Imaging of the pancreatic duct by linear endoscopic ultrasound

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ABSTRACT

The current gold standard investigation for anatomic exploration of the pancreatic duct (PD) is endoscopic retrograde cholangiopancreatography. Magnetic resonance cholangiopancreatography is a noninvasive method for exploration of the PD. A comprehensive evaluation of the course of PD and its branches has not been described by endoscopic ultrasound (EUS). In this article, we describe the techniques of imaging of PD using linear EUS.

Key words: Endoscopic ultrasound, pancreas, pancreatic duct

INTRODUCTION

Recent advances in imaging have enabled *in vivo* studies of the pancreatic duct (PD). The current gold standard investigation for anatomic exploration of the PD is endoscopic retrograde cholangiopancreatography, which is an invasive technique, requiring anesthesia, and not free of complications. Magnetic resonance cholangiopancreatography is a fast and noninvasive method for exploration of the PD. Its contraindications are limited to those of magnetic resonance imaging (which are rare).[1-5] The techniques of endoscopic ultrasound (EUS) examination of the pancreas and pancreatic vessels have been described.[6,7] Ultrasound imaging has provided a description of PD.[8] A comprehensive EUS evaluation of the course of the PD and its branches has not been described so far. In this article, we describe the techniques of imaging of the different parts of PD by linear EUS.

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EMBRYOLOGY OF PANCREAS AND SEGMENTS

Based on conventional gross anatomy the pancreas is divided into the head, neck, body and tail. On a combined anatomical and embryological basis the pancreas is divided into four segments: The anterior head, posterior head, body and tail.[9] The ventral bud forms the posterior part of the head of the pancreas including most of the uncinate processes. The dorsal bud forms the anterior part of the head, the body and tail of the pancreas although there are no distinct borders between these segments.[10,11] The fusion line between the dorsal and ventral parts of the pancreas has no marked border, but it is the so-called locus minoris resistance, and it is the "pathway" for a duodenal diverticulum to penetrate the pancreas. The fusion line contains fascia that is histologically composed of a loose connective tissue membrane. The fusion fascia of the head of the pancreas is called the "fusion fascia of Treitz" and that of the body and tail of the pancreas is termed the "fusion fascia of Toldt."[12-15]

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APPLIED ANATOMY OF PANCREAS

The head

The head lies to the right of midline in the right paravertebral gutter in the concavity of the C loop of duodenum ("the abdominal area of romance where the head of the pancreas lies folded in the arms of the duodenum"). It is a flattened antero-posteriorly and has an anterior and posterior surface (A-P dimension-thickness of head 24 ± 3.6 mm). It has a superior border, lateral or duodenal border and an inferior border. The anterior surface is covered by peritoneum, and the posterior surface rests on inferior vena cava (IVC), the right renal vessel, the right crus of the diaphragm and common bile duct (CBD). The intrapancreatic or retropancreatic part of the CBD lies in front of the portal vein (PV), which in turn is identified just anterior to the IVC. The gastroduodenal artery is seen on the anterior surface of the head (neck). The uncinate process is a triangular hook-like leftward extension of the lower left part of the head extending variably behind the superior mesenteric vessels and in front of the abdominal aorta.

Neck

The neck of pancreas is 2 cm wide, and it is often the most anterior part of the pancreas and lies anterior to the vertebral column. The lower part of the neck lies anterior to superior mesenteric vein (SMV) and the upper part lies anterior to PV. The boundary of the head and neck contains a groove anteriorly and posteriorly. The two grooves contain the gastroduodenal artery anteriorly and the PV posteriorly.

Body

The width of the pancreatic body is noticeably less (thickness 16 ± 2.0 mm) than that of the head. The body of pancreas has three surfaces anatomically: Anterosuperior, anteroinferior and posterior. The anterosuperior surface and anteroinferior surfaces are separated by the attachment of transverse mesocolon. Posteriorly the body of the pancreas gently slopes upwards across the left renal vein and the aorta (with the origin of superior mesenteric artery), the left suprarenal gland, hilum and anterior surface of the left kidney. The splenic vein (SV) lies in a groove on the posterior surface of the body of pancreas.

Tail

The tail of pancreas lies in the lienorenal ligament along with splenic vessels (thickness 15.1 ± 1.9 mm). It may or may not reach up to the splenic hilum.

THE MAIN PANCREATIC DUCT

Diameter of the PD ranges from 3 to 3.7 mm in the head 2.1-2.5 mm in the body and from 1.5 to 1.7 mm in the tail. The length of the PD ranges from 9.5 to 25 cm.[16-18]

The main PD arises in the tail of the pancreas. Through the tail and body of the pancreas, the duct lies midway between the superior and inferior margins and slightly more posterior than anterior. In the pancreatic parenchyma, the main PD and the accessory duct lie anterior to the major pancreatic vessels. The main duct crosses the vertebral column between the 12th thoracic and the second lumbar vertebrae. In more than one-half of persons, the crossing is at the first lumbar vertebra. The main duct turns caudal and posterior on reaching the head of the pancreas. At the level of the major papilla, the duct turns horizontally to join the caudal surface of the CBD. It then enters the wall of the duodenum, usually at the level of the second lumbar vertebra. The main PD, which is known as Wirsung's duct in the absence of pancreas divisum, runs along the central segment of the pancreatic gland, that is, in the middle of the pancreas along the tail, body and neck. In the pancreatic head, however, the main PD extends first along the anterior segment of the head, then along the middle of the head of pancreas, and finally along its posterior segment, towards the ampulla of Vater, which lies in the most posterior segment of the pancreatic head. The duct of Santorini drains the anterior head segment, and the posterior segment is drained by the duct of Wirsung, and usually houses the CBD.

Pancreatic duct has a number of side branches in a normal person, (about 20-30) which joins the superior or inferior border at right angles to the course of PD in an alternating manner [Figure 1a and b]. When the accessory PD is prominent, it empties into the main duct at the superior border of the PD in neck of the pancreas. The main duct receives one or two side branches draining the uncinate process. Small side branches in the head may open directly into the intra pancreatic portion of the CBD.

IMAGING OF PANCREATIC DUCT

Many authors prefer to start the examination of the pancreas from the descending duodenum while others prefer to start the examination immediately

upon entering the stomach. The PD is almost always visualized in the head but may be sometimes difficult to find in body and tail in normal persons. The imaging of PD can be described from three positions.

1. Imaging from stomach.
2. Imaging from bulb.
3. Imaging from descending duodenum.

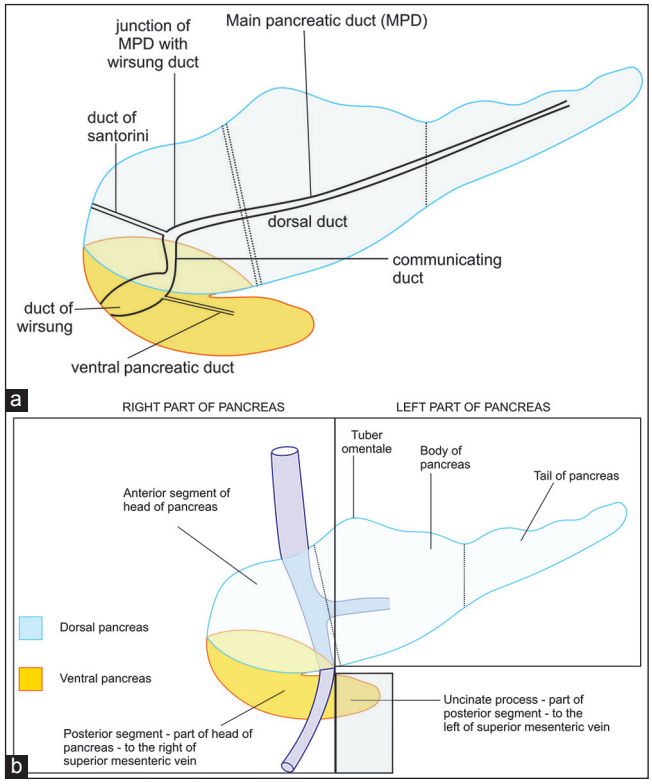

Figure 1. (a) The pancreas develops from dorsal and ventral buds that first appear in the fifth gestational week as outgrowths of the primitive foregut. By the seventh gestational week, expansion of the duodenum causes the ventral bud to rotate and pass behind the duodenum from right to left and fuse with the dorsal bud. The ventral bud forms the posterior head and uncinate process, whereas the dorsal bud forms the anterior head, body, and tail. Following this fusion, the ductal systems anastomose. The portion of the ventral duct between the dorsal-ventral fusion and major papilla is termed the duct of Wirsung. The portion of the dorsal duct upstream to the dorsal-ventral fusion point is called the main PD. The segment of the dorsal duct downstream to the dorsal-ventral fusion point is termed the duct of Santorini, or accessory PD, which drains at the papilla minor. (b) The splenoportal axis and union of SV and SMV with formation of PV divides Pancreas into two main sonologically distinct areas. One area lies to the right of PV and SMV axis and another area lies to the left of PV and SMV axis. The area lying on right of this axis can be subdivided into a superior part (called anterior head) and an inferior part called (posterior head). The area lying on left of this axis is largely composed of body and tail of pancreas and the area below the body in continuity with head of pancreas is called the uncinate process. It is generally considered that the head of the pancreas ends and the body starts at the left border of the SMV. The border between the body and tail of the pancreas is not definite, but is generally agreed to be located at the midpoint of the total length of the body and tail. The uncinate process, which is located in the area underneath the superior mesenteric artery and vein, and the neck, which sits over the superior mesenteric artery and vein, are commonly regarded as parts of the head. PD: Pancreatic duct; SMV: Superior mesenteric vein

Table 1 demonstrates the scanning position from different parts of stomach and duodenum for evaluation of pancreas. Several general principles are helpful in orientation. The pancreas can be imagined as a four-segmented structure, and the posterior segment can be further divided into two parts: Uncinate process and posterior head of the pancreas.

Imaging from the stomach

Movements of the scope

The general orientation of the structures in stomach is as shown in Figure 2. Clockwise rotation of the shaft with up angulation presses the scope against the posterior side of the stomach, and allows the examination of the left portion of the pancreatic body and tail. Anti-clockwise rotation of the shaft with up angulation usually places the echo endoscope along the vertical part of the lesser curve, and allows the examination of right portion of the pancreatic body up to its junction with the neck. Further rotation, up angulation and positioning of the

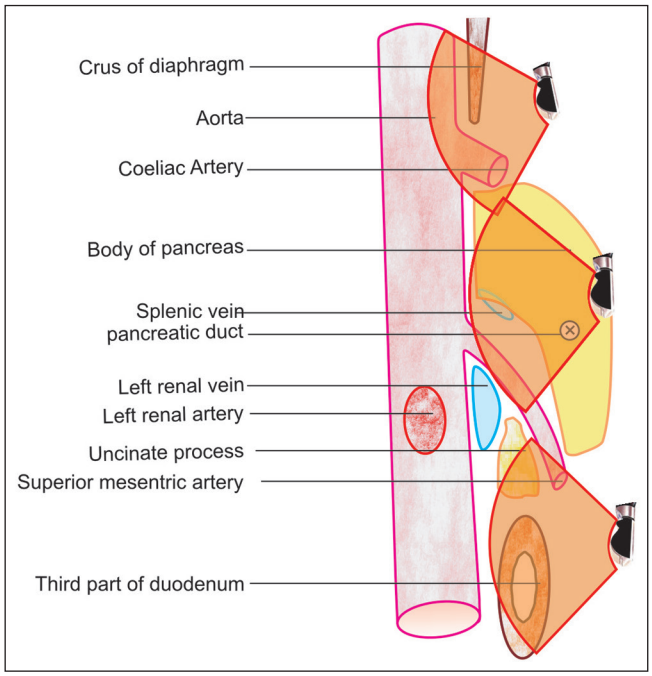

Figure 2. The home base of the aorta can be regularly used for identifying the pancreas as the aorta is followed down from the esophagus and the origin of the coeliac artery and superior mesenteric artery are seen. In the middle of the body of the stomach (between 45 and 50 cm from the incisors) a neutral position and up angulation usually positions the echoendoscope over the pancreatic body. The posterior surface of the pancreas rests between the origin of coeliac and superior mesenteric artery. On linear EUS the body of pancreas is easily identified in front of the aorta as a pyramid shaped structure. The important vascular relations include the splenic vessels, that is, the splenic artery, which travels along the top part of the pyramid and the SV, which lies behind the pyramid. The PD lies in the middle of the pyramid generally below the level of the splenic artery and vein. Other important vascular structures in this position are the left renal artery and left renal vein. PD: Pancreatic duct; EUS: Endoscopic ultrasound

scope in the distal part of the body of the stomach can usually allow the examination of the entire head of the pancreas. Changing from one of these positions to the other is usually done by slightly withdrawing the echo endoscope by 1-2 cm to examine the left side of the pancreatic body and tail and by slightly advancing the endoscope 1-2 cm to visualize the right segment of the pancreatic body and neck. During a clockwise rotation the junction of body and tail is approximately located at the midpoint of the total length of the body and tail. This midpoint on clockwise rotation is found approximately at a point where the renal vessels have entered the kidney and are no longer visualized separately in the EUS frame [Figure 3].

Imaging of structures

The pancreas extends diagonally from right to left and bottom to top. The pancreatic tail is usually located above the pancreatic body and is easily seen close to the posterior surface and the greater curve of the stomach. In 10-15% of cases, however, the pancreatic tail is lower than the pancreatic body and lies farther away from the posterior surface and the greater curve of the stomach. This information can be easily available to operator on computed tomography scans and in such cases a linear echoendoscope, allows visualization of the whole of the distal end of the pancreatic tail due to the longer tip and an expanding direction of the beam [Figure 4].

The imaging of PD from stomach may be started in the body of pancreas where it is seen lying in the middle of the pancreatic parenchyma. During imaging of the PD in the body generally maximum magnification should be done, as the PD may not be seen in low magnification. Beginners can make the mistake of looking for the PD near the upper part of the pancreas but the PD generally lies a little towards posterior surface and also a little towards the lower part of the pyramid of the pancreas [Figure 5].

The falls

Most of the anechoic structures (PD, splenic vessels) in and around the the pancreas are closest to the transducer near the body of the pancreas. As the pancreas falls away from the transducer in the paravertebral gutters, the anechoic structures also tend to move away from

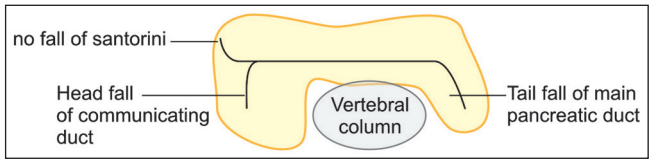

Figure 3. This figure shows a highly schematic representation of the movement of the ducts on a clockwise and anti-clockwise rotation from the stomach. The head and tail lies in the paravertebral gutter whereas the body lies anterior to the vertebral column. The PD lies closest to the probe in the body of stomach. It tends to fall away from the transducer when the transducer is rotated. This movement of duct away from the transducer can be considered similar to a waterfall and this sign can be named as PD head fall (anti-clockwise rotation) or tail fall (clockwise rotation). The duct of Santorini continues to remain close to the transducer on an anti-clockwise rotation. As the PD is followed in the stomach by anti-clockwise rotation towards the head of the pancreas it tends to move within the pancreatic parenchyma as the communicating duct towards the papilla. PD: Pancreatic duct

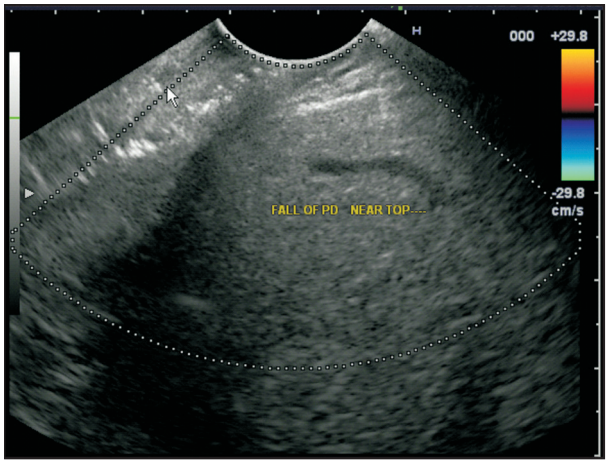

Figure 4. When the PD is followed from the body of pancreas towards the tail it moves away (Tail fall). The fall of the PD away from the tail is generally less steep as compared to the tail fall. PD: Pancreatic duct; TOP: Tail of pancreas

Table 1. The vascular indices and the imaging of different parts of pancreatic duct from different stations

Scanning position	Vascular indices	Clockwise rotation images	Anti-clockwise rotation images	Movement of scanning area from maximum clockwise rotation
Stomach	SV, RV, SMV, SMA	TOP	HOP	TOP to BOP to neck to HOP (A) to HOP (P)
Duodenal bulb (long loop)	Portal vein, HAP, GDA, PV	Papilla	HOP	Papilla to HOP (P) to HOP (A) to NOP through transition zone to BOP (limited)
D3	Aorta, IVC, MV	HOP (A)	UP, HOP (P)	HOP (A) to UP and HOP (P)
D2	Aorta, IVC, SMV, SMA	HOP (A)	HOP (P)	HOP (A) to HOP (P) to papilla through transition zone
D1	IVC, PV, GDA HA	HOP (A)	NOP, BOP	HOP (A) to NOP to BOP (limited)

SV: Splenic vessels, RV: Renal vessels, SMV: Superior mesenteric vein, SMA: Superior mesenteric artery, IVC: Inferior vena cava, HAP: Hepatic artery proper, GDA:Gastroduodenal artery, PV: Portal vein, HOP: Head of pancreas, NOP: Neck of pancreas, BOP: Body of pancreas, TOP: Tail of pancreas, A: Anterior, P: Posterior, Limited: Limited evaluation of structure is possible, UP: Upper part, HA: Hepatic artery, MV: Mesenteric vein

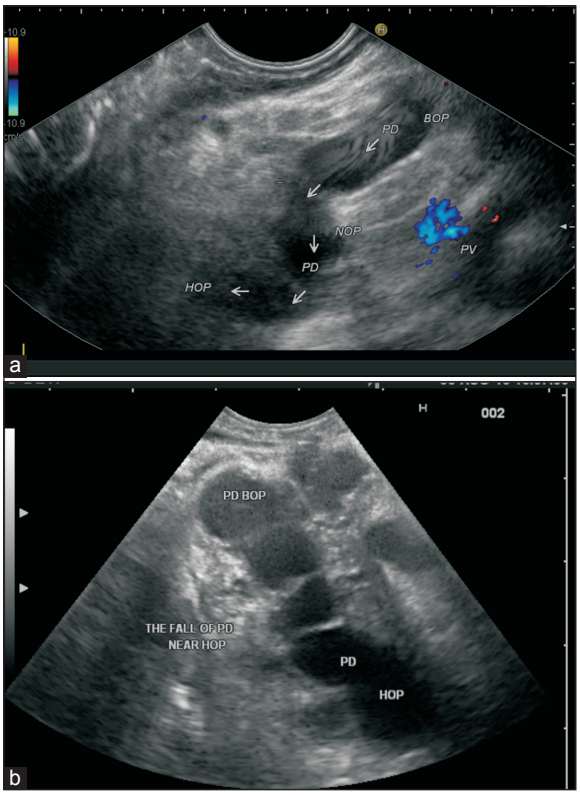

Figure 5. (a) The PD is seen going away from the pancreas and also moving towards the caudal part of the screen. The head the pancreas generally lies in a position below the body of pancreas so the head fall is usually associated with caudal movement of the PD. In the image a head fall of the dilated PD along with cranial movement is due to the angulated position of the probe. BOP: Body of pancreas; HOP: Head of pancreas; PD: Pancreatic duct

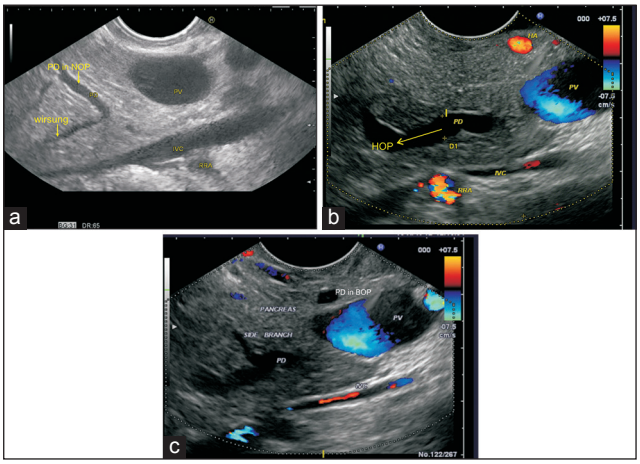

Figure 7. (a) The fall of PD in the neck of pancreas and then PD moves towards the head of pancreas. The movement of PD in this part occurs in an antero-posterior axis. The PD is normally seen in front of IVC in such cases. (b) The dilated PD in the head part of pancreas, which is seen anterior to IVC and also appears within the hypoechoic ventral part of pancreas. RRA = right renal artery, HA = hepatic artery. (c) In the same case slight rotation of the scope shows the PD in the body of pancreas (which is hyperechoic) and the PD in the head of pancreas (which is hypoechoic). A side branch is seen joining the anterior aspect of dilated PD in the head of pancreas. PD = Pancreatic duct. PD: Pancreatic duct; IVC: Inferior vena cava; PV: Portal vein

the transducer towards the lower part of the screen. The movement of an anechoic structure away from the transducer can be considered a fall, similar to a waterfall. Clockwise rotation/rightward angulation shows the fall of tail of the pancreas into the left paravertebral gutter where the PD (more easily seen when dilated) tapers down to disappear in the pancreatic parenchyma and the splenic vessels fall toward the splenic hilum after going through the lienorenal ligament [Figure 4]. Anti-clockwise rotation and upward angulation show fall of the head of the pancreas into the right paravertebral gutter [Figures

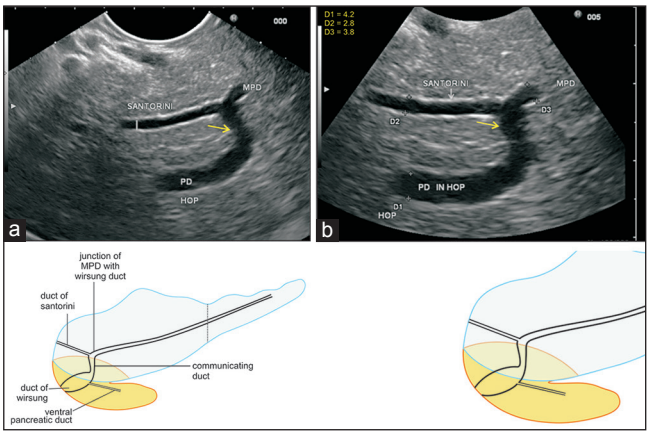

Figure 6. Initially the PD is identified in the body of the stomach. (a) The PD is seen going away from the pancreas and also moving towards the caudal part of the screen after taking a curve (yellow arrow). In this case the communicating duct, the dorsal duct of Santorini and the duct of Wirsung are equally prominent due to obstruction at the head of pancreas. In both the images the duct of Santorini is seen running close to the transducer. The similarity of (a and b) to the line art diagram can be seen for an analogical explanation. PD: Pancreatic duct

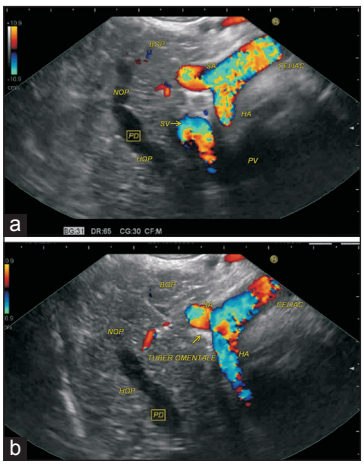

Figure 8. (a and b) A tuber is called the swollen underground part of the stem of plant. Where the anterior surface of the pancreas joins the neck there is a well-marked prominence, the tuber omentale, which abuts against the posterior surface of the lesser omentum. The tuber omentale lies to the left of SMV. (a) The head fall of the PD is seen and the tuber omentale is identified in fig. b lying below the bifurcation of the hepatic and splenic artery. SA: Splenic artery; SV: Splenic vein; PD: Pancreatic duct; SMV: Superior mesenteric vein

5-7]. Along with the fall of the head the SV is seen to move away from the transducer to join the SMV coming from the caudal part of the screen to form a butterfly shaped union and continue as the PV and the splenic artery is seen to move away from the transducer to join the hepatic artery coming from bottom part of screen to form a Y shaped union and continue as the celiac artery [Figure 8]. The PD passes from hyperechoeic part of the dorsal pancreas to a hypo echoic part of the ventral pancreas [Figure 9].

Imaging from duodenal bulb

Positioning of transducer

The positioning of the scope in the duodenal bulb can be done in a long loop while advancing towards the duodenum or after reinsertion into the duodenal bulb once the scope comes out of the duodenal bulb. Many operators prefer to inflate the balloon during bulb imaging for establishing proper contact whereas others rely on gentle up down and right, left movement with suction of a small amount of air in duodenal bulb to come closer to duodenal wall.

Orientation of structures in bulb

The bulb provides the best opportunity to examine the boundary of the head and neck, which contains a groove anteriorly, and posteriorly. In a long loop the image is inverted in appearance and the left side of the screen normally corresponds to the cranial part of the neck of the pancreas and the right side of the screen corresponds to caudal the part of the neck. The gastroduodenal artery is located in the groove anteriorly and the CBD, and PV are located in the groove posteriorly [Figure 10]. With clockwise and anti-clockwise rotation both the gastroduodenal artery (running close to the duodenal wall) and PV (running away from the duodenal wall,) are seen in the same plane fairly regularly. The entire course of PV can be followed from the point of its formation near the left and the lower part of screen beyond the neck of pancreas by union of SMV with SV up to its bifurcation in the hepatic hilum. In this position the gastroduodenal artery identifies the anterior boundary and the PV identifies the posterior boundary of neck of the pancreas [Figures 10 and 11a]. The superior mesenteric artery, which is visualized beyond the SMV, is sometimes used as an additional landmark for the location of the boundary of the head and neck [Figures 10 and 11b]. The main PD in the neck is almost always visible between the duodenal wall (gastroduodenal artery) and the PV. The CBD and IVC are also located along the posterior part of the neck of the pancreas.

Movements of scope

In the duodenal bulb, a clockwise and anti-clockwise rotation causes significant changes in views [Figure 11]. The most important change in views is the fall of the muscularis propria layer of the duodenal wall in which the ampulla is located along the distal part of the duodenal fall [Figure 12]. On a clockwise rotation, the disappearance of the PV toward the cranial part of the screen and appearance of the CBD from the cranial part of the screen occurs as it proceeds towards the

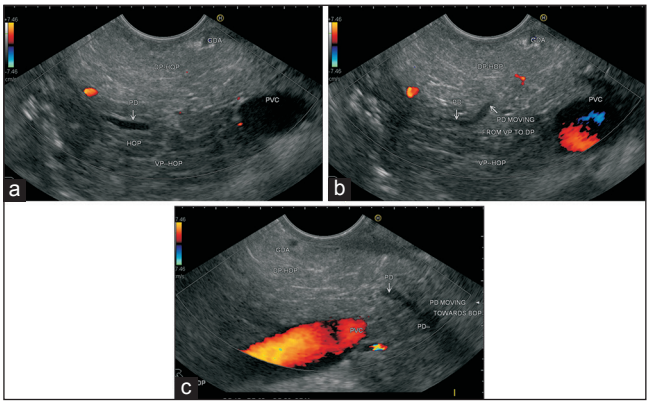

Figure 9. (a-c) The imaging of transition zone of the dorsal and ventral pancreas can be done from stomach, bulb and descending duodenum. In this case the transition zone of the hyper and hypoechoeic pancreas is seen from stomach and the duct is seen traversing from hyperechoeic dorsal pancreas to hypoechoeic ventral pancreas. Figure a shows hypoechoeic head of the pancreas with the PD and hyperechoeic dorsal pancreas, Figure b shows movement of the duct through the transitional zone of the hypoechoeic head of pancreas to the hyperechoeic dorsal pancreas in the same plane with slight angulation and Figure c shows movement of duct through the transitional zone in a different plane. PD: Pancreatic duct

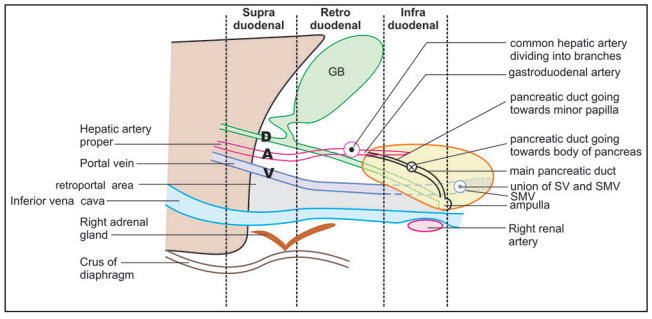

Figure 10. The duodenal imaging after nestling the scope into bulb positions the scope in a natural position to examine the retroduodenal area and in this position the neck of pancreas is usually identified between the gastroduodenal artery and CBD. This schematic diagram shows that five linear structures are normally closely related to the duodenal bulb. These structures are PV, CBD, hepatic artery or gastroduodenal artery and IVC. During imaging from the duodenal bulb in the infraduodenal area the gastroduodenal artery lies to the close to duodenal wall, IVC lies behind the pancreas and the CBD and PV course through the pancreatic parenchyma. IVC: Inferior vena cava; CBD: Common bile duct

papilla [Figures 13 and 14]. On a clockwise rotation, the PD more or less remains stationary in the same place and moves around in a circle as it proceeds toward the muscularis propria layer of the duodenal wall and opens at the ampulla/papilla. An anti-clockwise rotation follows the gastroduodenal artery towards its formation where it joins the common hepatic artery. The PV and CBD are followed-up into hepatoduodenal ligament. In this anti-clockwise rotation the fall of neck is regularly seen as it goes away from the transducer toward the body of the

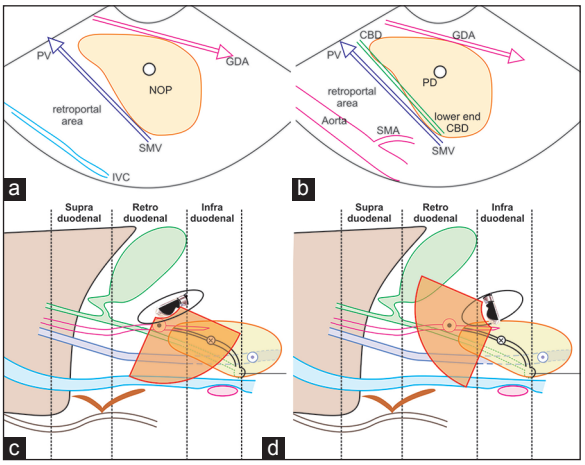

Figure 11. (a and b) This diagram shows the general location of the mesenteric vessels, PV and IVC during imaging from a duodenal bulb. The aorta and superior mesenteric artery can be also seen from the duodenal bulb beyond the head of the pancreas. GDA = Gastroduodenal artery. (c) A clockwise rotation moves the image towards the head of pancreas into the infraduodenal area, and in this position the movement of the PD from the dorsal pancreas to the ventral pancreas can be seen. In this position the PV and IVC are more likely to be seen in the distal part of the screen. (d) An anti-clockwise rotation moves the image towards the supraduodenal area and in this position the body of the pancreas, aorta and superior mesenteric artery are more likely to be seen beyond the neck of the pancreas. The fall of the PD in the neck and the pancreatic parenchyma can be seen only to a limited extent going towards the body of pancreas. The continued movement of anti-clockwise rotation takes the direction of imaging further and higher up towards the hepatoduodenal ligament. PD: Pancreatic duct; IVC: Inferior vena cava

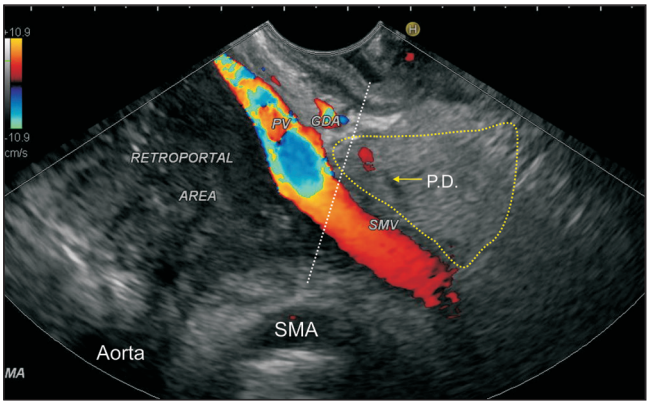

Figure 13. The PD in neck is identified in front of PV. In this case a hypoechoeic lymph node is seen in the retroportal area. The area shown among the white line demarcates the upper boundary of the neck of the pancreas. The neck of the pancreas is outlined by yellow triangular outline. In this case the superior mesenteric artery is seen beyond the PV and is an additional marker to identify the neck of pancreas. The PD is seen in the pancreatic parenchyma. PD: Pancreatic duct

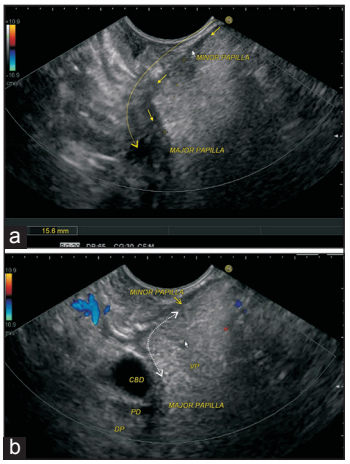

Figure 12. (a) When the imaging from the bulb is done the muscular layer of the duodenum is seen to fall away from the transducer. This fall of the muscular layer is known as the duodenal fall (dotted arrow indicates the general direction of fall and the small yellow arrow is shown within the muscularis layer of the fall of the duodenal wall). The minor papilla is generally seen in the wall of the 2nd part of the duodenum as a small triangular hypoechoeic area in the falling muscular layer of the duodenal fall. Any mucosal fold does not cover the minor papilla in the majority of cases. (b) In the second figure the PD is seen joining the CBD near the major papilla which is generally covered by a fold in the duodenum. The distance between the minor and major papilla is approximately 1–2 cm (white arrow). The minor papilla is seen as a triangular hypoechoeic area along the duodenal wall close to the hypoechoeic ventral pancreas. The size of the minor papilla depends on the amount of pancreas that is drained through the duct of Santorini. Sometimes the course of the duct of Santorini is identified in the hyperechoeic ventral pancreas with more difficulty because of the small caliber of the duct. PD: Pancreatic duct; CBD: Common bile duct

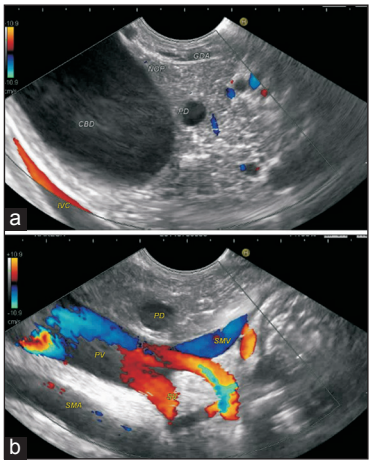

Figure 14. (a) The PD in the neck is identified between the wall of duodenum where the gastroduodenal artery is present and the bile duct. (b) In this figure the PD in the neck is also identified classically between the duodenal wall and PV. (a) In the IVC, it is seen beyond the dilated CBD and (b) in the superior mesenteric artery, it is seen beyond the PV. PD: Pancreatic duct; IVC: Inferior vena cava; CBD: Common bile duct

pancreas [Figure 15]. Generally, a triangular neck is easily identified between the PV and gastroduodenal artery and an anti-clockwise rotation follows the fall of the PD in body of the pancreas and a clockwise rotation follows it toward the papilla [Figure 16].

Imaging from duodenum

Positioning of the transducer and orientation of structures

Duodenal imaging from horizontal (d3) beyond papilla descending (d2) near papilla or ascending superior (d1) part of the duodenum above papilla (after wedging at the duodenal bulb) is the mainstay of pancreatic head imaging. A combination of movements of withdrawal and rotation is useful. As experience is gained the movements of withdrawal and rotation get combined into a single smooth movement.

Imaging beyond papilla

Repeated pushing of the scope 2 or 3 times and positioning the scope deeper into the third part of the duodenum (d3). Imaging from d3 demonstrates the uncinate process, mesenteric vessels, aorta and IVC. In this position, the UP is generally seen between the transducer and aorta. On the withdrawal when the probe reaches around the inferior duodenal angle UP becomes continuous with the posterior segment of head of the pancreas.

Imaging near papilla

The ampulla is the mainstay of endoscopic imaging for identifying the position of the scope. The ampulla is identified by following the muscular layer where it appears as thickening of the duodenal wall making a rounded five-layered structure protruding into the duodenal lumen. It is better seen after good water coupling, keeping the transducer perpendicular to papilla and in motionless duodenum. If a balloon is used, only a small amount of water should be filled into the balloon to avoid smashing the delicate ampulla [Figure 17].

Following the CBD and PDs as the scope is withdrawn from d3, it also identifies the ampulla. The CBD and PDs are identified as two avascular and anechoic structures within the pancreatic parenchyma. The distal CBD is closer to the duodenal wall than the PD. The PD can take a straight course towards the papilla or it can take a tortuous course by going below the papilla deeper into ventral pancreas before coming up to open at ampulla/papilla. A d3 and d2 clockwise rotation shows the anterior segment of the head of the pancreas and the mesenteric vessels and an anti-clockwise rotation shows the posterior segment of the head of the pancreas and the uncinate process [Figures 18-21]. In general if imaging is started keeping the ampulla in a neutral position a clockwise rotation generally moves the beam anteriorly and follow the course of pancreas and PD from within the ventral pancreas toward the dorsal pancreas and an anti-clockwise rotation generally moves the scanning beam posteriorly and follows the bile duct from within the ventral pancreas towards the posterior surface of the pancreas and finally into the hepatoduodenal ligament and the retroportal area.

Imaging above papilla

Higher up once the scope is positioned/wedged/fixed in a d1 transversely neutral position clockwise rotation shows the anterior segment of the pancreas where the

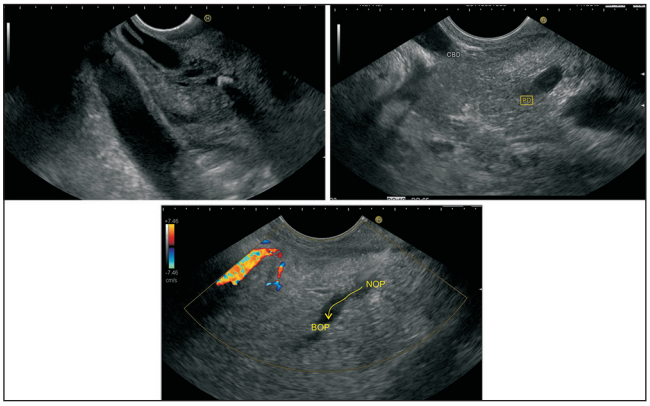

Figure 15. The PD in the neck is identified between the wall of the duodenum and the PV. In this case the upper end of the bile duct lies close to the probe and the lower end is seen going towards the lower part of the screen into the pancreatic parenchyma. The stone within the PD is seen in the area below the duodenal wall. Anti-clockwise rotation traces the PD towards the body of pancreas, which in this case is seen as a falling duct and can be called a PD neck fall. PD: Pancreatic duct

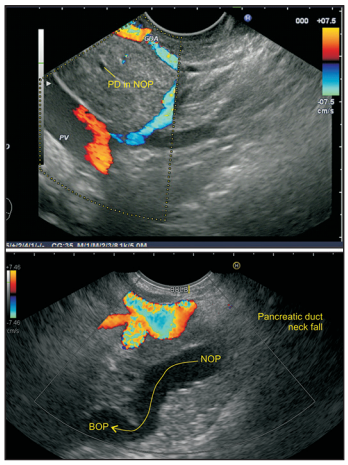

Figure 16. The PD in the neck is identified between the gastroduodenal artery and the PV. The PD can be imagined from the duodenal bulb and the PD of the neck of the pancreas falls away towards the PD of body of the stomach and this can be considered as the neck fall of the PD. PD: Pancreatic duct

duct of Santorini can be identified [Figure 22] whereas an anti-clockwise rotation shows the structures in the hepatoduodenal ligament.

CONCLUSION

Recognition and understanding of the imaging anatomy of the pancreas, might lead to better evaluation of pancreatic disease. Knowledge of segmental anatomy of the pancreas might be useful for better evaluation of pancreatic pathology and before considering intervention by endotherapy or surgery.

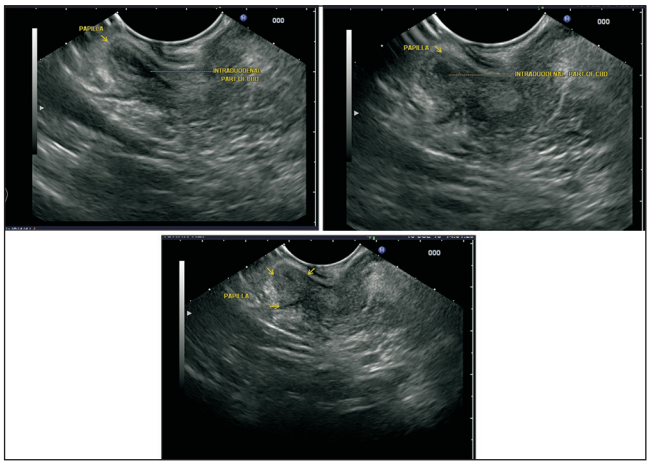

Figure 17. The papilla is the protruding structure in the lumen of the duodenum and is covered on both sides by the muscular layer of the wall. At the point of the entry of the papilla into the duodenal bulb the continuity of the muscular layer as a smooth duodenal fall is absent. At the point of union of the bile duct and PD the dilation of both ducts is known as ampulla. An attempt should be made to trace the intra papillary part of the PD all the way to the tip of the papilla or into a common ampulla. PD: Pancreatic duct

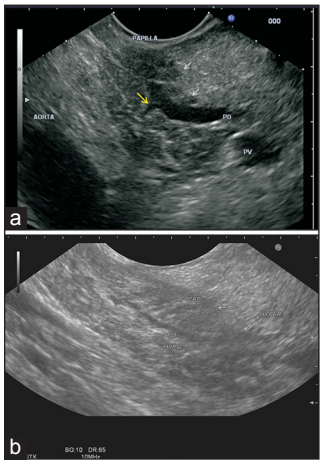

Figure 19. The imaging of the transition zone of the dorsal and ventral pancreas can be done from the descending duodenum. In these two different cases (a and b) the transition zone of the hyper and hypoechoeic pancreas is seen from the duodenum and the Wirsung duct is seen traversing from the hypoechoeic ventral pancreas to the hyperechoeic dorsal pancreas. From this position a clockwise rotation with a slight withdrawl of the scope is able to trace the PD into the neck and body of the pancreas. A duct coming from the uncinate process (ventral PD) is also seen (a). PD: Pancreatic duct

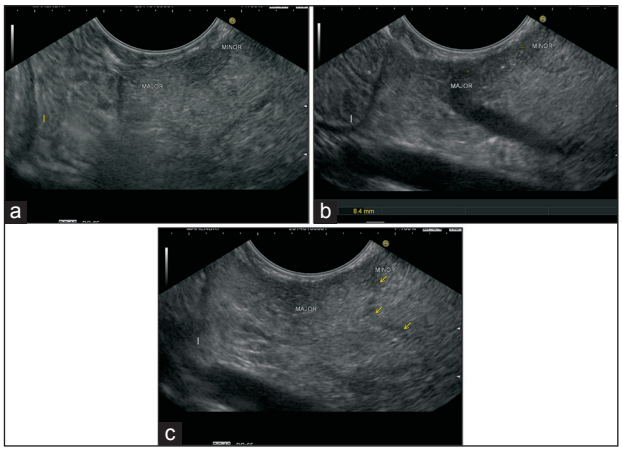

Figure 18. Imaging of PD from the 2nd part of the duodenum. (a) The imaging of the opening of the major and minor PD can be done from the 2nd part of the duodenum. In this case the hypoechoeic area close to the wall of the duodenum indicates the major and minor papilla. (b and c) On a clockwise rotation from this position the major duct is seen first. On a continued clockwise rotation the minor duct is seen approximately 1 cm above the major duct. Usually the major PD and aorta are seen together during imaging from the 2nd part of the duodenum. On a clockwise rotation of the scope the imaging goes from a ventral plane to a dorsal plane and the visualization of the minor duct is more often seen with the SMV. PD: Pancreatic duct; SMV: Superior mesenteric vein

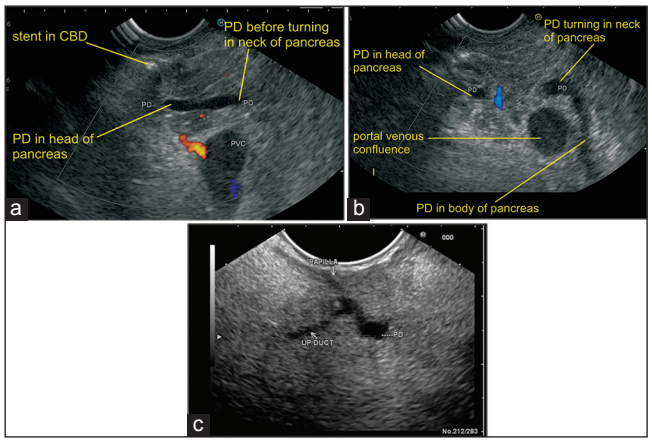

Figure 20. (a and b) The main duct turns caudal and posterior on reaching the head of the pancreas. At the level of the major papilla, the duct turns horizontally to join the caudal surface of the CBD. It then enters the wall of the duodenum, usually at the level of the second lumbar vertebra. In this case, the imaging of the PD is done from the second part of duodenum and as the scope is withdrawn a little the fall of the PD from the head portion towards the body portion is seen in (b). The CBD has a stent inside. The fall of PD in the neck of pancreas can be seen both from bulb as well as from the 2nd part of duodenum. (c) In a normal person, the uncinate process duct may be visualized only from the second part of the duodenum. In this case the opening of the PD is seen in the second part of the duodenum and the uncinate process duct is seen joining the main PD on the aspect away from the duodenal wall. The course of branch of the uncinate process is a little caudal and the origin of the duct is about 1-cm above the insertion of main PD into the ampulla. The uncinate process duct is also called the ventral PD and is visualized in about 30% of cases in normal people. PD: Pancreatic duct; CBD: Common bile duct

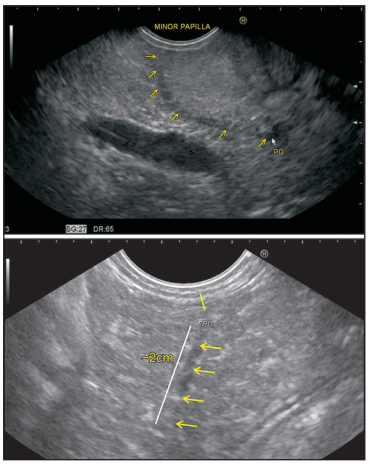

Figure 21. Application of color Doppler can identify the anechoic duct coming to duodenal wall within the dorsal hyperechoeic part of the pancreas. During withdrawal the opening of the minor papilla is about 1.5-2 cm. above the major papilla. The length of the duct of Santorini that can be visualized is variable and depends on the amount of pancreatic tissue that it drains. Normally the minor papillary duct is seen only for a distance of about 1-2 cm. In the first case the course of the duct is seen for a longer distance of more than 3 cm whereas the second case the PD is seen only for a distance of about 2 cm. PD: Pancreatic duct

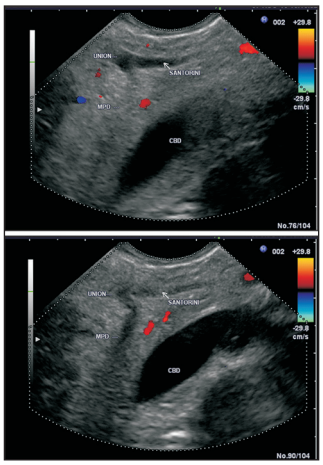

Figure 22. Once the scope is wedged at the D1, D2 junction the PD is followed by an anti-clockwise rotation to the head fall. The Santorini duct may be seen joining the cranial aspect of this union and can be followed-up towards the duodenal wall. In this case the Santorini duct is well visualized and the communicating duct to Wirsung is also well seen. PD: Pancreatic duct

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