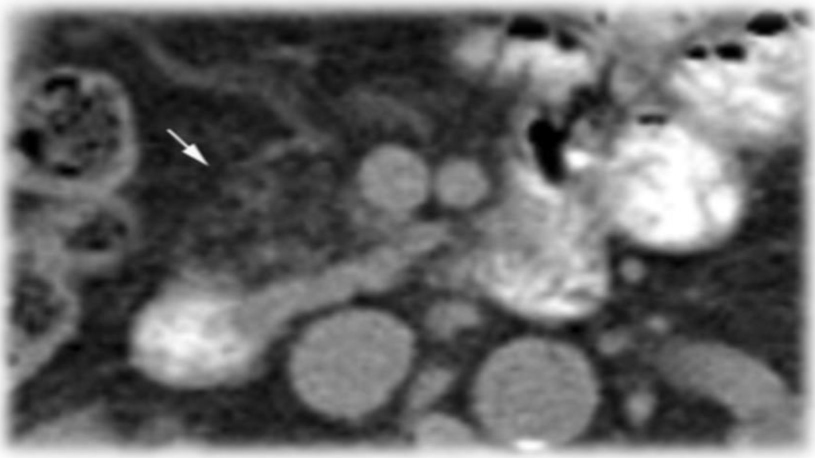

Fig-7: CT scan shows type 1a fatty replacement of the pancreatic head (arrow) [14].

However, they subdivided the PS into mild (grade I), moderate (grade II), and severe (grade III), according with Lee et al criteria[15].The four echogenicity grades of PS: Non-fatty pancreas, pancreatic echogenicity is equal to renal cortical echogenicity; Grade I: Mild fatty pancreas, pancreatic echogenicity is definitely lower than retroperitoneal fat; Grade II: Moderate fatty pancreas, pancreatic echogenicity is slightly lower than retroperitoneal fat; and Grade III: Severe fatty pancreas, pancreatic echogenicity is equal to retroperitoneal fat[15].

Fatty infiltration of the pancreas is relatively common condition and is often incidentally identified on abdominal computed tomographic (CT) scans [23]. Fatty infiltration is also known as adipose atrophy, fatty replacement, and lipomatosis of the pancreas [24, 25, 13]. Fatty infiltration of the pancreas is generally a diffuse process occurring uniformly throughout the gland and occurs most frequently in the elderly and obese populations [23, 25]. However, fatty infiltration may be unevenly distributed in the pancreas and can be confined to 1 region of the pancreas (focal fatty infiltration)[26,27,10,28,29,30]. Similarly, fatty infiltration may spare regions of the pancreas (focal fatty sparing) that is analogous to focal fatty spearing in the liver [31,32]. The sonographic[26,27,29,31] , CT[30,31,32],and magnetic resonance imaging (MRI) findings [10,28,31], of focal fatty infiltration and focal fatty sparing of the pancreas.

Computed tomography is accurate in detecting macroscopic fat. However, for lesions containing both fatty and non fatty tissue within a voxel, CT is less accurate in revealing microscopic fat deposits [28].

For focal nodular fatty infiltration of the liver, MRI, including a combination of in-phase and opposed-phase gradient-echo imaging, can reliably differentiate focal fatty infiltration from malignancy [33, 34]. Isserow et al reported that MRI using chemical shift technique can detect and characterize focal fatty infiltration of the pancreas and exclude a diagnosis of neoplasm [28].

On MRI, regions of focal fatty infiltration are is intense to hyper intense region relative to the surrounding pancreatic parenchyma on in-phase T1-weighted gradient-echo images, and these regions show moderate to marked signal intensity loss on opposed-phase gradient-echo images [28]. In patients with focal fatty sparing, MRI may also be helpful to exclude the presence of neoplasm by the lack of a hypo intense lesion on T1-weighted imaging with normal appearance on T2-weighted images [11, 28].

Focal fatty infiltration in the pancreas is seen as a region of decreased attenuation in the pancreas on non contrast or postcontrast CT [10].Computed topographic attenuation within the focal fatty infiltration may be negative and show apparent fat attenuation [30]. In these cases, diagnosis of focal fatty infiltration can be supported by measuring CT attenuation. However, when focal fatty infiltration is mild, the region may not show apparent fat attenuation and may simulate a hypo attenuating mass on CT [28].

Although no single cause has been established for fatty infiltration of the pancreas, it occurs most frequently in the elderly and obese populations [25].It has also been associated with diabetes mellitus, chronic pancreatitis, hepatic disease, dietary deficiency, viral infection, steroid therapy, and obstruction of the pancreatic duct [13]. Fatty infiltration of the pancreas may be reversible in patients if they lose weight [35], and in patients with Cushing syndrome or steroid therapy [36].

Magnetic resonance (MR)imaging, however ,allows sensitive assessment of tissue fat tissue fat content[37].one simple approach to quantifying tissue fat content is chemical shift-based technique with measurement of the proton density fat fraction(PDFF)[38,39].

Measurement of PDFF improves the reliability of fat quantification by correcting for Confounders such as T2*decay, T1 bias, and noise bias and for the multispectral complexity of Fat [10]. The high accuracy of the PDFF-based technique for tissue fat quantification has been shown in various organs in recent studies [37, 40, 41]. Nevertheless, only a few cohort studies have dealt with the quantification of pancreatic fat content with MR imaging [18, 42].

To the best of our knowledge, only one group of investigations has calculated the PDFF by using chemical shift imaging to assess the pancreatic fat content in a small patient group (n=43) according to Patel NS et al[43].

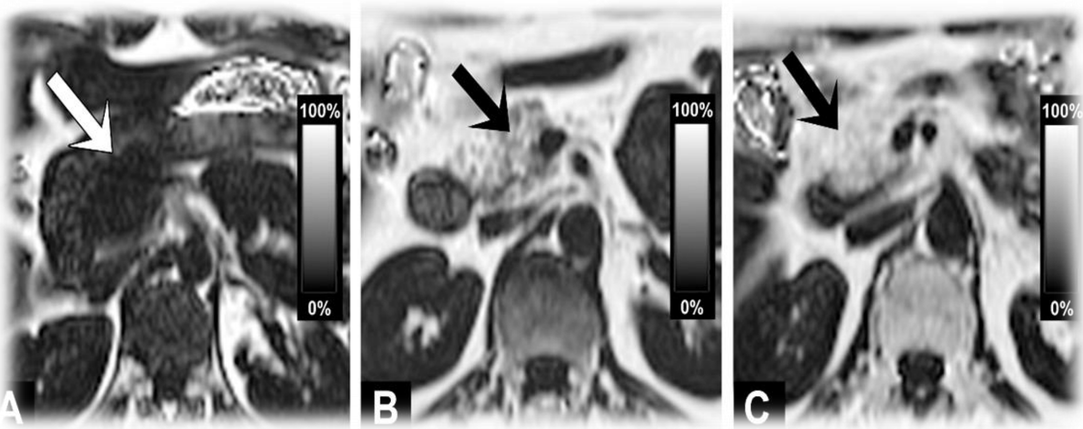

Figure 8: PDFF maps illustrate different amounts of pancreatic fat in pancreatic head (arrow) in subjects without diabetes. (a)Image shows a very small amount of fat in pancreatic head. (b)Image shows fatty replacement of pancreatic head with PDFF of 19 %.(c) Image shows complete fatty replacement as a maximum variant of pancreatic steatosis[38].

Fat accumulation in the pancreas can also influence pancreatic function. Intra pancreatic fat amount has been closely associated with pancreatic-cell dysfunction [8, 44, 4].Age, obesity, physical inactivity and dyslipidemia contribute to fat accumulation in the pancreas [45, 7]**,** with ensuing pancreatic dysfunction. Thus, pancreatic volume and fat accumulation might together contribute to the development and progression of diabetes [46].

Authors found deficiency in literature regarding the current study of PS and little knowledge concerning this site of imaging among Practitioners in hospital and even radiologist in different departments visited by authors. So this manuscript considered attempt to enhance the role of different imaging in diagnose the PS, also it account as contribution for elevating the accurate diagnosis for these cases in hospitals.

Objectives:

The main Objectives of this review article is to summarize the authors articles about the pancreatic steatosis. And to review the clinical significance of pancreatic steatosis by using various imaging modalities. Other goal of this study is to discuss and illustrate the CT appearance of fatty infiltration in the pancreas that may simulate a hypo attenuating mass, and also to illustrate CT findings to help to differentiate fatty infiltration from a pancreatic neoplasm.

Materials and Methods.

35 articles in different peer reviewed journals were selected by authors and then analyzed and summarized using Microsoft EXCEL 2010 version to compare between different findings. The manuscripts were selected according to the main objective of this review article , any manuscript that were not found as full-text were excluded from this review article .the article were accessed by Saudi digital library provided by Tiaf university and other were accessed by open access internet using Google search.

Discussion

Authors found that the CT MDCT scanning, which is the most practical method to evaluate the volume and quantity of fat in the pancreas. By using two different approaches to evaluate pancreatic fat deposit complementarily: a histogram analysis with local thresholding and the measurement of pancreatic parenchyma attenuation estimated from HU values.

So lim et al found that patients with T2D had smaller pancreatic volume and greater pancreatic fat content than normoglycemic subjects. Within patients with T2D, as duration of diabetes increased, pancreatic volume decreased and pancreatic fat content increased, resulting in an increased fat percentage in the pancreatic parenchyma. Pancreatic fat density assessed by HU values based on unenhanced MDCT images also decreased according to the duration of diabetes [46].

This means that the MDCT can be useful tools for scanning patients with high risk or development of diabetes. Represented this result by the table below.

Table 1: The pancreatic volume and fat assessment by CT and Hounsfield unit obtained from pre enhanced CT according to glycemic status and duration of diabetes [46].

	Normal		**T2D-new**		**T2D<5Y**		**T2D≥5Y**		**P[a]**
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Pancreatic volume (cm^3)	66.3	13.9	58.4	9.9	54.0	13.9	49.1	16.0	<0.01
Pancreatic fat (cm^3)	1.9	1.9	2.4	2.0	3.3	2.2	4.0	2.6	<0.01
Pancreatic fat %	2.9	3.4	4.3	4.0	6.6	4.9	9.3	7.7	<0.01
HU pancreas[c]	54.6	5.8	51.2	5.6	49.7	6.2	47.3	5.1	<0.01
HU spleen[d]	55.9	4.5	54.7	5.3	54.3	3.7	54.6	4.3	NS
HUp–s (HUpancreas–HUspleen)	−1.4	8.1	−3.5	7.3	−4.6	6.9	−7.3	6.7	<0.01

Kawamoto et al reported that Focal fatty infiltration of the pancreas is usually most prominent in the anterior aspect of the head of the pancreas and seen as a region of decreased attenuation on computed tomography and may mimic pancreatic neoplasm [9] same as the study done by Matsumoto et al they reported that 57 of the 80 patients (71%) had type 1 fatty infiltration which is uneven fatty infiltration in the head of the pancreas with sparing of the posterior aspect of the head and uncinate process of the pancreas, and 23 patients (29%) had type 2 which is uneven fatty infiltration in the head and uncinate process of the pancreas with the focal area of sparing only around the common bile duct that means in the both type the head of the pancreas was involved with fatty infiltration and may affect the diameter of the pancreas head[30] .

This is similar to study that done by Atri et al reported by ultrasound. The area of focal fatty sparing is seen as the hypo echoic zone with sharp margin with anterior aspect of the pancreatic head, and the common bile duct is often seen within this hypo echoic zone on both the transverse and sagittal views by ultrasound [26].

The area of intense fatty infiltration in the pancreatic head may gradually change to less intense fatty infiltration in the body and tail of the pancreas, and can be seen as a geographic area of hypo attenuation on axial or coronal reformations. The hypo attenuating portion of the pancreas due to focal fatty infiltration usually extends to the anterior and inferior surface of the pancreatic head, but not affect the contour of the normal the pancreas and fatty infiltration may be diffuse or focal ,it’s usually more prominent in the anterior aspect of the head .

Many authors discussed the appearance of the pancreatic steatosis by using ultrasound and classified the finding depending on many part and echogensity differences Mortelé et al reported that the PS was diagnosed when there was an increase in echogenicity of the pancreas compared with the kidney pancreato-renal echo contrast [14]. and Lee et al diagnosed the non-fatty pancreas, if the pancreatic echogenicity is equal to renal cortical echogenicity, and also diagnosed the fatty pancreas depending on the echogencity of the retroperitoneal fat as stander and classified the presence of the fatty pancreas into Grade I: Mild fatty pancreas, pancreatic echogenicity is definitely lower than retroperitoneal fat; Grade II: Moderate fatty pancreas, pancreatic echogenicity is slightly lower than retroperitoneal fat; and Grade III: Severe fatty pancreas, pancreatic echogenicity is equal to retroperitoneal fat, and between hepatic and pancreatic echogenicity, to obtain an objective pancreato-renal echo contrast[15],this attributed to thatsome researchers believe that fatty infiltration of pancreas positively correlates with fatty infiltration of liver ultrasound-determined steatosis grade as the paper done by Luis J etal and also showed that advanced age was positively associated with PS and NAFLD[1], compatible with the results of previous study carried by Glaser J et al ,due to the age-related decrease in pancreatic parenchyma volume and increased pancreatic fat content[47].

The PS is highly associated with the metabolic syndrome the definition of metabolic syndrome remains a matter of debate, however, obesity, hyperglycemia, dyslipidemia and hypertension have been constant syndrome components and the central concept of such descriptions is the unity of the background path physiologic process and the interaction between the elements. According to

WU et al found that the presence of fatty pancreas and fatty liver represents a meaningful manifestation of metabolic syndrome together with obesity .the pancreatic fat replacement with acinar cell death and pancreatic fat infiltration duo to obesity contribute to PS [48] .

Also another study done by Noronha M et al found that another important risk factor for pancreatic fat infiltration and liver fat infiltration is alcohol ingestion. Fat infiltration within pancreatic acinar cells was observed by examination in patients consuming more than 30 gr/day of ethanol. Ultra-structural changes within the cells are described on those without clinical pancreatitis, changes which are similar to those seen in the hepatocytes of alcoholics [49].

Is serow et al reported that MRI using chemical shift technique can detect and characterize focal fatty infiltration of the pancreas and exclude a diagnosis of neoplasm. On MRI, regions of focal fatty infiltration are iso-intense to hyper-intense region relative to the surrounding pancreatic parenchyma on in-phase T1-weightedgradient-echo images, and these regions show moderate to marked signal intensity loss on opposed-phase gradient-echo images .In patients with focal fatty sparing, MRI may also be helpful to exclude the presence of neoplasm by the lack of a hypo-intense lesion on T1-weighted imaging with normal appearance on T2-weighted images [28].

CONCLUSION

Pancreatic steatosis is easy to be appear, measured using modern imaging techniques, such as ultra sonography, computed tomography and magnetic resonance imaging. Pancreatic steatosis is not due to the presence of diabetes mellitus but is highly associated with the metabolic syndrome.

Also the study concluded that that axial CT scan is considered as an appreciable radiological method for measuring the pancreas size and characterizing its structure using CT number (Hounsfield). The study also revealed that the pancreas size and CT number had significant relations with age and other body habits us.

REFERENCES

1. Luis Jesuino de Oliveira Andrade, Larissa Rocha Guimarães, et al. Pancreatic steatosis and its association with nonalcoholic fatty liver disease evaluated by ultrasonography. Brazilian Journal of Medicine and Human Health. 2015;3:37-43.
2. Smits MM, van Geenen EJ. The clinical significance of pancreatic steatosis. Nat Rev Gastroenterol Hepatol. 2011; 8:169–177.
3. Unger RH, Zhou YT. Lip toxicity of beta-cells in obesity and in other causes of fatty acid spillover. Diabetes 2001;50:118–121.
4. Pinnick KE, Collins SC, Londos C, Gauguier D, Clark A, Fielding BA. Pancreatic ectopic fat is characterized by adipocyte infiltration and altered lipid composition. Obesity (Silver Spring) 2008;16:522–530.
5. Shimabukuro M, Higa M, Zhou YT, Wang MY, New gard CB, Unger RH. Lip apoptosis in beta-cells of obese prediabetic fa/fa rats. Role of serine palmitoyltransferase over expression. J BiolChem 1998;273(49):32487–90.
6. Shimabukuro M, Wang MY, Zhou YT, New gard CB, Unger RH. Protection against lip apoptosis of beta cells through leptin-dependent maintenance of Bcl-2 expression. Proc Natl AcadSci U S a 1998; 95(16):9558–61.
7. Heni M, Machann J, Staiger H, et al. Pancreatic fat is negatively associated with insulin secretion in individuals with impaired fasting glucose and/or impaired glucose tolerance: a nuclear magnetic resonance study. Diabetes Metab Res Rev 2010; 26(3):200–205.
8. Tushuizen ME, Bunck MC, Pouwels PJ, et al. Pancreatic fat content and beta-cell function in men with and without type 2 diabetes. Diabetes Care 2007; 30(11):2916–2921.
9. Kawamoto, S., Siegel man, S. S., Bluemke, D. A., Hruban, R. H., & Fishman, E. K. (2009). Focal fatty infiltration in the head of the pancreas: Evaluation with multi detector computed tomography with multi planar reformation imaging. Journal of Computer Assisted Tomography, 33, 90-95.
10. Hague J, Amin Z. Focal pancreatic lesion: can a neoplasm be confidently excluded? Br J Radiol. 2006;79:627-629
11. Philippe soyer, Laurent Spelle, Jean-pierre et al, Cystic fibrosis in adolescent and adults: Fatty replacements of the pancreas CT evaluation and functional correlation. RSNA Radiology Vol 210,Issue3;1998
12. Ogilvie RF. The islands of Langerhans in 19 cases of obesity. J Pathol Bacterial. 1933; 37:473-8.
13. Patel S, Bellon EM, Haaga J, Park CH. Fat replacement of the exocrine pancreas. AJR Am J Roentgenol. 1980;135:843-5.
14. Mortelé KJ, Rocha TC, Streeter JL, Taylor AJ. Multimodality imaging of pancreatic and biliary congenital anomalies. Radio graphics. 2006;26:715-31.
15. Lee JS, Kim SH, Jun DW, et al. Clinical implications of fatty pancreas: correlations between fatty pancreas and metabolic syndrome. World J Gastroenterol 2009;15(15):1869–1875
16. Raeder H, Haldorsen IS, Ersland L, et al. Pancreatic lipomatosis is a structural marker in non diabetic children with mutations in carboxyl-ester lipase. Diabetes 2007; 56(2):444–449.
17. Schwenzer NF, Machann J, Martirosian P, et al. Quantification of pancreatic lipomatosis and liver steatosis by MRI: comparison of in/opposed-phase and spectral-spatial excitation techniques. Invest Radiol 2008; 43(5):330–337.
18. Hu HH, Kim HW, Nayak KS, Goran MI. Comparison of fat-water MRI and single-voxel MRS in the assessment of hepatic and pancreatic fat fractions in humans. Obesity (Silver Spring) 2010;18(4):841–847.
19. Hoff FL, Gabriel H, Hammond NA, Gore RM. Pancreas: normal anatomy and examination techniques. In: Gore RM, Levine MS, eds. Textbook of gastrointestinal radiology. Philadelphia, Pa: Saunders, 2008; 1839–1853.
20. Ricci C, Longo R, Gioulis E, et al. Noninvasive in vivo quantitative assessment of fat content in human liver. J Hepatol 1997; 27(1):108–113.
21. Lingvay I, Esser V, Legendre JL, et al. Noninvasive quantification of pancreatic fat in humans. J ClinEndocrinolMetab 2009; 94(10):4070–4076.
22. Yeh WC, Jeng YM, Li CH, Lee PH, Li PC. Liver steatosis classification using high-frequency ultrasound. Ultrasound Med Biol. 2005; 31:599-605.
23. Katz DS, Hines J, Math KR, et al. Using CT to reveal fat-containing abnormalities of the pancreas. AJR Am J Roentgenol. 1999;172:393-396.
24. Walters MN. Adipose atrophy of the exocrine pancreas. J Pathol Bacteriol. 1966; 92:547-557.
25. Olsen TS. Lipomatosis of the pancreas in autopsy material and its relation to age and overweight.

ActaPathol Microbial Scand [A]. 1978; 86A:367-373.

26. Atri M, Nazarnia S, Mehio A, et al. Hypo echogenic embryologic ventral aspect of the head and uncinate process of the pancreas: in vitro correlation of US with histopathology findings. Radiology. 1994; 190:441-444.
27. Donald JJ, Shorvon PJ, Lees WR. A hypo echoic area within the head of the pancreas-a normal variant. ClinRadiol. 1990;41:337-338.
28. Isserow JA, Siegel man ES, Mammone J. Focal fatty infiltration of the pancreas: MR characterization with chemical shift imaging. AJR Am J Roentgenol. 1999; 173:1263-1265.
29. Marchal G, Verbeken E, Van Steenburgen W, et al. Uneven lipomatosis: a pitfall in pancreatic sonography. Gastrointestinal Radial. 1989; 14:233-237.
30. Matsumoto S, Mori H, Miyake H, et al. Uneven fatty replacement of the pancreas: evaluation with CT. Radiology. 1995; 194:453-458.
31. Jacobs JE, Coleman BG, Arger PH, et al. pancreatic sparing of focal fatty infiltration. Radiology. 1994; 190:437-439.
32. Silverman PM, Mc Vay L, Zeman RK, et al. Pancreatic pseudo tumor in pancreas divisum: CT characteristics. J Compute Assist Tomogr. 1989; 13:140-141.
33. Kroncke TJ, Taupitz M, Kivelitz D, et al. Multifocal nodular fatty infiltration of the liver mimicking metastatic disease on CT: image in findings and diagnosis using MR imaging. Eur Radiol. 2000; 10:1095-1100.
34. Hussain SM, Zondervan PE, IJ zermans JN, et al. Benign versus malignant hepatic nodules: MR imaging findings with pathologic correlation. Radio graphics. 2002; 22:1023Y1036; discussion 1037-1029.
35. Dreiling DA, Elsbach P, Schaffner F, et al. The effect of restriction of protein and total calories on pancreatic function in obese patients. Gastroenterology. 1962;42:686-690.
36. Tham RT, Heyerman HG, Flake TH, et al. Cystic fibrosis: MR imaging of the pancreas. Radiology. 1991; 179:183-186.
37. Kuhn JP, Hernando D, Munoz del Rio A, et al. Effect of multi peak spectral modeling of fat for liver iron and fat quantification: correlation of biopsy with MR imaging results .Radiology2012;265(1):133-142.
38. Reeder SB, Hu HH, Sirlin CB. Proton density fat-fraction: a standardized MR-based biomarker of tissue fat concentration. J Magn Reson Imaging 2012; 36(5):1011–1014.
39. Yu H, Shimakawa A, McKenzie CA, Brodsky E, Brittain JH, Reeder SB. Multiecho water-fat separation and simultaneous R2* estimation with multi frequency fat spectrum modeling. Magn Reson Med 2008; 60(5):1122–1134.
40. Meisamy S, Hines CD, Hamilton G, et al. Quantification of hepatic steatosis with T1-independent, T2-corrected MR imaging with spectral modeling of fat: blinded comparison with MR spectroscopy. Radiology 2011;258(3):767–775.
41. Yokoo T, Shiehmorteza M, Hamilton G, et al. Estimation of hepatic proton-density fat fraction by using MR imaging at 3.0 T. Radiology 2011;258(3):749–759.
42. Noetzli LJ, Papudesi J, Coates TD, Wood JC. Pancreatic iron loading predicts cardiac iron loading in thalassemia major. Blood 2009;114(19):4021–4026.
43. Patel NS, Peterson MR, Brenner DA, Heba E, Sirlin C, Loomba R. Association between novel MRI-estimated pancreatic fat and liver histology-determined steatosis and fibrosis in non-alcoholic fatty liver disease. Aliment PharmacolTher 2013;37(6):630–639.
44. Rasouli N, Molavi B, Elbein SC, Kern PA. Ectopic fat accumulation and metabolic syndrome. Diabetes Obes Metab, 2007; 9:1–10
45. Van der Zijl NJ, Goossens GH, Moors CC, van Raalte DH, Muskiet MH, Pouwels PJ, Blaak EE, Diamante M .Ectopic fat storage in the pancreas, liver, and abdominal fat depots: impact on beta-cell function in individuals with impaired glucose metabolism. J ClinEndocrinolMetab2011;96:459–467
46. So Lim, Jae Hyun Bae, Eun Ju Chun et al. Differences in pancreatic volume, fat content, and fat density measured by multi detector-row computed tomography according to the duration of diabetes. Springer link, 2014;51: 739–748,.
47. Glaser J, Stienecker K. Pancreas and aging: a study using ultrasonography. Gerontology. 2000; 46:93–96.
48. Wu WC, Wang CY. Association between non-alcoholic fatty pancreatic disease (NAFPD) and the metabolic syndrome: case-control retrospective study. Cardiovasc Diabetol. 2013; 12:77:84.
49. Noronha M, Salgadinho A, Ferreira De Almeida MJ, Dreiling DA, Bordalo O. Alcohol and the pancreas. I. Clinical associations and histopathology of minimal pancreatic inflammation. Am J Gastroenterol. 1981; 76:114–119.