

# Sonographic Determination of the Pancreatic Duct Diameter among Healthy Individuals in Gaborone, Southeast District, Botswana

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**Abstract:-** The pancreatic duct is an intrapancreatic restricted tube that connects the pancreas to the common bile duct. The pancreatic duct transports pancreatic juice to the common bile duct for digesting. Pancreatic duct diameter is an important index in assessing pancreatic duct pathology as well as the pancreas. Duct obstruction may lead to dilatation due to cancer of the pancreas, pancreatitis, cholelithiasis or duodenal pathology. Recent studies have established a direct relationship between dilatation of the pancreatic duct and cancer of the pancreas. The objective of this study is to determine the pancreatic duct diameter in apparently healthy individuals in Gaborone and its relationship with anthropometric variables.

Sonographic determination of the pancreatic duct diameter is very important for providing an objective evaluation of the pancreas and the nature and extent of disease if pathologic. Establishment of a baseline reference value for the pancreatic duct diameter is therefore important for providing a normogram in healthy individuals in Gaborone, Botswana. A total of 384 randomly selected individuals and 330 pancreatic duct diameter measurements were used for the study between July 2020 and May 2021. Optimum sonographic scanning technique described by Taylor *et al* was utilized in measuring the pancreatic duct diameter in this study. The mean pancreatic duct diameter was:  $2.40 \pm 0.58$ mm for the head,  $2.10 \pm 0.50$ mm for the body and  $1.84 \pm 0.54$ mm for the tail. The mean pancreatic duct diameter for the present study was  $2.11 \pm 0.50$ mm. The pancreatic duct diameter increased with age from 45 years, indicating statistically significant relationship (P-value=0.0492). There was no significant statistical difference in the overall mean pancreatic duct diameter between male and female ( $p > 0.05$ ).

The present study has established that the pancreatic duct diameter for adults in Gaborone is  $2.11 \pm 0.50$ mm and could be used in clinical setting as baseline reference value. The normogram also will be a valuable tool in age related pancreatic duct pathologies.

**Keywords:-** Pancreatic Duct Diameter, Sonographic Determination.

## I. INTRODUCTION

The pancreas is a retro-peritoneal, heterocrine, non-encapsulated glandular organ with endocrine and exocrine functions (Juza *et al*, 2019). As an endocrine gland, it functions to regulate blood sugar, secrete insulin, glucagon, somatostatin, vasoactive intestinal polypeptide, and serotonin (Hobbs *et al*, 2016). While as an exocrine gland, it secretes digestive enzymes such as amylase, lipase, trypsin, and chymotrypsin into the duodenum through the pancreatic duct (Gyanprakash *et al*, 2019). This pancreatic fluid contains digestive enzymes that break down carbs, proteins, and lipids in food that enters the duodenum from the stomach, as well as bicarbonate, which neutralises acid. Pancreatic enzymes are secreted by a network of ducts that discharge into the duodenum via the Wirsung and Sartorini major and accessory pancreatic ducts (Joseph *et al*, 2019).

Locating and measuring the pancreatic duct in real time provide invaluable information about the health status and prognosis of the pancreas. The pancreas is spongy in texture and measures about 15cm to 25cm in length, with the shape of a flat pear or a fish placed transversely across the upper abdomen; at the level of the first lumbar vertebra. The pancreas is separated into the head, neck, body, and tail, with measurements of around 1.7-3.5cm for the head, 1-2cm for the body, and 1.6-2.5cm for the tail (Joseph *et al*, 2019).

The pancreatic duct measures about 2mm - 3mm in mean AP diameter and 184mm in mean length (Joseph *et al*, 2019). Dilatation of the pancreatic duct may be an indication of obstruction of the normal flow of pancreatic secretions and pancreatic pathology. This can occur in acute and chronic pancreatitis as well as in cancer of the pancreas (Lamps and Kakar 2017). This suggests that slight dilatation of the major pancreatic duct increases the risk of pancreatic cancer.

## II. STATEMENT OF PROBLEM

The pancreatic duct is the channel through which pancreatic juice is secreted into the duodenum for the breakdown of carbohydrates, proteins and fat. Change in the pancreatic duct diameter is an indication of pathology within the organ and may be caused by obstruction or luminal stricture of the main or accessory pancreatic duct

(Wang, 2011). Pathologies such as pancreatic cancer, pancreatic duct calculi, and pancreatitis affect the pancreatic duct diameter, and impact its functions. Studies have established a linear relationship between dilatation of the pancreatic duct and pancreatic pathology (Raman, 2012). Identifying and determining the pancreatic duct diameter is therefore very important for providing objective assessment of the health status of the pancreas and the nature and extent of disease if pathologic (Kim 2010).

Sonographic determination and assessment of the main pancreatic duct is invaluable because dilation of the pancreatic duct may be the principal and early detectable sonographic feature in patients with pancreatic disease and a predictor of pancreatic pathology, treatment, and prognosis. Determination of a baseline reference value for the pancreatic duct diameter is important for providing a normogram in healthy individuals in Gaborone since none is currently available. The present study is therefore aimed at determining the pancreatic duct diameter of the adult population in Gaborone and compares same with results from other populations.

#### ➤ General Objective of the Study

To determine the sonographic baseline values of the pancreatic duct diameter in healthy adult population in Gaborone.

#### ➤ Specific Objective of the Study was to

- Determine the pancreatic duct diameter of the head, body, and tail of the pancreas.
- Correlate the pancreatic duct diameter with age, weight, and BMI.
- Determine differences in the pancreatic duct diameter according to sex.
- Develop a regression equation with the pancreatic duct diameter and body biometry.

### III. LITERATURE REVIEW

#### ➤ Embryology of the Pancreas

According to Susan Bonner-Weir (2016), the pancreatobiliary anlagen begin to form in the fifth week of pregnancy and fuse with the ventral anlagen in the seventh week. The acinar tissue fully develops throughout the postnatal period. The dorsal and ventral pancreatic buds emerge from the primitive foregut at the beginning of pancreatic development (Suzanne, 2019). The dorsal and ventral buds fuse together to create the pancreas. While the ventral pancreatic bud generates the caudal aspect of the head and uncinata process, the dorsal pancreatic bud forms the cranial aspect of the head, neck, body, and tail of the developed pancreas (Tadokoro et al, 2008). The biliary duct is the common origin of the ventral buds. According to Fusco (2019), the right ventral bud joins posteriorly with the inferior portion of the dorsal bud, while the left ventral bud atrophies. The dorsal duct becomes the auxiliary duct and the ventral duct the main duct.

#### ➤ Histology of the Pancreas

The pancreas is composed of two types of tissues: exocrine and endocrine. The exocrine pancreas is structurally similar to the salivary gland, with a highly branching and lobulated ductal system terminating in secretory acini (Ana, 2019). The pancreas has a flattened cuboidal epithelium that extends into the acinus lumen and forms centroacinar cells. The pancreatic acinar cells are plump, pyramidal cells that exude pancreatic zymogens, whereas the pancreatic ductal cells secrete aqueous bicarbonate-rich fluid. The endocrine pancreas is distributed throughout the pancreatic body in little ball-shaped cells known as Islets of Langerhans. The highly vascularized Islets of Langerhans comprise around 2% of total pancreatic mass and vary in size. All the three cell types are mixed within the Islet in the following percentage: Alpha cells 25%, Beta cells 60% and Delta cells 5% respectively (Chera, 2014). The secreted enzymes flow through intercalated ducts, intralobular and interlobular ducts into the duodenum through the pancreatic duct.

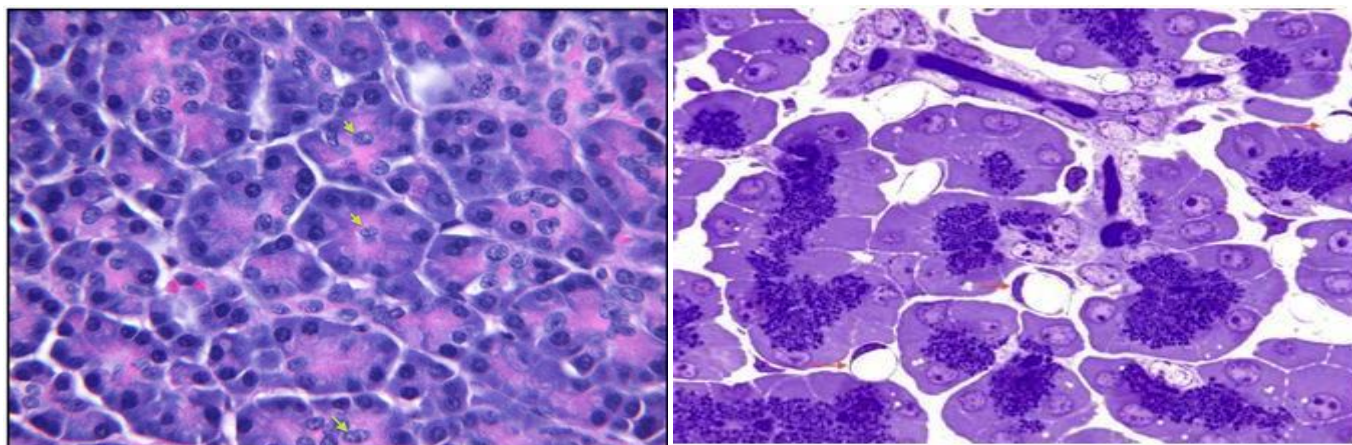


Fig 1: Because of their High RNA Content and Nuclei, Acinar Cells Stain Blue at the Base. At Their Peak, where Zymogen Proteins—Digestive Enzymes—are abundant, they Appear Pink. Sometimes, an Acinus contains the Centro Acinar Cell Nuclei (medcell.med.yale.edu, 2020).

### ➤ *Gross Anatomy*

The pancreas is an elongated, auxiliary digestive gland located retroperitoneally and transversely across the posterior abdominal wall at the level of the first lumbar vertebra (Mahadevan 2019). It is located in the anterior pararenal facial area, anterior to the aorta and inferior vena cava.

The pancreas measures about 12cm-15cm in length in adults and weighs about 60-100 grams with a lobulated shape and salmon-colored appearance (Henry, 2008). The pancreas is anatomically separated into four parts: the head, neck, body, and tail. It extends from the duodenum's inner curvature, where the head protects the superior mesenteric artery and vein. The pancreas' body extends behind the stomach, with the tail ending next to the spleen.

The tail appears slightly higher than the head. The pancreatic head lies in the concavity of the duodenum, with the pylorus and duodenal cap and wraps around the superior mesenteric artery and vein, overlapping it minimally on the upper surface. The uncinate process is situated behind the superior mesenteric vessels. The rest of the pancreatic head is located anterior to the vena cava, renal veins, aorta, and its celiac and superior mesenteric branches. The main pancreatic duct and the smaller accessory pancreatic duct flow through the pancreas' body, connecting with the common bile duct at the ampulla of Vater.

The ampulla of Vater is surrounded by the sphincter of Oddi at the point of entry into the duodenum (Joseph *et al*, 2019).

The uncinate process, which originates at the back of the superior mesenteric vein and ends at the superior mesenteric artery, protrudes from the back of the skull. The superior mesenteric vein ascends on the right side of the artery and unites with the lienal vein to produce the portal vein behind the neck, whereas the superior mesenteric artery goes left across the uncinate process. The short neck that divides the pancreatic body from the head. The neck, which is situated in front of the portal vein, is around 2 cm wide.

The pancreas is crossed by the gastroduodenal and anterior superior pancreaticoduodenal arteries, which continue where the neck and pancreatic head meet. The stomach's pylorus is primarily behind the neck.

The pancreas' main portion, the body, is mostly located near the back of the stomach. The base of the pancreatic body is located at the bottom, while the tip is located close to the upper part of the organ. The pancreatic body is triangular in shape. The aorta, splenic vein, left renal vein, and a portion of the superior mesenteric artery are among the blood vessels located behind the pancreas.

Some of the small intestine is located beneath the pancreatic body, particularly the final segment of the duodenum and jejunum, as well as the duodenal suspensory ligament (Joseph *et al*, 2019).

The pancreas narrows towards the tail, which is close to the spleen. The pancreatic tail is 1.3cm to 3.5cm long and located between the spleen and the left kidney. The splenic vein is located behind the pancreas' body and tail. Wirsung's pancreatic duct begins in the tail at the union of ductules and travels transversely towards the head, closer to the pancreas' anterior side.

It widens towards the head and acquires tributaries along the way until it joins the common bile duct at the pancreas' neck, forming the common dilated Ampulla of Vater, before entering the duodenum at the papilla. Santorini's minor pancreatic duct drains a portion of the pancreatic head and enters the duodenum around 2cm above the papilla. The common bile duct is located posterior to the pancreatic head (Joseph *et al*, 2019)

### ➤ *Blood Supply of the Pancreas*

The pancreas has a well-developed blood supply, with vessels branching off the coeliac and superior mesenteric arteries (Covantev *et al* 2019). The splenic artery travels along the pancreas' top edge, supplying the left side of the body and the pancreatic tail via pancreatic branches. The superior and inferior pancreaticoduodenal arteries run along the anterior and posterior borders of the pancreas' head, where it meets the duodenum. These supply the pancreatic head. The body and neck of the pancreas drain into the splenic vein, which is located behind the pancreas.

The head drains into and surrounds the superior mesenteric and portal veins (Henry, 2008). The pancreas excretes into lymphatic channels that run alongside the arteries. These lymphatic arteries drain primarily into pancreatic splenic lymph nodes, and some into lymph nodes positioned in front of the aorta.

### ➤ *Normal Variants of the Pancreas*

#### • *Pancreas Divisum*

The pancreas divisum is the most frequent congenital pancreatic duct anatomic variation. Autopsy results show that it affects 4-14% of the population (Zehra *et al* 2016). Pancreatic divisum develops when the dorsal and ventral pancreatic anlage do not fuse between the sixth and eighth weeks of gestation. In most cases of pancreatic divisum, the dorsal and ventral pancreatic ducts are not connected. The ventral pancreatic duct may not be present in all cases.

#### • *Annular Pancreas*

Annular pancreas is an uncommon congenital pancreatic defect that affects 0.00005% of the population (Sandrasegaran *et al.*, 2009). In the annular pancreas, a belt of pancreatic tissue entirely or partially surrounds the descending duodenum. The pancreatic tissue appears to be continuous with the head of the pancreas. The primary etiopathogenesis is that the ventral pancreatic anlage causes

the abnormality by separating into two. The annular pancreas has been associated to duodenal stenosis, post bulbular ulcerations, pancreatitis, and biliary blockage.

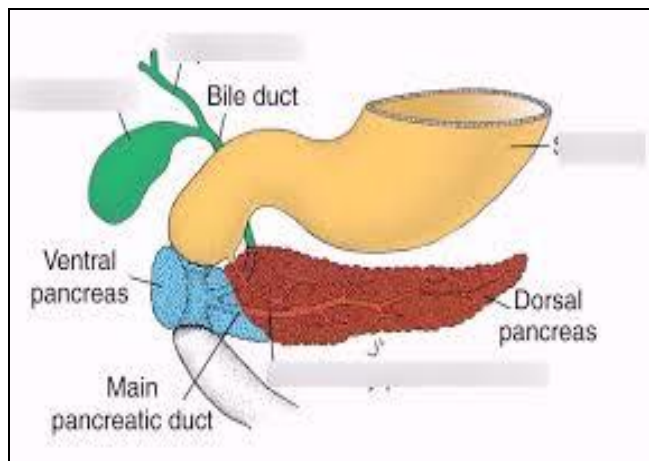


Fig 2: Front View Showing Pancreatic Tissue Encircling Descending Duodenum (quizlet.com, 2021)

- *Ectopic Pancreas*

Ectopic pancreatic tissue is an uncommon congenital pancreatic abnormality that affects 1–10% of the population. In an ectopic pancreas, the pancreatic tissue is mainly found in the submucosa of the gastric antrum or the proximal section of the duodenum. Ectopic pancreatic tissue, if functioning, is susceptible to the same inflammatory and neoplastic diseases as the natural pancreas. Ectopic pancreas manifests in the upper abdomen as an extra mucosal, smooth, broad-based mass located along the larger curvature of the gastric antrum or in the proximal duodenum. In 45% of reported cases, ectopic pancreatic tissue contains a central barium collection.

- *Pancreatic Contour Variations*

- *Pancreatic Head*

The normal pancreatic head appears smoothly outlined and contoured. However, the normal pancreatic head may sometimes show unusual contour, especially in lateral view, resembling a neoplasm. This variation is differentiated from a neoplasm by the attenuation and signal intensity of the lobular pancreas which is the same as a normal pancreatic tissue on unenhanced, arterial, and venous phase images.

- *Pancreatic Duct Variations*

The pancreatic duct exhibits a variety of anatomical differences, including ductal structure and duodenal entrance (Lucas et al, 2013). In a bifid pancreatic duct, the main pancreatic duct is divided along its length, whereas in many small auxiliary pancreatic ducts, the accessory pancreatic duct creates a loop in the pancreatic head.

- *Pancreatic Functions*

The pancreas has two key functions: exocrine, which aids digestion, and endocrine, which regulates blood sugar.

- *Exocrine Function:*

The pancreas contains exocrine glands, which create digestive enzymes. These enzymes include trypsin and chymotrypsin for protein digestion, amylase for carbohydrate digestion, and lipase for fat breakdown (Glaser et al, 2007). When food enters the stomach, pancreatic secretions exit via a network of channels that connects to the main pancreatic duct. The Vater's ampulla is formed when the pancreatic duct enters the common bile duct in the duodenum. Bile is produced by the common bile duct, which connects the liver and gallbladder. Pancreatic fluids and bile discharged into the duodenum help digestion of lipids, carbs, and proteins (Colney et al. 2021).

- *Non- Functioning and Poorly Functioning Pancreas*

Diabetes is directly related to the pancreas. The pancreas generates insulin, which is required to regulate blood sugar levels and release energy. If the pancreas does not create enough insulin or does not use the insulin it produces effectively, glucose builds in the bloodstream, starving the cells for energy. When glucose accumulates in the bloodstream, hyperglycaemia occurs. Symptoms of hyperglycaemia include thirst, nausea, and shortness of breath. Hypoglycaemia causes a variety of symptoms, including shakiness, dizziness, and loss of consciousness. Hyperglycaemia and hypoglycaemia can be life-threatening (Berra et al 2019). carbs and proteins (Colney et al, 2021).

- *Types of Diabetes*

Diabetes is a disease condition in which the body's ability to produce or respond to insulin is impaired, resulting in abnormal metabolism of carbohydrates and elevated levels of blood glucose. Diabetes is caused by non-functioning or poorly functioning pancreas and requires regular monitoring of blood glucose levels for appropriate action (Kirk and Stegner 2010).

- *Type 1 Diabetes*

In type 1 diabetes, the immune system erroneously attacks the beta cells that produce insulin in the pancreas, causing permanent damage to the pancreas and leaving the pancreas unable to produce insulin. What triggers the immune system to attack the pancreatic beta cells is still unknown, however genetic, environmental, and family history of the disease are predisposing factors. Diagnosis of type 1 diabetes is usually made during childhood or early adulthood. Type 1 diabetes is not preventable or curable. Insulin therapy is necessary because the pancreas does not function at all (Abdelalim, 2021).

- *Type 2 Diabetes*

Type 2 diabetes begins with insulin resistance. That means the body does not use insulin well, so blood glucose levels can become too high or too low. It can also mean that the pancreas is not producing enough insulin. Type 2 diabetes mostly develops due to a combination of insulin deficiency and ineffective use of insulin. Some of the predisposing factors for type 2 diabetes include genetic or environmental factors, poor diet, lack of exercise, and obesity. Treatment for type 2 diabetes involves either

reducing the blood glucose or stimulating the pancreas to produce more insulin (Belete, 2020).

➤ *Sonographic Anatomy*

The pancreas lies in the midline of the retroperitoneum behind hollow viscera, anterior to the aorta and inferior vena cava and superior to the superior mesenteric artery. The pancreas lies between the porta-splenic axis posteriorly, gastric antrum anteriorly and left lobe of the Liver. The head is cradled in the C-loop of the duodenum, and curves postero-medially around the superior mesenteric vessels. The pancreatic neck is demarcated by its anterior course over the superior mesenteric and splenic vein confluence into the portal vein. The tail of the pancreas is bordered by the splenic hilum. The superior mesenteric vessels are important landmarks that divide the pancreas into the head and body. The pancreas is surrounded and bordered by the celiac trunk superiorly, the lesser sac and the stomach anteriorly. The left lobe of the liver acts as an acoustic window into the pancreatic bed, even in obese patients.

The normal pancreatic parenchyma appears echogenic and homogeneously accentuated. The pancreatic duct appears as a thin anechoic tube with echogenic walls and measures about 2mm-2.5mm in AP diameter. Occasionally the pancreatic duct may appear as a single echogenic line within the gland. The pancreatic duct is surrounded by pancreatic tissues anteriorly and posteriorly. The pancreatic duct is visualized in 80% of normal subjects. The muscular layer of the posterior gastric wall occasionally appears as the pancreatic duct in caliber, echopattern and configuration. However, the gastric wall is differentiated from the pancreatic duct by its dynamic feature.

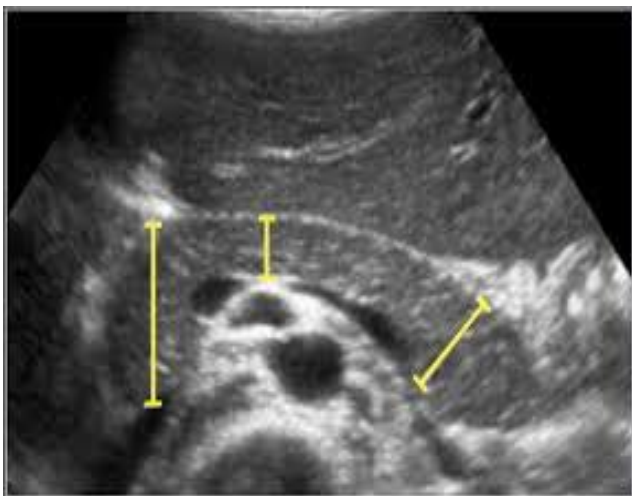


Fig 3(a): AP Diameter of Pancreas (Straight Lines). (Radiologykey.com 2020)

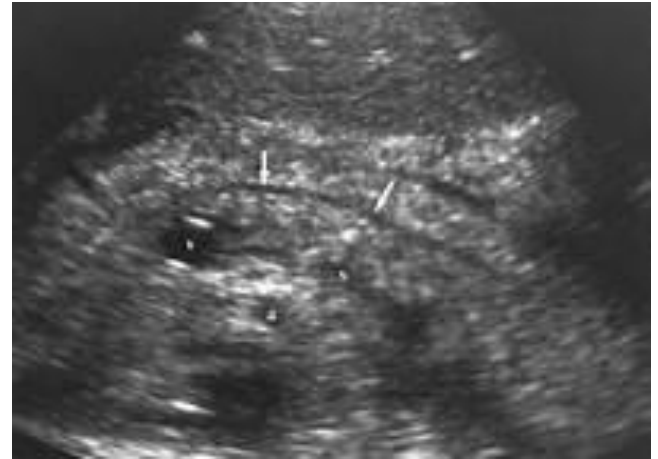


Fig 3(b): Pancreatic Duct (Small Arrow) (Radiologykey.com 2020)

**IV. RESEARCH METHODS**

The study design used was prospective experimental cross-sectional study. This study was carried out at Mall Scan Centre, Gaborone, Botswana. The study population included apparently healthy individuals between 18 and 75 years referred to Mall Scan Centre for abdominal ultrasound examination. Cochran’s formula was used to calculate the minimum sample size for this study.

$$n = \frac{z^2 pq}{e^2}$$

Where:

n= the desired sample size

z= the selected critical value of desired confidence level (1.96)

p= the estimated proportion of an attribute that is present in the population (0.5)

q= proportion of sampling error in each population = 1-p (0.5)

e= desired level of precision (0.05)

$$n_0 = \frac{(1.96)^2 (0.5) (0.5)}{(0.05)^2} = 384.16$$

A sample size of 384 individuals between the age ranges of 18 – 75years were used for this study. However, only 330 subjects qualified for the study while 54 subjects were disqualified due to non- visualization of the pancreas. Convenient sampling technique was used for this study.

➤ *Selection Criteria*

• *Inclusion Criteria*

- ✓ Apparently healthy adults aged 18 years to 75years (with normal abdominal ultrasound examination)

• *Exclusion Criteria*

- ✓ Subjects below 18 years
- ✓ Subjects with clinical history of pancreatic or liver pathology

- ✓ Subjects with history of metabolic disease
- ✓ Subjects with history of smoking
- ✓ Subjects with history of alcoholism
- ✓ Pregnancy
- ✓ Subjects with history of drug and substance abuse
- ✓ Subjects who are unable to fast for at least 6 hours.
- ✓ Subjects on certain medications (e.g. steroids)

➤ *Ethical Consideration*

Ethical approval was sought and obtained from the Ministry of Health, Botswana before data collection. Informed consent form was obtained from each volunteer participant before data collection. All collected information was solely used for this study and handled according to prescribed rule of confidentiality.

➤ *Study Equipment.*

All the ultrasound examinations were performed using a commercially available, high resolution, real time Doppler ultrasound equipment, Mindray DC-40 manufactured in 2019 by Mindray Bio-Medical Electronics Company Limited, located at Mindray Building, Keji 12th Road South, High-tech industrial Park, Nanshan, Shenzhen 518057, P.R. China. The scanning machine is incorporated with electronic calipers for accurate measurements and equipped with the following transducers: 8Y-3C5A and D7-2E convex transducers, V10-4B Endo cavitary transducer and 7L-4A linear transducer. Other materials utilised in this investigation were a balanced beam scale with an integrated height adjustable rule (seca Germany) for weight and height measurements, aqueous gel for coupling at the probe-skin interface, and a pre-prepared recording chart for logging observations.

➤ *Study Procedure.*

Before enrolling in this study, the procedures were described to the subjects, and each subject provided written informed consent. The pancreatic duct diameters were measured using high resolution, real-time doppler ultrasonography equipment, the Mindray DC-40, which was equipped with electronic callipers for accuracy. (Colney et al. 2021).

In line with the Helsinki Declaration, approval for this study was obtained from the Ethics Committee of the Ministry of Health, Botswana. Each examination was carried out in the fasting state, with the subject lying supine on a couch. Some modifications in patient preparation and scanning technique were applied; these included scanning during deep inspiration using the liver as an acoustic window, scanning in the erect position with ingested water to displace air bubbles within the gastric antrum. After application of ultrasound gel to the upper abdomen, optimum scanning techniques described by Taylor *et al* 2017 were utilized. The chosen scanning plane was parallel to the long axis of the pancreas, with each subject examined in the supine, right posterior oblique, left posterior oblique and upright positions. The pancreas was examined through sections passing above the gastric antrum, trans gastric and subgastric sections. The transducer was placed midway between the umbilicus and the xiphoid appendix, using the

acoustic windows of the high epigastric sections that avoid the colon. Starting from a longitudinal scanning plane, the pancreas was located anterior to the aorta and inferior vena cava by placing the probe in the midline and slowly moving right and then left. The probe was then directed obliquely along the longitudinal axis to show the vascular markings and then slowly moved to the left of the median sagittal plane of the body. After the longitudinal scan, the probe was directed in a transverse scanning plane and moved slowly downwards until the splenic vein was seen as a linear, tubular structure with broadened medial end. The probe was angled cranially until the head and tail of the pancreas were located. After that, the probe was slowly moved upwards and angled caudally to visualize the head, body, and tail of the pancreas as well as the pancreatic duct. The pancreatic duct was visualized as a thin anechoic tube with echogenic walls.

To acquire a quality image of the pancreas through the trans gastric section, the stomach was filled with 400-600mls of water to act as an acoustic window and moderate pressure applied. Using electronic callipers, the anterior-posterior diameter of the pancreatic duct, including the echogenic wall components, was measured in the head, body, and tail regions. Anthropometric measurements were taken in accordance with the Centre for Disease Control and Prevention standard (2008): During the measurements, participants were asked to stand with their feet together, their weight evenly distributed across both feet, and their arms relaxed at their sides. To determine the weight, participants were instructed to empty their pockets of mobile phones, keys, wallets, and anything else that could add a gramme or more to the weight.

The patient took the weight barefoot and stood tall on the beam balance, not resting his hands or body on the table or wall. The weight, in kg, was measured to the nearest 0.5 kg while standing straight and as still as possible, with heels, gluteal muscles and occiput contacting the upright bar of the height scale. The scale's short, horizontal bar was adjusted to establish firm contact with the vertex of the head, and the height was then measured to the closest centime. BMI was calculated by multiplying weight (kg) by height (m). To limit intra-observer variability, two measurements were taken and averaged (Seak, 2015).

➤ *Model Specification.*

Descriptive statistics such as frequency distributions, means, cross tabulation and correlation relationships were used for analysis of this study. The general objective of this study was to determine the sonographic baseline values of the pancreatic duct diameter in healthy adult population in Gaborone. And the specific objectives were to: determine the pancreatic duct diameter of the head, body and tail of the pancreas; correlate the pancreatic duct diameter with age, weight and BMI; determine differences in the pancreatic duct diameter according to sex and develop a regression equation with the pancreatic duct diameter and body biometry.

To address the objectives of this study, I had to specify the regression model used from the array of regression models available, namely, linear regression, logistic regression, polynomial regression, stepwise regression, ridge regression, lasso regression, and elastic net regression (O’Gorman & MacIntosh, 2015). The regression model used is mostly dependent on the dependent and independent variables used, whether to specify a simple model with only one independent variable or multivariate model with multiple independent variables.

In this study, ordinal logistic regression model is the appropriate model to apply to derive or obtain the factors that influence the pancreatic duct diameter. This study has specified a multivariate ordinal logistic regression model with three independent variables. The dependent variable is continuous while the independent variables are either continuous or discrete. The dependent variable (pancreatic duct diameter) has four categories, namely 1 = 1.1-1.5, 2 = 1.6-2.0, 3 = 2.1-2.5 and base category = 2.6-3.0.

$$\text{logit}[p(Y \leq j)] = \text{log} \left[ \frac{P(Y \leq j)}{P(Y > j)} \right] = \alpha_j - \beta X, j \in [1, J - 1] \quad (1)$$

Where,  $j \in [1, J - 1]$  are the levels of the ordinal outcome variable Y. The proportional odds model assumes there is a common set of slope parameters  $\beta$  for the predictors. The ordinal outcomes are distinguished by the J - 1 intercept  $\alpha_j$ . The X’s variables are the independent or explanatory variables (Sex, BMI and Age) and are defined as follows –

- **X<sub>1</sub>** connotes gender or sex of the respondents, which is a binary variable captured as male and female with female as the base category.
- **X<sub>2</sub>** connotes BMI of respondents which has three categories, namely: underweight = 1, normal weight = 2 and the base category is obese.
- **X<sub>3</sub>** denotes the age of the respondents, which has five categories and with 56 and above as the base category.

**V. DATA PRESENTATION AND ANALYSIS**

A study population of about 330 healthy individuals (those with visualized pancreatic duct in various age groups) out of 450 participants was used for this study. Out of the 330-study population, 169 were males while 161 were females. Data was collected and analyzed using the descriptive statistical package for social sciences (SPSS) version 23 and Microsoft excel 2018. The mean, standard deviation and other descriptive statistical values were determined for categorical and continuous variables as appropriate. Statistical significance was assessed using students test and chi-square (X<sup>2</sup>) tests. Probability values less than 0.05 were accepted as statistically significant.

Table 1 shows the mean pancreatic duct diameter and the standard deviation for the studied subjects. The mean pancreatic duct diameter of participants between 18-25 years was 2.101 with a standard deviation of 0.077. The mean pancreatic duct diameter of participants between 46-55 years was 2.208 with a standard deviation of 0.096 and the mean pancreatic duct diameter of participants between 65-75 years was 2.344 with a standard deviation of 0.145.

Table 1: Distribution of the Pancreatic Duct Diameter for the Studied Subjects

Age Groups	Frequency	Mean Pancreatic Duct Diameter	Std. Deviation
18-25	217	2.101	0.077
26-35	54	2.090	0.139
36-45	23	2.124	0.140
46-55	17	2.208	0.096
56-65	14	2.252	0.091
66-75	5	2.344	0.145
Total	330	2.117	0.108

Table showing the distribution of the pancreatic duct diameter for the studied subjects.

Table 2 shows the correlation between pancreatic duct diameter and age using correlation coefficient and sig (2-tailed) p-value.

Table 2: Shows Correlation between Pancreatic Duct Diameter and age.

		Age	Pancreatic duct diameter
Age	Pearson Correlation	1	0.40**
	Sig. (2-tailed)		0.00
	N	330	330
Pancreatic duct diameter	Pearson Correlation	0.40**	1
	Sig. (2-tailed)	0.00	
	N	330	330

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

The result shows a moderate positive (r=0.40) significant relationship between age and the pancreatic duct diameter.

Table 3: Case Processing Summary

		N	Marginal Percentage
Pancreatic duct diameter	1.1-1.5	1	0.3
	1.6-2.0	12	3.7
	2.1-2.5	311	95.7
	2.6-3.0	1	0.3
Sex	Male	165	50.8
	Female	160	49.2
BMI	Under weight	26	8.0
	Normal weight	165	50.8
	Obese	134	41.2
Age group	18-25	213	65.5
	26-35	54	16.6
	36-45	22	6.8
	46-55	17	5.2
	56-75	19	5.8
Valid		325	100.0
Missing		5	
Total		330	

## VI. DISCUSSION

Currently, there is a scarcity of data in our environment for determining pancreatic duct diameter. It is believed that using the data collected in this study will reduce the false positive rate (type 1 mistake) in symptomatic patients. This is because healthy people have a low pretest probability of having a condition, but individuals who have been clinically referred for an abdominal ultrasound have a higher pretest probability of having a disease.

These patients were thoroughly examined to exclude other diseases before the sonographic examination. Only apparently healthy adults were included in the study. According to the Bayes theorem, (1763) healthy subjects who have a low pretest probability of disease are likely to have a false positive test result due to their low positive predictive value. The result can be validated based on the normal distribution pattern of the sample population as shown by Lyapunov (ref & date) central limit theorem. The pancreatic duct's calibre was measured at the head, body, and tail of the pancreas and analysed. Pancreatic duct measures are a vital aspect of routine abdominal ultrasonography and provide useful information about pancreatic health. Dilatation of the pancreatic duct indicates a restriction in the normal flow of pancreatic secretions and is a risk factor for acute pancreatitis, chronic pancreatitis, and pancreatic cancer. As a result, it is critical for high-risk individuals to have regular check-ups with a non-invasive, non-ionizing imaging modality for early diagnosis of pancreatic disease. For this to be of value, a local baseline reference normogram is required. Pancreatic duct diameter measurements provide a reference normogram of the pancreatic duct as well as the health of the pancreas in apparently healthy individuals. It's relationship with age, gender, and anthropometry underscores the importance of the organ in the general wellbeing of the patient.

Pancreatic duct Sonography is an operator dependent, non-invasive, and non-ionizing diagnostic imaging modality which has been reported to achieve a sensitivity of between 75%- 90% by well trained and experienced Sonographers (Wijayapala *et al*, 2016). The study evaluated the pancreatic duct diameter of healthy adult population in Gaborone to determine the pancreatic duct diameter and to proffer a baseline reference value. This was a prospective cross-sectional experimental study involving 450 subjects aged 18 to 75 years. The pancreatic duct is the channel of flow of pancreatic juice. The pancreatic duct diameter is a strong index in measuring the health status of the pancreas. The pancreatic duct diameter measured includes the echogenic duct diameter at the head, body, and tail of the organ.

The present study measured the pancreatic duct diameter of the 314 out of 329 participants. This represents 95.4% of the study population. The pancreatic duct diameter from the present study measured between 1.8mm - 2.5mm. This finding is in keeping with the findings of Akochi *et al.*, in the study of a Nigerian population. This finding is however less in value than the findings of Wijapala *et al*. The difference could be due to ethnic or environmental variations.

The study showed that the pancreatic duct diameter varies with the different pancreatic sections. This corroborates the findings of authors like Hadidi *et al*, Aliyu, Olowoyeye *et al*, and Ohto *et al*. This characteristic of the pancreas is of clinical importance because any variation may portend an underlying pathology. The pancreatic duct diameter measurement at the head of the pancreas in the present study measured  $2.40 \pm 0.58$ mm. This finding corroborates the findings of Akochi, Wijayapala and Olowoyeye.



The pancreatic duct diameter measured  $2.10 \pm 0.50$  mm at the body, this finding is in keeping with the results of the study by Olowoyeye and Akochi et al. The body of the pancreas is the part that is easily accessed than any other part of the pancreas. Pathological changes within the organ are readily observed in the transverse technique which readily shows the body and the duct.

The pancreatic tail is the last segment of the organ, its duct diameter from the present study measured  $1.84 \pm 0.54$  mm, this finding agrees with the findings of Akochi et al. The tail is the narrow segment of the pancreas, and the duct is correspondingly narrower than the body and the head. This characteristic was noted in the study by previous authors. Any deviation from this characteristic may be an indication of disease process.

The present study mean pancreatic duct diameter was  $2.11 \pm 0.50$  mm. This finding agrees with the findings of Akochi et al., Olowoyeye et al., Hadidi et al. and Yusuf Aliyu, but differs with the mean pancreatic duct diameter of 2.23 mm reported by Wijayapala & Ranasinghe and 2.2 mm mean pancreatic duct diameter reported by Chao et al. However, these differences in findings may be due to ethnic or environmental factors.

#### ➤ *Correlating The Pancreatic Duct Diameter with Age, Weight and BMI*

Pancreatic duct diameter was correlated with age, weight, and body mass index (BMI). These variables were used in the ordinal regression analysis. The pancreatic duct was used as the dependent variable while gender, age and BMI were the independent variables. There were 311 participants with pancreatic duct diameter of 2.1 mm - 2.5 mm and 12 participants with pancreatic duct diameter of 1.6 mm - 2.0 mm. 50.8% of the participants were males while 49.2% were females. Majority of the participants (65.5%) were between the ages of 18 and 25 years, while 19% were between 56 and 75 years. Furthermore, most of the participants (50.8%) had normal weight, while 8% and 41.2% were underweight and obese respectively. No observable statistically significant difference was noted in the overall mean pancreatic duct diameter between male and female ( $p > 0.05$ ). There is a moderate positive ( $r=0.40$ ) significant relationship between the pancreatic duct diameter and age. There is a weak positive ( $r=0.22$ ) relationship between the pancreatic duct diameter and weight as well as a weak positive ( $r=0.22$ ) relationship between the pancreatic duct diameter and BMI. In this study, most elderly subjects without pancreatic disease were observed to have dilated pancreatic duct unlike younger subjects with an upper limit mean diameter of  $3.16 \text{ mm} \pm 1.5 \text{ SD}$ . This observation is like what was observed by Hadidi probably due to increased viscosity of the exocrine secretions. The present study showed a moderate positive ( $r=0.40$ ) significant relationship between age and the pancreatic duct diameter. This finding agrees with the findings of Hadidi et al., Olowoyeye et al., Qiushi Wang et al., Chao et al., Frøkjær as well as Glaser and Stienecker but differs with the findings by Sato et al., Yusuf Aliyu and Wijayapala & Ranasinghe, which found no

significant correlation between mean pancreatic duct diameter and age ( $p > 0.05$ ).

The result of the present study showed no statistically significant difference between the pancreatic ducts of males and females within the same age group ( $p > 0.05$ ) and therefore no correlation between pancreatic duct diameter and gender. This finding corroborates the findings by Olowoyeye et al., Akochi et al., Chao et al., Frøkjær, Qiushi Wang et al., Glaser and Stienecker as well as Wijayapala and Ranasinghe. However, this finding is not in agreement with the finding by Yusuf Aliyu, who found a statistically significant difference in the pancreatic duct diameters between male and female with higher values in females ( $p > 0.05$ ). This variation was explained by the relative lack of increase in the pancreatic fat volume in third and fourth decades in females in contrast to males.

The present study result showed a weak positive ( $r=0.22$ ) statistically significant relationship between the pancreatic duct diameter and weight as well as BMI. This finding corroborates the findings by Glaser et al. and Akochi et al. ( $r = 0.11$ ,  $p > 0.05$ ) but differs with the findings by Yusuf Aliyu, who found no significant correlation between the pancreatic duct diameter and anthropometric dimensions.

#### ➤ *Regression Analysis of the Pancreatic Duct Diameter and Anthropometric Biometry.*

**Anthropometric variables** and pancreatic duct diameter were used to develop a regression model. The study shows that age have no significant impact on the pancreatic duct diameter. The BMI has a statistically significant impact on pancreatic duct diameter; an increase in normal weight by one will decrease the log odd of pancreatic duct diameter of 2.1-2.5 by 1.504, given other variables as constant. A unit increase in normal body weight will cause a corresponding unit to increase of the pancreatic duct diameter in the pancreatic duct diameter range of 1.6 mm - 2.0 mm and the same apply in the pancreatic duct diameter by the same quantity. If other variables remain constant, an increase in underweight by one unit will decrease the pancreatic duct diameter range of 2.1-2.5 by 2.556 compared to pancreatic duct diameter of 2.6-3.0 which is the base. The same increase in weight will cause a corresponding increase in the pancreatic duct diameter in the range of 1.6 mm - 2.0 mm by the same quantity if other variables remain constant. The result of the ordinal regression shows that an increase in the age group of 18-25 years will decrease by 3.099 as compared to those above 60 years. There was no significant relationship between pancreatic duct and gender. There was a weak positive ( $r = 0.307$ ) significant relationship between pancreatic duct and age as well as a weak positive ( $r = 0.156$ ) significant relationship between pancreatic duct and BMI.

### ➤ Observer Variability

The study examined inter rater and intra observer reliability; the pancreatic duct diameter assessed at the level of the pancreas' body exhibits very good concordance within and between sonographers. This result indicates coefficients of 0.988 and 0.988 as intra raters, as well as coefficients of 0.977 between sonographers. This is consistent with the value obtained (Akochi et al), in their investigation of the sonographic determination of pancreatic duct width in apparently healthy persons in the Abakaliki metropolis. This implies that pancreatic duct measurements are highly reproducible and reliable between raters, meeting Campbell's requirements.

The ANOVA model was used to corroborate the conclusion using the intraclass correlation, yielding a coefficient of 0.989 and a class correlation value of 0.977, both of which are excellent for clinical applications. The Lin's Concordance correlation coefficient was used to assess reproducibility for a single observer, yielding a result of 0.988, indicating excellent agreement between the two measurements. Table 15 shows a straight connection with little scatter, demonstrating strong concordance between the two measurements. Furthermore, the bland Altman plot demonstrates that the two measurements are not substantially different from zero. Fulfilling Campbell's criteria.

## VII. CONCLUSION

The pancreatic duct diameter is an important component of a pancreas ultrasound examination. The current study was done to assess duct diameter in apparently healthy persons, thereby providing doctors in Gaborone with a reference value. The study had an outstanding intra- and inter-class correlation coefficient, indicating good measurement agreement and reproducibility.

The mean pancreatic duct diameter for the study was 2.11±0.5mm however the mean values of the head, body, and tail of the pancreas in the study were 2.42±0.58mm, 2.11±0.50mm and 1.84±0.54mm respectively. These measurements are like documented literatures from previous studies and are important in assessing the pancreatic duct for early diagnosis of pancreatic diseases. The pancreatic duct in this study showed a positive weak correlation with weight and BMI. The technique used in the present study shows that Sonography is a reliable imaging modality for the determination of the pancreatic duct diameter. The normogram thus developed will serve as indigenous baseline value rather than relying on normogram from other population.

## STUDY LIMITATIONS

Disturbing artefact from overlying bowel gas caused difficulty in visualization of the pancreas. This was mitigated by filling the stomach and duodenum with water to dispel the overlying gas. Poor visualization of the pancreatic duct in obese patients due to attenuation of the ultrasound beam.

However, intravenous administration of one clinical unit of secretin per kilogram bodyweight has been found to achieve transient dilation of the duct within two minutes, allowing better visualization of its morphologic features. This technical modification was not applied in this study.

## RECOMMENDATION

Multicenter validation of this discovery is critical for establishing a reference baseline value for the pancreatic duct in Gaborone. zero. Fulfilling Campbell's criteria.

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