INTRODUCTION

Acute pancreatitis (AP) is one of the most commonly observed pancreatic disorders. It is described as an acute nonbacterial inflammatory condition of the pancreas and is caused by early activation of the digestive enzymes found in the acinar cells of pancreatic tissue. Although the clinical presentation varies widely between individuals, it is usually a self-limiting disease. However, among all the AP patients, 20–30% of AP patients develop severe necrotic pancreatitis with high morbidity and mortality rate up to 20 to 45% ***(Busireddy et al., 2014).***

Owing to its varied clinical presentation, treatment of AP is highly dependent on the severity of the disease. Therefore, grading of AP is mandatory to manage the disease appropriately. In clinical practice, there are many laboratory findings and scoring systems to predict the course of the disease. Clinical signs such as epigastric pain are nonspecific and can be absent in up to 10% of patients with pancreatitis. Although serum lipase and amylase levels have commonly been used to diagnosis pancreatitis, they are normal in up to 20% of cases ***(Yencilek et al., 2014).***

Therefore, clinical and laboratory findings are not sufficient to establish an accurate diagnosis in clinical practice, but radiological examinations are helpful for making the diagnosis and determining the severity of AP. Among the

radiological studies, contrast-enhanced CT is the most commonly used radiological tool to stage the disease and determine associated complications. It also provides a sensitive structural evaluation of the pancreas as well as identifying pancreatic and extra pancreatic inflammation, which is highly associated with a severe clinical course ***(Pongprasobchai et al., 2017).***

Balthazar et al. developed a system for grading disease severity to predict clinical outcome based on CT findings. Elements of this grading system, which categorizes the disease into stages A through E, include the degree of pancreatic enlargement and inflammation, presence and number of fluid collections, and degree of necrosis ***(Zhao et al., 2015).***

However, there were several limitations with CT, namely the contraindication to iodinated contrast medium in some patients and the risk of using enhancement material has been reported to aggravate AP, and it can also lead to worsening renal failure related to AP ***(Bollen, 2016).***

MRI is an alternative tool in the imaging of the pancreas. It has an advantage over CT in depicting mild AP, peripancreatic fat infiltration, and the pancreatic duct and biliary duct. Today, MRI has an expanded role in the radiological investigation of abdominal pathologies. It can successfully reflect the functional as well as the morphological status of the parenchymatous organs ***(Aydin et al., 2014).***

High cost, long examination times and limited availability have restricted the use of MRI within emergency departments. Recent advances in MRI technology have facilitated ultrafast imaging, reducing examination times and imaging artifacts caused by motion. Diffusion- weighted imaging (DWI) is the method of choice in the emergency setting due to its rapid implementation, the absence of exposure to radioactivity, and high contrast resolution ***(Aydin et al., 2014).***

DWI is a new MRI technique that gives us information about the diffusion of water protons in vivo. Molecular diffusion is a physical process, which is related to the Brownian motion of water molecules within the tissues. However, it cannot be explained by this motion alone, and additional factors have been considered such as perfusion in the capillary network ***(Rege et al., 2017).***

Since the pancreas is also an endocrine organ, it has a good vascular supply. Therefore, it is expected that the pancreas would have good diffusion characteristics that may help to evaluate the impact of diffusion changes in AP ***(Nissan et al., 2014).***

Previous studies showed that increased signal on DWI and a decrease in ADC values have the potential to detect inflammatory changes in pancreatic tissues, even in Balthazar grade A patients who usually do not have radiological findings on CT. The alteration in signals may be due to any or to a combination of these components including acinar cell death,

invasion of acinar spaces by leukocytes, fibrin deposits in intercellular spaces, and microthrombi in blood vessels. DW-MRI yields ADC as a quantitative parameter, which reflects the microenvironment of diffusing water molecules. Previous studies have proved that the mean pancreatic ADC in the AP group is significantly lower than in the control group where the threshold ADC value that best separated the acute pancreatitis and control groups was $1.62x10^{-3}$ mm^2/s which yielded a sensitivity of 93 % and a specificity of 87 % ***(Thomas et al., 2012).***

Another important advantage of MRI for the diagnosis of AP is its ability to visualize the inflammatory changes associated with AP without use of contrast materials ***(Xinghui et al., 2016).***

AIM OF THE WORK

The purpose of this study is to determine the accuracy of Diffusion-weighted MR imaging (DWI) in the diagnosis of acute pancreatitis and whether it could be used as investigation tool in clinically suspected acute pancreatitis or not.

Chapter 1

ANATOMY OF THE PANCREAS

The Pancreas is a retroperitoneal organ that lies in an oblique position, sloping upward from the C-loop of the duodenum to the splenic hilum. The adult pancreas weighs 75 to 100 gm and is about 15 to 20 cm long. Due to its position, Pain associated with pancreatitis is described as pain penetrating through to the back. The pancreas is divided into the head, neck, body and tail ***(William et al., 2015).***

As part of embryonic development, the Ventral (caudal) and dorsal (cranial) buds develop at the junction of the foregut and midgut during the fourth week of gestation. The dorsal diverticulum forms the dorsal portion of the pancreas, and the ventral diverticulum forms the liver, gallbladder, bile ducts, and ventral pancreas. As the foregut elongates, the developing ventral pancreas, gallbladder, and bile duct rotate clockwise posterior to the duodenum and join the dorsal pancreas in the retroperitoneum ***(Skandalakis et al., 2009).***

The Head of the pancreas is nestled in the C-loop of the duodenum and is posterior to the transverse mesocolon. Just posterior to the head of the pancreas lie the vena cava, the right renal artery and both renal veins. The head of the pancreas lies to the right of the midline, anterior and to the right of the vertebral column, within the curve of the duodenum. It is the thickest and broadest part of the pancreas but is still flattened in

the anteroposterior plane. Superiorly, it lies adjacent to the first part of the duodenum; close to the pylorus. The duodenal border of the head is flattened, slightly concave and adherent to the second part of the duodenum, particularly around the duodenal papillae. The superior and inferior pancreaticoduodenal arteries lie adjacent to this region. The inferior border of the pancreatic head lies superior to the third part of theduodenum and is continuous with the uncinate process. The anterior surface of the head is covered by peritoneum and related to the origin of the transverse mesocolon ***(Rela & Reddy, 2016).***

Posteriorly, the common bile duct is partially embedded within the head of the gland just proximal to where it joins the pancreatic duct near the major duodenal papilla. The posterior surface of the pancreatic head is also related to the inferior vena cava, the right crus of the diaphragm and the termination of the right gonadal vein. Near the midline, the head of the pancreas becomes continuous with the neck **(Fig. 1)** (***Rela & Reddy, 2016).***

The lower border of the pancreatic head forms the uncinate process, which extends to the left and lies superior to the third portion of the duodenum and posterior to the superior mesenteric vessels ***(Moo et al., 2009).*** The uncinate process may be absent or may completely encircle the superior mesenteric vessels ***(Skandalakis et al., 2009).***

The neck of the pancreas lies directly anterior to the portal vein. At the inferior border of the neck of the pancreas, the superior mesenteric vein joins the splenic vein and then continues toward the porta hepatis as the portal vein. The inferior mesenteric vein often joins the splenic vein near its junction with the portal vein **(Fig. 1)** ***(Snell, 2015).***

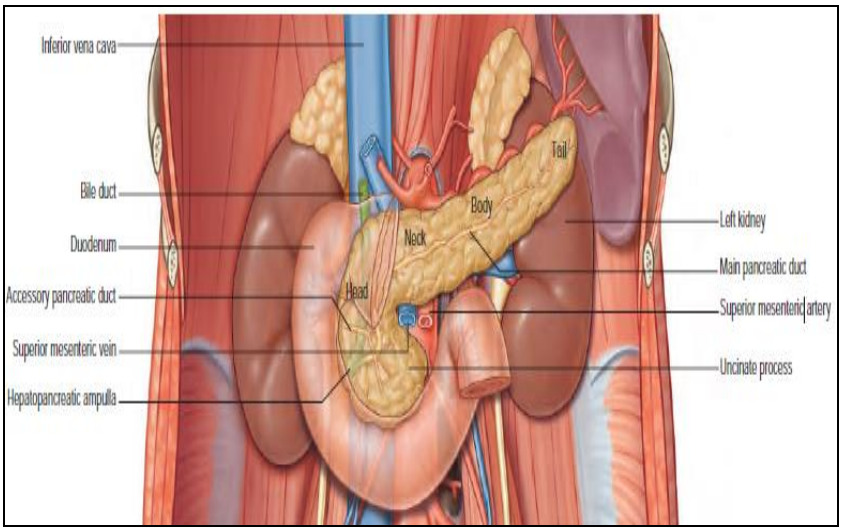

Fig. (1): Relations of the pancreas ***(Rela & Reddy, 2016).***

The Body of the pancreas is the longest part of the gland and runs from the neck to the tail, becoming progressively thinner. It is slightly triangular in cross-section and has anterior and posterior surfaces and superior and inferior borders **(Fig. 2)**.

a) Anterior surface:

The anterior surface is covered by peritoneum, which is reflected anteroinferiorly from the surface of the gland to be continuous with the posterior layer of the greater omentum and

the transverse mesocolon. The two layers of the transverse mesocolon diverge along this surface. Above the attachment of the transverse mesocolon, the anterior surface of the pancreas is separated from the stomach by the lesser sac. Inferiorly, it lies within the infracolic compartment, and its anterior relations include the fourth part of the duodenum, the duodenojejunal flexure and coils of jejunum ***(Rela & Reddy, 2016).***

b) Posterior surface:

The posterior surface of the pancreas is devoid of peritoneum. It lies on fascia (the fusion fascia of Toldt) anterior to the aorta and the origin of the superior mesenteric artery, the left crus of the diaphragm, left suprarenal gland, the upper pole of the left kidney surrounded by perirenal fascia, and left renal vein. The splenic vein runs from left to right directly on this surface of the gland and indents the parenchyma to a variable extent, ranging from a shallow groove to almost a tunnel ***(Rela & Reddy, 2016).***

c) Superior border:

The superior border is related to the coeliac artery and its branches; the common hepatic artery runs to the right just above the gland, and the splenic artery passes to the left in a tortuous manner, projecting above the superior border at several points ***(Rela & Reddy, 2016).***

d) Inferior border:

At the medial end of the inferior border, adjacent to the neck of the pancreas, the superior mesenteric vessels emerge from behind the gland. Laterally, the inferior mesenteric vein runs behind the inferior border to join the splenic vein or the confluence of the splenic and superior mesenteric veins. This is a useful site for identification of the inferior mesenteric vein on computed tomographic (CT) imaging and during left-sided colonic resections ***(Rela & Reddy, 2016).***

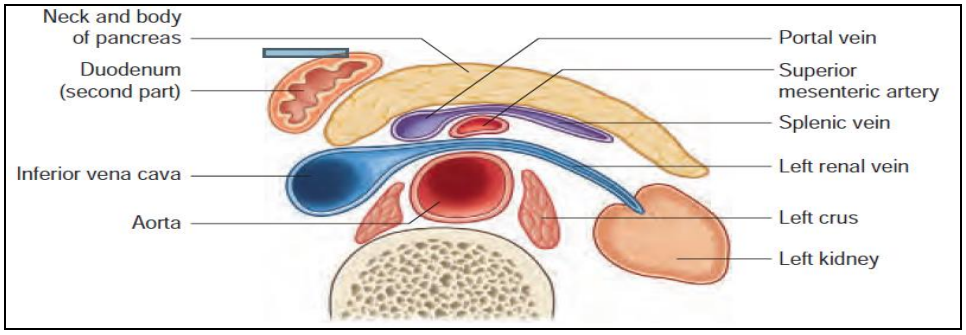

Fig. (2): Cross sectional diagram at the level of neck and body of pancreas ***(Rela & Reddy, 2016).***

The Tail of the pancreas is the narrowest, most lateral portion of the gland and is continuous medially with the body. It is between 1.5 and 3.5 cm long in adults and lies between the layers of the splenorenal ligament. It may terminate at the base of the splenorenal ligament or extend up to the splenic hilum, when it is at risk of injury at splenectomy during ligation or stapling of the splenic vessels. The splenic artery and its branches and the splenic vein and its tributaries, lie posterior to the tail **(Fig. 3)** ***(Rela & Reddy, 2016).***

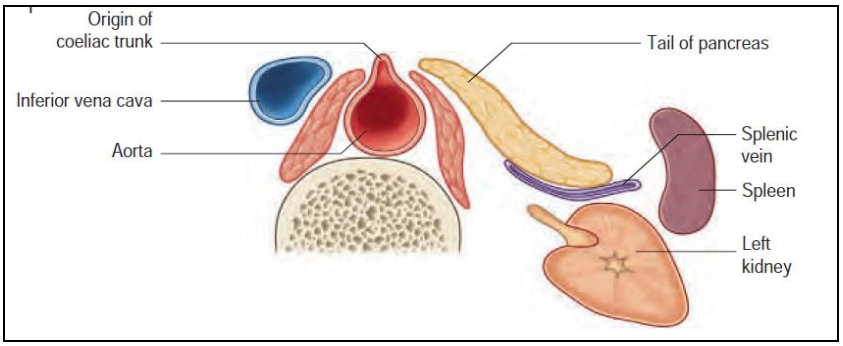

Fig. (3): Cross sectional diagram at the level of pancreatic tail ***(Rela & Reddy, 2016).***

The Pancreatic Ducts

There are two ducts, a main one and an accessory one **(Fig. 4)**. Usually the duct of the ventral pancreatic bud forms the proximal end of the main pancreatic duct, and the distal part of the dorsal pancreatic duct forms the remainder. Frequently the proximal (duodenal) end of the dorsal pancreatic duct also persists and forms an accessory pancreatic duct ***(Ryan et al., 2011).***

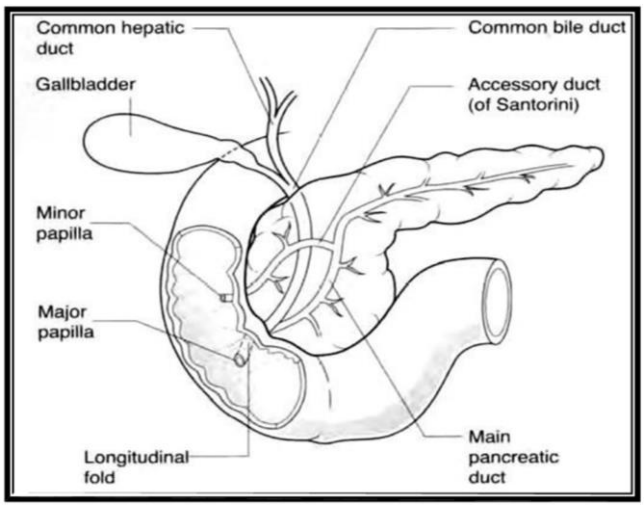

Fig. (4): Normal anatomy of the pancreatic ducts ***(Ryan et al., 2011).***

Pancreatic Duct Anatomy: An understanding of embryology is required to appreciate the common variations in pancreatic duct anatomy. The pancreas is formed by the fusion of a ventral and dorsal bud. The duct from the smaller ventral bud, which arises from the hepatic diverticulum, connects directly to the common bile duct. The duct from the larger dorsal bud, which arises from the duodenum, drains directly into the duodenum. The duct of the ventral bud becomes the duct of Wirsung, and the duct from the dorsal bud becomes the duct of Santorini. With gut rotation, the ventral bud rotates to the right and around the posterior side of the duodenum to fuse with the dorsal bud. The ventral bud becomes the inferior portion of the pancreatic head and the uncinate process, while the dorsal bud becomes the body and tail of the pancreas. They usually fuse together in the pancreatic head such that most of the pancreas drains through the duct of Wirsung, or main pancreatic duct, into the common channel formed from the bile duct and pancreatic duct **(Fig. 5)** ***(William et al., 2015).***

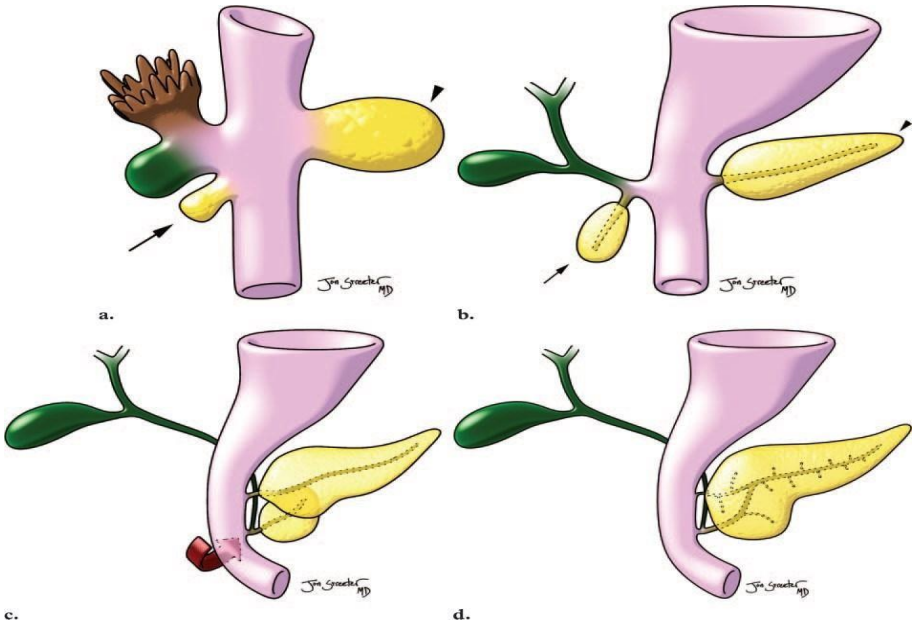

Fig. (5): Drawings illustrate the normal embryologic development of the pancreas and biliary tree. The ventral pancreatic bud (arrow in a and b) and biliary system arise from the hepatic diverticulum, and the dorsal pancreatic bud (arrowhead in a and b) arises from the dorsal mesogastrium. After clockwise rotation of the ventral bud around the caudal part of the foregut, there is fusion of the dorsal pancreas (located anterior) and ventral pancreas (located posterior). Finally, the ventral and dorsal pancreatic ducts fuse, and the pancreas is predominantly drained through the ventral duct, which joins the common bile duct (CBD) at the level of the major papilla. The dorsal duct empties at the level of the minor papilla ***(Mortele et al., 2006).***

The length of the common channel is variable. In about one third of patients, the bile duct and pancreatic duct remain distinct to the end of the papilla, the two ducts merge at the end of the papilla in another third, and in the remaining one third, and a true common channel is present for a distance of several millimeters. Commonly, the duct from the dorsal bud, the duct of Santorini, persists as the lesser pancreatic duct, and sometimes drains

directly into the duodenum through the lesser papilla just proximal to the major papilla. In approximately 30% of patients, the duct of Santorini ends as a blind accessory duct and does not empty into the duodenum ***(William et al., 2015).***

Pancreatic anatomical variants:

A) Pancreatic divisum: In 10% of patients, the ducts of Wirsung and Santorini fail to fuse. This results in the majority of the pancreas draining through the duct of Santorini and the lesser papilla, while the inferior portion of the pancreatic head and uncinate process drains through the duct of Wirsung and major papilla. This normal anatomic variant, which occurs in one out of 10 patients, is referred to as pancreas divisum. In a minority of these patients, the minor papilla can be inadequate to handle the flow of pancreatic juices from the majority of the gland. This relative outflow obstruction can result in pancreatitis and is sometimes treated by sphincteroplasty of the minor papilla ***(William et al., 2015).***

B) Annular pancreas: it is rare congenital anomaly occurring in 1 in 20,000. It is characterized by a portion of the pancreatic tissue, in continuity with the head that circumscribes the duodenum partially or completely. It usually encircles the second part of the duodenum (74% of cases), less often the first part (21%), & rarely the third part. It is usually associated with duodenal anomalies such as atresia, atrophy, or stenosis ***(Yu et al., 2006).***

C) **Agenesis of dorsal pancreas:** complete Agenesis of the pancreas is a congenital anomaly associated with other malformations and is not compatible with life. Agenesis of the ventral pancreas is extremely rare anomaly, reported just once in the literature; agenesis of the dorsal pancreas, though a rare anomaly, has been reported in around 20 case report ***(Lingareddy et al., 2007).***

D) **Ectopic pancreas:** ectopic pancreatic tissue may be found in different portions of the gastrointestinal tract, most commonly in its proximal segments & in Meckel's diverticulum. This tissue may be responsible for clinical symptoms related to the secretion of pancreatic enzymes. The diagnosis is not easy to make ***(Kim et al., 2003).***

E) **Pancreatic head lobulations:** it represents contour anomalies of the head and neck of the pancreas, composed of normal pancreatic tissue. They may be found in association with other anomalies, such as pancreatic divisum, or as isolated anomalies. They are not responsible for any clinical symptoms; their importance lies in the fact that they may be misinterpreted as pancreatic neoplasms. MDCT & MRI demonstrate normal density & signal density of the lobulations ***(Aysel et al., 2013).***