ORIGINAL PAPER

Correlation of Ultrasound and Computed Tomography Measurements of the Pancreas in a Normal Adult Nigerian Population

Hyginus N Arua[1], Felicitas U Idigo[1], Chioma L Arua[2]

[1]Department of Medical Radiography and Radiological Sciences, University of Nigeria, Nsukka, Enugu state, Nigeria

[2]Department of Radiology, University of Ilorin Teaching Hospital, Ilorin, Kwara state, Nigeria

ABSTRACT

Background Abdominal ultrasound and computed tomography (CT) utilization in pancreatic imaging has been found invaluable in the evaluation of pancreatic lesions. Although the gold standard modality for imaging of pancreas, CT is fraught with the limitations of radiation risk, cost and availability. Ultrasound (US) imaging of the pancreas is cost effective, readily available with no radiation risk but it is operator-dependent and limited by bowel gas. Comparative study of CT and US biometry of pancreas in normal adult population in Lagos State Nigeria has not been established. **Method** A prospective cross-sectional study of 150 apparently normal adult patients who underwent both CT scan and ultrasonography (US) at Clinix Healthcare Ilupeju, Lagos State, and who met the inclusion criteria, was carried out. Anterior-posterior (AP) dimensions of the pancreatic head, body and tail were obtained at right angles to the longitudinal axis of the organ. **Results** On US, the mean AP dimensions of the pancreas head, body, and tail in the studied population were 25.10 ± 2.75 mm, 15.98 ± 1.86 mm, and 13.50 ± 1.53mm respectively. On CT, the mean ± SD AP pancreas dimensions of head, body, and tail in the studied population were 26.77 ± 2.68 mm, 21.19 ± 2.12 mm, and 17.25 ± 2.12mm respectively. **Conclusion** AP dimensions of the pancreas segments measured on CT were significantly larger than that measured on US (P= 0.000), and CT is better modality in demonstration of pancreas segments especially the tail.

INTRODUCTION

Pancreas is an elongated, accessory retroperitoneal organ that lies between the duodenum on the right and the spleen on the left [1]. Increasing age is associated with reduction in size of body, tail and volume of the pancreas [2, 3]. During childhood and adolescence, the volumes of the total pancreas, pancreatic parenchyma and fat increase linearly with age [4]. From age 20 – 60years, pancreas volume reaches a peak and start declining afterwards [4, 5, 6, 7]. Mentioned in many studies is the relationship between pancreas size, ethnicity, body weight, genetic makeup and nutritional status [8, 9, 10]. Pancreatitis is one of the commonest pancreatic pathology encountered in clinical practice, and early detection significantly reduces the mortality and morbidity [11]. Pancreatic cancer is the twelfth most common cancer in the world [12] and fourth leading cause of cancer deaths in both men and women [9]. Attempts had been made to demonstrate the effect of

certain diseases like diabetes mellitus type 1 & 2 on the pancreas [13, 14, 15, 16].

Radiological imaging of pancreas is important tool in early detection and staging of pancreatic diseases. Diagnosing pancreatic lesion requires multimodality approach [17, 18]. Abdominal ultrasound and computed tomography (CT) are the most frequently used modalities in evaluation of pancreatic lesion [19, 11]. Abdominal ultrasound is widely available, even in developing countries and it is non- invasive and inexpensive with no risk of radiation effect or adverse effect of contrast agent [20, 21]. Although the anatomical position of pancreas, overlying bowel gas and level of sonographer's experience pose difficulties in ultrasound imaging of pancreas [22], it is usually the first choice imaging modality [19, 23].

Since introduction of CT in late 1970's, it has found wide application in radiological investigations [24, 25]. Contrast-enhanced multi-slice CT remains the gold standard in imaging acute pancreatitis and pancreatic cancer [26, 27, 28, 29], significantly better than ultrasound in demonstration of pancreas body and tail [30]. Unlike developed countries, CT is not readily available in Nigeria [31, 32]. The cost of diagnostic CT examinations is a limitation to its utilization in developing countries [33]. In spite of the benefit of CT in imaging of pancreas, it has associated radiation dose risk [34].

In view of the risk of radiation associated with CT and limitations of ultrasound imaging of the pancreas, it is

paramount that a study to compare pancreatic biometry on both modalities be carried out to validate ultrasound findings. Therefore, this study is to evaluate the pancreas in normal adult Lagos population using computed tomography and ultrasonography.

METHODS

Using convenient sampling method, 150 adult outpatients were prospectively scanned using both abdominal CT and US scans at Clinix Healthcare, Alhaji Adejumo Avenue, Ilupeju, Lagos State. Ethical approval was obtained from the relevant Research and Ethics Committee board. Informed consent was obtained from each of the patients that consented to participate in the study before commencement of scan. Absolute patient confidentiality was observed. Only patients who met the inclusion criteria were included in the study. Exclusion criteria were patients younger than 20 years and/or with a past or present history of pancreatico-biliary disorders including diabetes mellitus, and patients with abnormal findings like presence of CT signs of any pancreatic or peri-pancreatic pathology, presence of ascites or abdominal mass compressing on pancreas, scan error or artefact that would interfere with the ability to recognize the pancreatic contour, scan with inadequate opacification of the duodenum, and patient with limited ultrasound visualization of pancreas segments. On the whole, 83 cases did not qualify for inclusion based on the exclusion criteria and were thus excluded.

The CT scans were performed on 64-slice Siemens SOMATOM perspective CT scanner machine with the following product features: Cardiac imaging with rotation time of 33s, Isotropic special resolution of 24 mm, Spiral artifact free imaging, STRATON high performance CT x-ray tube, Z-sharp technology, and UFC detectors. Ultrasound scans were carried out using SonoAce X8 (Medison inc., Korea 2015) ultrasound machine with 3.5MHz curvilinear probes. The transducer gain control was adjusted to optimize visualization of the entire pancreas. Body weight measurement was made with a weight scale (RGZ- 160) manufactured in the year 2015 by Health & Medical Equipment, England. Its weight range is 0 –160 kgs. Standing height was measured with a stadiometer (seca 213) manufactured in the year 2008 by seca gmbh & co.kg, Germany. The measuring range in cm is 20-205cm. Abdominal circumference was measured with measuring tape. Uni-dimensional measurements of the pancreas head, body, and tail were taken on both CT and US. All the measurements were recorded in a prepared data sheet. AP diameters of pancreas head, body and tail were obtained from same patients on Ultrasonography and Computed Tomography.

The CT measurements were taken from the advantage workstation, operator consul, of the CT machine. A scanogram/scout was obtained to determine the range of the scan for the procedure. In most cases, pre-contrast, contrast and delay protocols were obtained. Pancreas segments dimensions were taken for patients that met the inclusion criteria after review by experienced radiologist.

All measurements were obtained from the axial CT images through the middle of the pancreatic head, body and tail. Anterior-posterior (AP) dimensions were measured at right angles to the longitudinal axis of the organ. The largest diameter of the pancreas lying to the left of the middle of the vertebral body was considered the head. The head was measured on the scan slice that had the plumpest pancreatic head. The body of the pancreas was measured on the left margin of the vertebral body and the tail opposite to the medial margin of the left kidney. The transverse diameter of the adjacent vertebral body was used as a reference as applied by Heuck *et al.* [5].

On ultrasound, patients were positioned in supine position. Longitudinal scan (scout) of the epigastric region was performed to identify the major upper abdominal vessels such as aorta, coeliac axis, superior mesenteric artery and vein, and splenic vein. Although the level of pancreas body was identified in longitudinal scan, pancreas itself was not clearly demonstrated. Transverse trans-abdominal scans of the pancreas were performed at a level 2.5-5 centimetres below the xyphisternum (20 - 30° cranially) with the left lobe of the liver serving as acoustic window into the pancreatic bed. Abdominal aorta, inferior vena cava, superior mesenteric vein (SMV), portal vein, and splenic vein were used as landmarks. In general, to improve visualization of the pancreas, especially in cases where it was poorly seen with the patient supine, the water technique was used whereby patient drank some water to displace stomach gas and provide acoustic window into the pancreas. In some cases, semi-erect position was adopted to displace epigastric bowel gas. The pancreatic tail was imaged in the diagonal coronal plane with the patient in the supine (30–45°) right posterior oblique position. Some examinations were performed with patient in the decubitus position. Change in position helped to overcome difficulties arising from bowel gas [35]. AP Pancreas head, body and tail dimensions were measured using technique adopted by Meire & Farrent [36].

Assessment of intra-observer and inter-observer reliability was performed. Thirty patients who met the inclusion criteria were selected to evaluate the reliability of the measurements of the pancreas segments, both on CT and US scans technique. Two independent radiologists with more than ten years' experience, each made two different measurements of the pancreas segments for each patient, both on CT and US scans technique. They were blinded to each other's results for all the subset. The measurements were subjected to paired sample T-test and showed no significant difference in intra-observer reading and inter-observer reading for the two modalities.

The collected data was categorized according to patient's age and sex, height, weight, BMI, and abdominal circumference (AC). All data obtained in the study was documented and analysed using SPSS version 23 for windows. Descriptive statistics, mean ± standard deviation (SD), maximal (Max), and minimal (Min) values were used. Independent samples t- test was used to estimate the sex-related differences.

Pearson's correlation coefficient was used to evaluate the correlations of the size of the pancreas with the subject's age, and parameters of body character. P-value of less than 0.05 was considered to be statistically significant. Linear regression models were performed between the variables.

RESULTS

Table 1 showed that the mean age, height, weight, AC, and BMI of the subjects were 48yrs, 161cm, 73Kg, 95cm and 28 Kg/cm^2 respectively.

It can be seen from **Table 2** that on US, the mean AP diameter of the pancreas head, body, and tail in the studied population were 25.10 ± 2.75 mm (Range: 18.80 – 30.50 mm), 15.98 ± 1.86mm (Range: 10 – 20 mm), and 13.50 ± 1.53 mm (Range: 10 – 17 mm) respectively. On CT, the mean ± SD AP pancreas diameters of head, body , and tail in the studied population were 26.77 ± 2.68 mm (Range : 21.40 – 32.30 mm), 21.19 ± 2.12 mm (Range: 16.20 – 25.50mm), and 17.25 ± 2.12   mm (Range: 11.5 – 22.20 mm) respectively.

Table 1. Descriptive Statistics of the subjects' biometric variables (Age, height, weight, BMI, Abdominal Circumference (AC)).

Variables	N	Minimum	Maximum	Mean	SD
AGE	150	23.00	82.00	48.6800	13.57273
HEIGHT	150	150.00	183.00	161.4780	8.32552
WEIGHT	150	42.60	102.40	72.8467	12.05887
AC	150	68.70	129.50	95.0107	12.92954
BMI	150	18.39	44.20	28.0128	5.14411

Table 2. Descriptive Statistics of US and CT pancreas segments measurements.

Segments of pancreas	Head	Body	Tail
No of patients	150	150	150
Ultrasound measurements (mm)			
Minimum	18.80	10.00	10.00
Maximum	30.50	20.00	17.00
Mean	25.1015	15.9825	13.5038
SD	2.74697	1.86875	1.53388
CT Measurements (mm)			
Minimum	21.40	16.20	11.50
Maximum	32.30	25.50	22.20
Mean	26.7667	21.1888	17.2553
SD	2.68592	2.11979	2.12001

Table 3. Independent Samples Test between subject biometric parameters, US pancreas measurements and CT pancreas measurements against gender of subjects.

Variables	Gender of subjects		T-test	P value
	Male	Female		
Biometric parameters				
AGE	48.98 ± 13.43	48.52 ± 13.72	0.204	0.839
HEIGHT	165.86 ± 8.01	158.96 ± 7.27	5.430	0.000
WEIGHT	72.22 ± 8.45	73.21 ± 13.82	-0.489	0.626
AC	91.91 ± 14.09	96.31 ± 16.38	-1.680	0.095
BMI	26.41 ± 3.50	29.10 ± 5.61	-3.247	0.001
CT measurements				
HEAD	26.89 ± 2.85	26.72 ± 2.54	0.370	0.712
BODY	21.53 ± 2.33	20.98 ± 1.96	1.559	0.121
TAIL	17.60 ± 1.91	17.04 ± 2.21	1.575	0.117
US measurements				
HEAD	25.59 ± 2.95	24.75 ± 2.56	1.846	0.067
BODY	15.92 ± 2.36	16.02 ± 1.50	-0.314	0.754
TAIL	13.78 ± 1.50	13.33 ± 1.53	1.760	0.081
Independent Samples t- test between CT & US pancreatic measurements				
HEAD				
US	25.0749	2.73805	-5.492	0.000
CT	26.7867	2.65973		
BODY				
US	15.9825	1.86875	-22.564	0.000
CT	21.1888	2.11979		
TAIL				
US	13.5038	1.53388	-17.559	0.000
CT	17.2553	2.12001		

Table 3 showed that male subjects were significantly taller than the female subjects (P< 0.001). Also, BMI values of female subjects are significantly greater than that of male subjects (P< 0.005). The mean pancreatic size measurements in males were larger than in females but the variation between the genders was not significant. It also showed that Pancreas segments dimensions measured on CT were significantly larger than that measured on US. The result of independent samples T-Test revealed that only height and BMI of the subjects were significantly different between the genders (p<0.05). Independent sample t-test performed between US values and CT values showed that diameters of the pancreas segments measured on CT were significantly larger than that measured on US (P= 0.000).

From the correlation analysis table, it can be seen that for US measurements: Age showed strong correlation with pancreas size; Pancreas head diameter correlated well with subjects' height; Pancreas head and tail correlated with weight and; Pancreas body diameter correlated with AC and BMI (P<0.05). For the CT measurements, it was observed that: Age showed strong correlation with pancreas size; Pancreas head and tail diameters correlated well with subjects' height and; Pancreas tail correlated with weight (P<0.05). It was also shown from the regression equations that there is linear relationship between the pancreatic size and patient age (years), height (cm), Abdominal Circumference (cm), weight (kg), and BMI **(Table 4)**.

ANOVA test performed to compare the mean of measured AP diameters of pancreas segments on US and CT according to age groups showed significant difference at P < 0.05. Pancreas head, body, and tail diameter were noted to differ between the age groups and to decline from age 60years and above.

It can be observed that there is linear relationship between ultrasound and CT pancreas measurements for all the pancreatic segments. Equations were established between pancreas diameters measured on CT and US:

US pancreas head size = 15.69 + 0.3501 x CT pancreas head size.

US pancreas tail size = 9.31 + 0.2655 x CT pancreas tail size.

US pancreas body size = 17.20 + 0.0898 x CT pancreas body size.

DISCUSSION

Clinical examinations and routine radiological method of evaluating pancreas are insensitive and non-specific in diagnosis [37]. Other methods of evaluating the pancreas such as endoscopic retrograde cholangiography (ERCP), pancreatic arteriography, Percutaneous transhepatic cholangiography have improved sensitivity and accuracy but they are invasive procedures [37]. Ultrasonography (US) and computed tomography (CT) of the pancreas provide better and higher quality pancreas imaging and thus, are the most frequently used modalities in evaluation of pancreatic lesions [19, 11].

This study was carried out to compare normal US and CT biometry of pancreas segments in normal Lagos State adult population. Comparative study of pancreas size measurements on US and CT showed that CT is better modality in demonstration of pancreas segment especially the tail in accordance with the findings of Kolmannskog *et al.* [32]. Independent Sample T-Test performed between US values and CT values showed that diameters of the pancreas segments measured on CT were significantly larger than that measured on US (P= 0.000) **(Table 1)**. The difference could be attributed to inclusion of splenic veins and superior mesenteric veins to the diameter of pancreas measured on CT. US was more effective in distinguishing pancreas from surrounding vessels. This agreed with the work of Kolmannskog *et al.* [32] who compared pancreas segment diameters measured on CT and US on same patients. They included 47 patients in the study **(Table 5, 6)**. Paivansalo [38] measured

Table 4. Pearson Correlation between US and CT Pancreas measurements and the biometric variables and Predictive equation of Regression between US Pancreas measurements and the biometric variables.

Subject biometric variables	Pancreatic segments (US) ULTRASOUND MEASUREMENTS			Predictive equation of Regression
	HEAD	BODY	TAIL	
AGE	0.001**	0.002**	0.020*	$y = -0.051x + 27.58$ ($R^2 = 0.065$)
HEIGHT	0.019*	0.247	0.113	$y = 0.5507x + 14.67$ ($R^2 = 0.0328$)
WEIGHT	0.001**	0.056	0.001**	$Y = 0.055x + 21.068$ ($R^2 = 0.0586$)
AC	0.819	0.034*	0.779	$y = 1.2008x + 75.819$ ($R^2 = 0.0301$)
BMI	0.202	0.005**	0.671	$y = 0.0826x + 13.67$ ($R^2 = 0.0517$)
	COMPUTED TOMOGRAPHY MEASUREMENTS			
AGE	0.000**	0.000**	0.015*	
HEIGHT	0.035*	0.619	0.042*	
WEIGHT	0.382	0.171	0.036*	
AC	0.879	0.733	0.951	
BMI	0.154	0.271	0.588	

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

pancreas size on US and CT in 70 patients without pancreas disease and reported that in 87% of the cases, pancreas segments diameter measured by CT were thicker than by US. However, he maintained that US was more effective in distinguishing pancreas parenchyma from the surrounding retroperitoneal fat and vessels. Equations (I, ii, iii) were established between pancreas dimensions measured on CT and US **(Figures 1-5)**.

Table 5. ANOVA test between mean CT pancreas segments sizes across age groups.

Pancreatic segments	US		CT		Predictive equation of Regression
	F	P-value	F	P-value	
HEAD	5.416	0.000	6.901	0.000	$Y = 0.3501x + 15.69$ ($R^2 = 0.1156$)
BODY	13.593	0.000	5.817	0.000	$Y = 0.2698x + 10.42$ ($R^2 = 0.0888$)
TAIL	4.360	0.001	3.933	0.002	$Y = 0.2155x + 9.82$ ($R^2 = 0.087$)

Table 6. Regression and T-test analysis of measurements of the pancreatic segments between ultrasound and computed tomography.

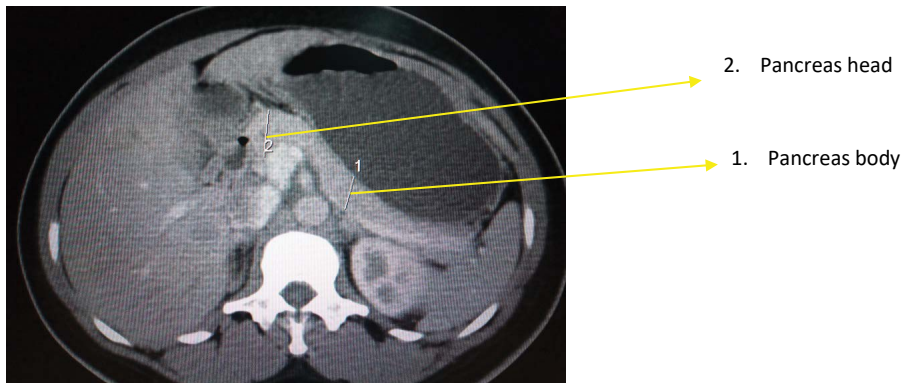| Regression/Variables	Sample size	T-test	P-value	Predictive equation of Regression
Ultrasound and CT pancreatic Head size	150	-5.492	0.000	$Y = 0.3501x + 15.69$ (R2 = 0.1156)
Ultrasound and CT pancreatic Body size	150	-22.564	0.000	$Y = 0.2698x + 10.42$ (R2 = 0.0888)
Ultrasound and CT pancreatic Tail size	150	-17.559	0.000	$Y = 0.2155x + 9.82$ (R2 = 0.087)

2. Pancreas head

1. Pancreas body

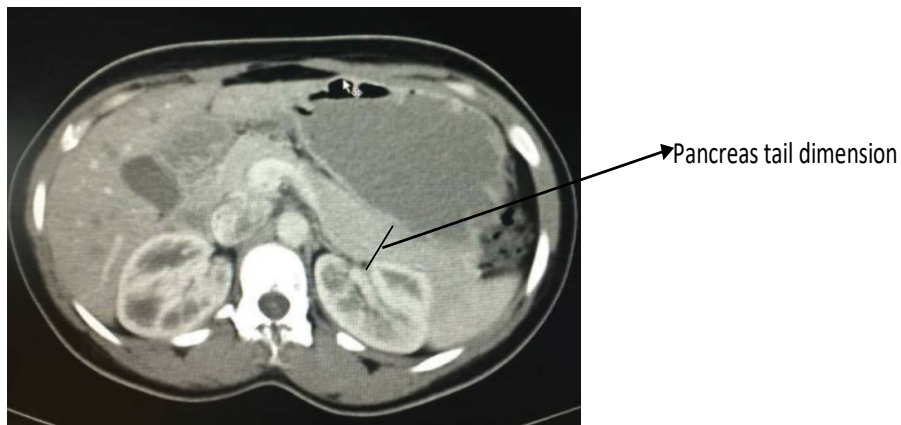**Figure 1.** AP Pancreas head and body dimensions on CT.

Pancreas tail dimension

Figure 2. AP Pancreas tail dimension on CT.
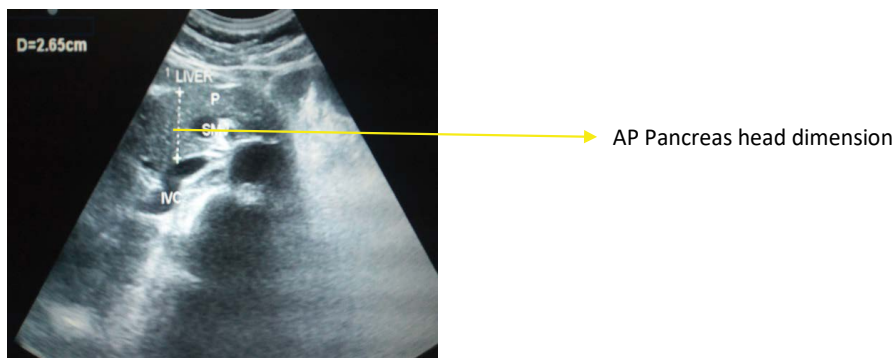

AP Pancreas head dimension
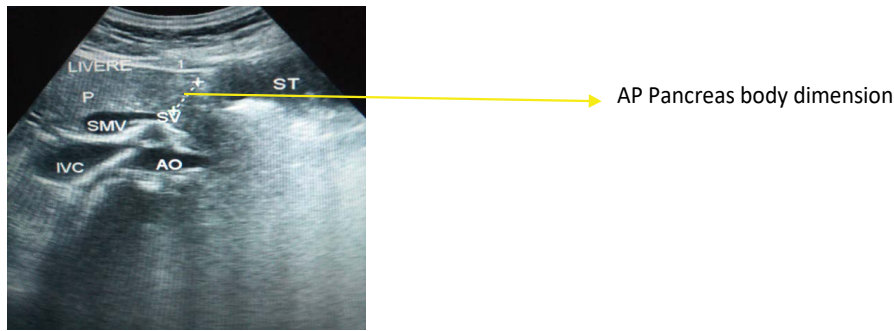
Figure 3. AP Pancreas head dimension on US.
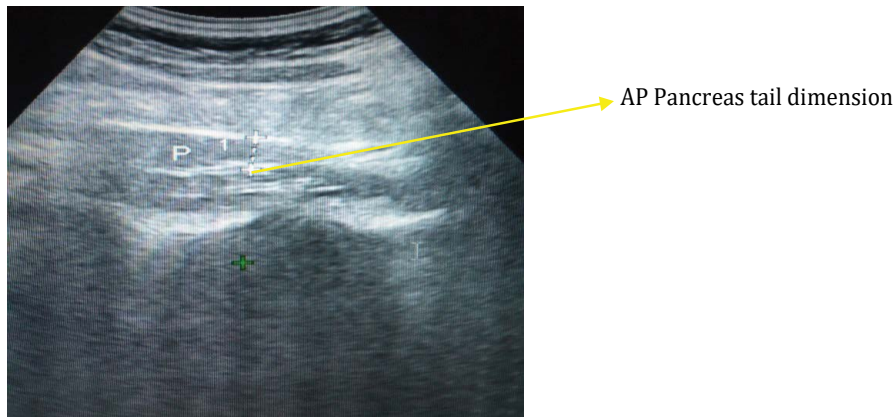
Figure 4. AP Pancreas body dimension on US.

Figure 5. AP Pancreas tail dimension on US.

US pancreas head size = 15.69 + 0.3501 x CT pancreas head size......(i)

US pancreas body size = 10.42 + 0.2698 x CT pancreas body size......(ii)

US pancreas tail size = 9.82 + 0.2155 x CT pancreas tail size.........(iii)

CONCLUSION

Dimensions of the pancreas segments measured on CT were significantly larger than that measured on US (P= 0.000). Ultrasound was more effective in distinguishing pancreas from surrounding vessels.

Conflict of interest

There is no conflict of interest.

References

1. Parson SH. Clinically Oriented Anatomy, 6th edn. J Anat 2009; 215:474. [PMICID: PMC2766067]

2. Syed AB, Mahal RS, Schumm LP, Dachman AH. Pancreas size and volume on computed tomography in normal adults. Pancreas 2012; 41:589-95. [PMID: 22158073].

3. Sato T, Ito K, Tamada T, Sone T, Noda Y, Higaki A, et al. Age-related changes in normal adult pancreas: MR imaging evaluation. Eur J Radiol 2012; 81:2093-8. [PMID: 21906894].

4. Saisho Y, Butter AE, Meier JJ, Monchamp T, Allen-Auerbach M, Rizza RA, et al. Pancreas volumes in humans from birth to age one hundred taking into account sex, obesity, and presence of type -2 diabetes. Clinical Anatomy 2007; 20: 933-42.

5. Heuck A, Maubach PA, Reiser M, Feuerbach S, Allgayer B, Lukas P, et al. Age-related morphology of the normal pancreas on computed tomography. Gastrointest Radiol 1987; 12:18-22. PMID: 3792751].

6. David AS, Paul SB. Paediatric Gastrointestinal imaging and intervention, 2nd edn. 699.

7. Caglar V, Songur A, Yagmurca M, Acar M, Toktas M, Gonul Y. Age-related volumetric changes in pancreas: a stereological study on computed tomography. Surg Radiol Anat 2012; 34:935-41. [PMID: 22684677]

8. Chao HC, Lin SJ, Kong MS, Luo CC. Sonographic evaluation of the pancreatic duct in normal children and children with pancreatitis. J Ultrasound Med 2000; 19:757-63. [PMID: 11065264].

9. Yadav D, Lowenfels AB. The epidemiology of pancreatitis and pancreatic cancer. Gastroenterology 2013; 144:1252-61. [PMID: 23622135]

10. Hassan AF, Ayad CE, Ebrahim TEM, Abdalla EA. Characterization of pancreas in Sudanese population of computed tomography. Int J Biomed Imaging 2014; 2:199-124.

11. Ullal S, Joshi KS, Pant P. Computed Tomographic Evaluation of Pancreatitis and its complications. Pictoral review. Nepal J Med Sci 2012; 1:123-131.

12. Ferlay J, Soerjomataram I, Dikshit R, Eser S, Mathers C, Rebelo M, et al. Cancer incidence and mortality worldwide: sources, methods and major patterns in GLOBOCAN 2012. Int J Cancer 2015; 136:E359-86. [PMID: 25220842]

13. Alzaid A, Aideyan O, Nawaz S. The size of the pancreas in diabetes mellitus. Diabet Med 1993; 10:759-63. [PMID: 8261759]

14. Vesterhus M, Haldorsen IS, Raeder H, Molven A, Njølstad PR. Reduced pancreatic volume in hepatocyte nuclear factor 1A-maturity-onset diabetes of the young. J Clin Endocrinol Metab 2008; 93:3505-9. [PMID: 18593771]

15. Acar M, Degirmenci B, Tatli S. Short pancreas: evaluation with multi-detector row CT. Surg Radiol Anat 2010; 32:853-8. [PMID: 20165948]

16. Agabi JO, Akhigbe AO. Comparative sonographic evaluation of the anteroposterior dimensions of the pancreas in diabetics and nondiabetics. Niger J Clin Pract 2016; 19:175-81. [PMID: 26856277]

17. Catalano C, Laghi A, Fraioli F, Pediconi F, Napoli A, Danti M, et al. Pancreatic carcinoma: the role of high-resolution multislice spiral CT in the diagnosis and assessment of resectability. Eur Radiol 2003; 13:149-56. [PMID: 12541123]

18. Chaudhary V, Bano S. Imaging of the pancreas: Recent advances. Indian J Endocrinol Metab 2011; 15(Suppl 1):S25-32. [PMID: 21847450]

19. Tummala P, Junaidi O, Agarwal B. Imaging of pancreatic cancer: An overview. J Gastrointest Oncol 2011; 2:168-74. [PMID: 22811847]

20. Rickes S, Unkrodt K, Neye H, Ocran KW, Wermke W. Differentiation of pancreatic tumours by conventional ultrasound, unenhanced and echo-enhanced power Doppler sonography. Scand J Gastroenterol 2002; 37:1313-20. [PMID: 12465731]

21. Abam RO, Nwankwo NC. Sonographic measurement of the antero-posterior diameter of the head of pancreas in normal adult population in Port- Harcourt, South- South Nigeria. J Med Medical Sci 2011; 2:1162-117.

22. Sirli R, Sporea I. Ultrasound examination of the normal pancreas. Med Ultrason 2010; 12:62-5. [PMID: 21165455]

23. Lalith S, Ilangovan G. Comparative study of ultrasonography and computed tomography in diagnosis of acute pancreatitis. Inter J Contem Med Surg Rad 2019; 4:C28-C33

24. Lower AS, Kay CL. Recent Development in CT: Review of the clinical applications and advantages of multi-detector CT. Imaging 2006; 18: 62-67.

25. Brenner DJ, Hall EJ. Computed tomography--an increasing source of radiation exposure. N Engl J Med 2007; 357:2277-84. [PMID: 18046031]

26. Patel SV, Spencer JA, el-Hasani S, Sheridan MB. Imaging of pancreatic trauma. Br J Radiol 1998; 71:985-90. [PMID: 10195019]

27. Von-Hoff DD, Evans DB, Hruban RH. Pancreatic cancer. Endoscopic staging: EUS, ERCP. Sudbury: Jones and Bartlett Publishers. 2005; 181–190.

28. William RJ. Blumgant's Surgery of liver pancreas and biliary tract. 2012; 843.

29. Hirota M, Satoh K, Kikuta K, Masamune A, Kume K, Hamada S, et al. Early detection of low enhanced pancreatic parenchyma by contrast-enhanced computed tomography predicts poor prognosis of patients with acute pancreatitis. Pancreas 2012; 41:1099-104. [PMID: 22699199]

30. Kolmannskog F, Swensen T, Vatn MH, Larsen S. Computed tomography and ultrasound of the normal pancreas. Acta Radiol Diagn (Stockh) 1982; 23:443-51. [PMID: 7158408]

31. Erondu OF, Okoro CR, Aniemeka JI, Ugwu AC. Patterns of CT referrals among physicians in the South-South region of Nigeria. American J Sci Indus Res 2011; 2:482-487.

32. Uduma UF, Eduwem UD, Obong VJ. 288 Pioneer Computed Tomographic Examinations in University of Uyo Teaching Hospital, Uyo, Nigeria. Int J Trop Dis Health 2014; 4:233-243

33. Saini S, Sharma R, Levine LA, Barmson RT, Jordan PF, Thrall JH. Technical cost of CT examinations. Radiology 2001; 218:172-5. [PMID: 11152797]

34. Shrimpton PC, Hillier MC, Lewis MA, Dunn M. National survey of doses from CT in the UK: 2003. Br J Radiol 2006; 79:968-80. [PMID: 17213302]

35. Muffin J. The Pancreas. In: David Sutton editor. Text book of Radiology and Medical Imaging. Churchill Livingstone, Edinburgh 2007.

36. Meire HB, Farrant P. Pancreatic ultrasound--a systematic approach to scanning technique. Br J Radiol 1979; 52:562-7. [PMID: 465941]

37. Lee JK, Stanley RJ, Melson GL, Sagel SS. Pancreatic imaging by ultrasound and computed tomography: a general review. Radiol Clin North Am 1979; 17:105-117. [PMID: 461738]

38. Päivänsalo M. Normal pancreatic echogenicity: relation to structural unevenness and thickness in CT. Ann Clin Res 1984; 40:69-71. [PMID: 6732175]