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Ultrasound of the pancreas

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Topographic remarks

The pancreas is a medium retroperitoneal organ, slightly flattened and tapered. It is located transversally in front of the main vessels at the level of the first or second lumbar vertebra. It is considered to be a fixed posterior organ. It presents as a slightly oblique shape extending left and upward, with the cephalic portion in a generally lower position compared with the body and the tail. It lies against the vertebral column, which determines the slight curvature of the organ, and is surrounded by soft retroperitoneal and peritoneal tissue.

Pancreas anatomy

The pancreas is a compound acinar gland. Its exocrine excretion is pancreatic juice, an important digestive fluid, while the endocrine secretion consists of peptid hormones involved mainly in sugar metabolism. The pancreas is usually divided in four parts: the head with the uncinata process, neck, body and tail. The head lies within the curve of the duodenum and appears in complete contact with the posterior abdominal wall, the inferior vena cava (IVC) and the portal vein at the top. The uncinata process originates from the lower left portion of the head and lies posterior to the superior mesenteric vessels. The neck or isthmus generally appears as a slight constriction connecting the head to the body. It is located in front of the superior mesenteric vein and is completely overlaid on its anterior surface by the posterior parietal peritoneum; its postero-inferior surface is related to the origin of the portal vein, which is formed by the junction of the superior mesenteric and splenic veins. The posterior parietal peritoneum, which overlays the front face of the pancreatic body, limits the posterior face of the lesser sac (Bursa omentalis). The pancreatic body is covered frontally by the gastric cavity, posteriorly it is in contact with the splenic vein and it is related to the superior mesenteric artery and the left renal vein, which courses between the superior mesenteric artery and the aorta to merge into the IVC. The superior margin is slightly crossed anteriorly by the splenic artery, which arises from the coeliac trunk, whereas the inferior margin lies on the duodeno-jejunal flexure. The tail is orientated posteriorly, left and upwards, it touches the splenic hilum as well as the left adrenal gland and the upper kidney. It represents the mobile part of the gland and, similar to the body, it is separated from the stomach by the lesser sac. The anteroposterior dimension of the pancreas varies greatly between individuals and tends to decrease with age. The normal

measurements are: head, 2 cm; neck < 1 cm; body and tail, 1 - 2 cm; mean length is 13 - 15cm [(1)].

Pancreatic and peri-pancreatic veins

The veins of the pancreas open into the splenic and superior mesenteric veins, from where the junction of the portal vein originates. The superior mesenteric vein runs over the uncinate process, whereas the splenic vein, rising from the splenic hilum, courses along the supero-posterior surface of the pancreas.

Pancreatic and peri-pancreatic arteries

The arteries of the pancreas derive from the splenic and the pancreaticoduodenal branches of the hepatic and superior mesenteric arteries.

The splenic artery, arising from the coeliac artery, runs along the superior margin of the gland; from it, some arteries perpendicular to the splenic artery enter the body and tail parenchyma. In 92% of cases the common hepatic artery, which courses along the superior margin of first portion of the duodenum and continues into the proper hepatic and gastroduodenal arteries, also arises from the coeliac trunk [(2)]. The gastroduodenal artery courses along its ventral surface.

The superior mesenteric artery arises from the aorta behind the lower portion of the pancreatic body then courses anteriorly to the uncinate process and the third portion of the duodenum.

Pancreatic ductal system

The pancreatic ductal system is represented by the main pancreatic duct (also known as the Wirsung duct) and the accessory, functional or not, pancreatic duct (also known as the Santorini duct).

The main pancreatic duct takes its origin from the junction of the small ducts of the tail lobules. It courses transversely from left to right through the pancreatic body and flows into the major duodenal papilla (of Vater) jointly with the common bile duct (CBD). It appears as a thin hypoechoic line bordered by two echogenic margins and its maximum diameter varies from 3 mm in young adults to 4 mm in older people in the genu pancreatis. The CBD crosses

the anterior surface of the portal vein to the right of the proper hepatic artery and runs behind the first portion of the duodenum to arrive into the parenchyma of the pancreatic head, close to the second portion of the duodenum.

The accessory pancreatic duct originates from the main pancreatic duct and just crosses the head of the pancreas, superficial to the main duct. It flows into the minor duodenal papilla, which is 2 cm higher than the major duodenal papilla.

Pancreas development

The pancreas develops in two parts, the dorsal and ventral. The dorsal part arises as a diverticulum from the dorsal side of the duodenum, just above the hepatic digression and, grows upwards and backwards into the dorsal mesogastrium forming a part of the head and the uncinata process as well as the whole body and tail.

The ventral portion appears as a diverticulum from the primitive bile duct, which forms the remaining part of the head and the uncinata process. As a consequence, the duct of the dorsal part (accessory pancreatic duct) opens independently into the duodenum, while the duct of the ventral part (main pancreatic duct) opens together with the CBD. Around the sixth week of gestation the two parts of the pancreas meet and fuse to establish a communication between their ducts. Following fusion of both ducts the terminal part of the accessory duct remains thin and its opening into the duodenum is occasionally obliterated, whereas the pancreatic duct increases in size and forms the main duct of the gland.

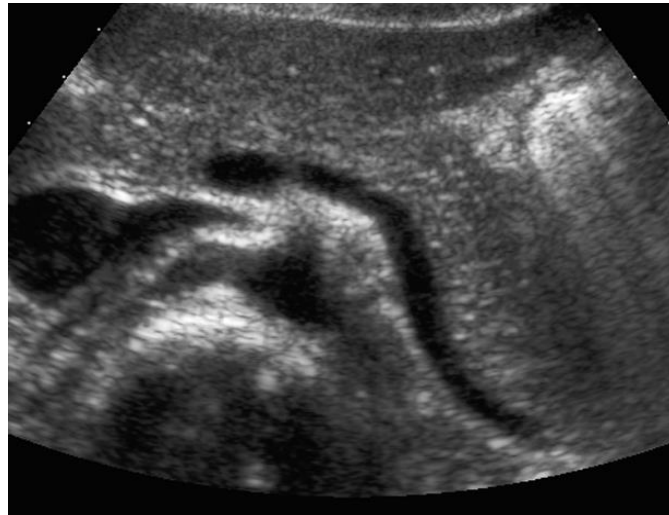
At first the pancreas is directed upwards and backward between the two layers of the dorsal mesogastrium, which gives it a complete peritoneal sheath, its surfaces facing the right and the left side. With a change in position of the stomach, the dorsal mesogastrium is drawn downward and to the left, so that the right side of the pancreas is directed backward and the left directed forwards. The right surface connects to the posterior abdominal wall and the peritoneum covering absorbed; thus, in the adult, the gland appears to lie behind the peritoneal cavity.

Knowing the physiological pancreatic embryogenesis is important to correctly recognize and evaluate some pancreatic anomalies and pseudo-lesions that potentially may occur as a result of the embryologic pancreatic fusion.

Ultrasound study of the pancreas and anatomy

The study of the pancreas includes transverse, longitudinal and angled oblique scan planes [Figure 1].

Figure 1 Oblique ultrasound scan of the pancreatic gland. The pancreatic tail, body, isthmus and the upper part of the head of the pancreas can all be visualised.



The plane passing through the emergence of the coeliac trunk identifies the beginning of body-tail. In the presence of gastric gas it can cover the left portion of the pancreatic gland. The plane passing through the splenic vein demonstrates typical “comma” morphology. In this scan, it is easy to identify the body with the pancreatic duct [Figure 2] and the isthmus of the pancreas on the confluence of the splenic vein with the superior mesenteric vein. At the level of the lateral border of the head the gastroduodenal artery is often seen ventrally represented by anechoic image; and the CBD can be seen dorsally.

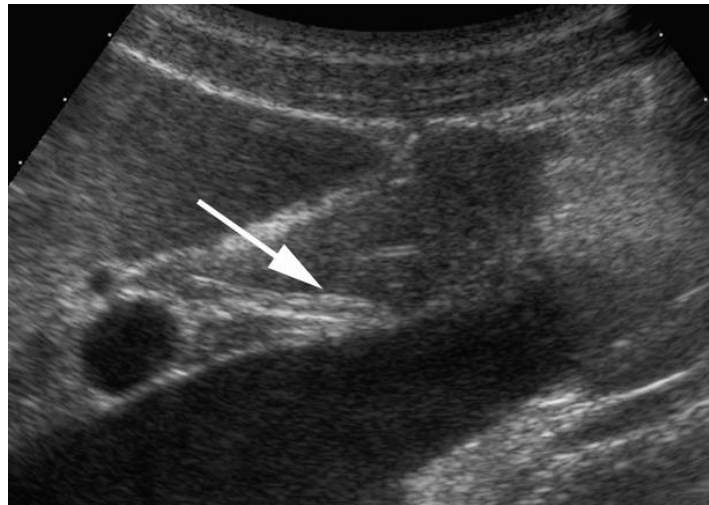
Figure 2 Pancreatic duct. Ultrasound oblique scan of the pancreatic body with visualisation of the main pancreatic duct (arrow).



The scan passing through the mesenteric vessels visualises the lower portion of the pancreatic head and the uncinata process, which is anatomically located between the superior mesenteric vein and the IVC. The superior mesenteric artery appears in front of the aorta and to the left of the superior mesenteric vein.

Longitudinal scans are executed on the four anatomical parts of the pancreas. The head is visualised in all its extensions, and in terms of its relationship with the IVC. Its cephalic portion is cranially delimited by the portal vein and the first duodenal part; more caudally it connects with the third duodenal portion. With a longitudinal and slightly oblique scan it is usually possible to visualise the intra-pancreatic CBD [Figure 3].

Figure 3 Intra-pancreatic common bile duct. Ultrasound longitudinal and slightly oblique scan of the pancreatic head with visualisation of the pancreatic duct and the intra-pancreatic tract of the common bile duct (arrow).



The scans at the neck level require the superior mesenteric vein as reference point; this is visualised at the junction with the splenic vein. Somewhat more dorsally it is possible to see the uncinata process. The main pancreatic duct can be visualised at the level of the pancreatic body [Figure 2]. The reference point on the body is represented by the splenic vessels, transversally orientated, which course on the superior border. The tail can be visualised on a longitudinal anterior scan; however, demonstration of this anatomical structure is often difficult owing to gastric gas, which can cover it. Left intercostal scans are generally used to localise the caudal portion by using the splenic acoustic window.

The normal US pancreatic echogenicity and appearance depends on patients age, due to the para-physiological changes that occur within the gland over the years. The echotexture of the normal pancreas is usually homogeneous, but a mottled appearance may sometimes be observed. In young patients there is few adipose tissue within the pancreatic gland, whereas during the years adipose tissue is collected among pancreatic lobules until a complete fatty replacement, also known as lipomatosis, of the pancreas. The normal “young” pancreas has a low echogenicity, similar to the normal liver or even more hypoechoic than the liver, whereas with aging and obesity, the more adipose tissue is collected, echogenicity is increasing. In case of severe lipomatosis the pancreatic gland may be as echogenic as the

adjacent retroperitoneal fat, occurring in up to 35% of cases [(1;3)]. Other causes of pancreatic fatty infiltration include chronic pancreatitis, dietary deficiency, viral infection, corticosteroid therapy, cystic fibrosis, diabetes mellitus, hereditary pancreatitis and obstruction caused by a stone or a pancreatic carcinoma [(4)].

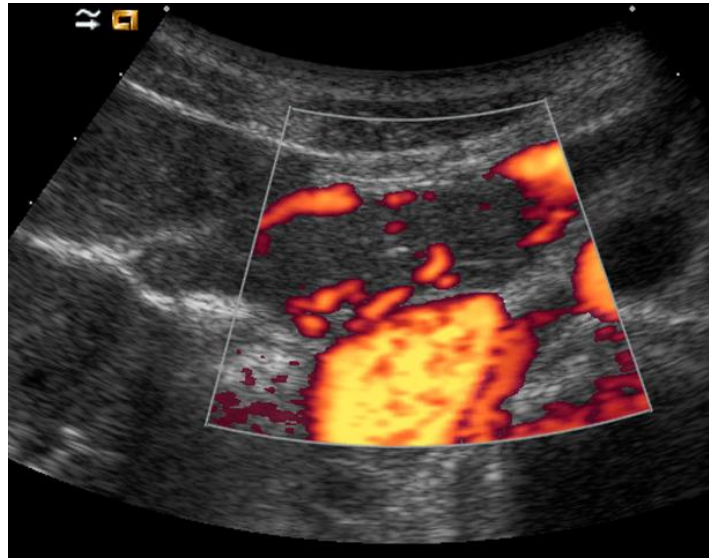
Doppler study of the pancreas and vascular anatomy

Doppler studies are an integral part of ultrasound examination of the pancreas [(5)]. The peri-pancreatic vascular structures that are evaluated and easily recognised are the portal vein, the celiac trunk, the splenic artery and vein, the gastro-duodenal artery, the superior mesenteric artery and vein, the aorta and the IVC. Only a few parenchymal vessels are usually appreciable in normal conditions; however, the visualisation of smaller peri-pancreatic [Figure 4] and intra-pancreatic [Figure 5] vessels is possible thanks to increased Doppler sensitivity.

Figure 4 Gastro-duodenal artery. Colour Doppler ultrasound longitudinal scan of the pancreatic head. The gastro-duodenal artery can be visualised.



Figure 5 Pancreatic arterial arcades. Power Doppler ultrasound transverse scan of the pancreatic head. The pancreatic arterial arcades can be visualised.



Clinical applications of the Doppler studies of peri-pancreatic vessels include the assessment of patency and features of blood flow. Doppler and pulsed Doppler appearance of peri-pancreatic vessels have been well-documented [(1;2)]. In normal conditions, the mean speed of blood in peri-pancreatic arteries is approximately $103 \pm 8\text{cm/s}$ in the coeliac trunk, $78 \pm 6\text{cm/s}$ in the hepatic artery, $85 \pm 18\text{cm/s}$ in the splenic artery and $100 \pm 22\text{cm/s}$ in the superior mesenteric artery [(1)]. Mean portal flow velocity is $12 - 20\text{cm/s}$. The resistance index in the superior mesenteric artery is in general higher than in the coeliac trunk and its branches [(1)]. Abnormal signals and physiological variations in Doppler waveform in peri-pancreatic vessels are not fully understood because of the influence of physiological, pharmacological and pathological conditions [(1)]. However, Doppler examination allows the changes produced by diseases in peri-pancreatic vessels to be recognised. This may be of importance in staging of pancreatic cancer and for the detection of vascular complications of pancreatitis.

Other ultrasound techniques

Ultrasound evaluation has different tools available to study organs, and in particular the pancreatic gland. As previously described, the ultrasound B-mode (Brightness Mode) is the

conventional ultrasonography technique. Other techniques that could be used in the pancreatic evaluation are harmonic imaging, compound and volumetric imaging, Doppler imaging, already described, elastography imaging and contrast-enhanced ultrasound (CEUS). A pancreatic harmonic examination is characterized by a higher sensitivity than conventional B-mode ultrasound regarding focal pancreatic lesions detection, both solid and cystic ones [(4-6)]; moreover this technique is able to more clearly delineate lesion margins and mass internal solid components [(7)]. Harmonic imaging, compared to B-mode ultrasound, provides a higher differentiation of soft tissue, providing both the detection of even small lesions with little changes in echogenicity in respect to the adjacent parenchyma and the identification of calcifications. Furthermore, it has the ability to better clearly study deep structures and overweight patients [(5)]. Summarizing, harmonic imaging can increase both spatial and contrast resolution, providing an enhanced overall image quality, better lesion conspicuity, and advantages in fluid-solid differentiation in the pancreatic study, compared to conventional B-mode ultrasound [(4)]. Compound imaging is able to increase contrast and spatial resolution in the B-mode imaging. Volumetric ultrasound imaging is a relatively new technique based on the acquisition of a volume dataset of anatomic structures. The correct application of these new technologies in the ultrasound pancreatic study results in a conventional imaging with very high spatial and contrast resolution. Elastography imaging allows for a non-invasive analysis of tissue stiffness, giving a new revolutionary approach in the study of focal and diffuse diseases. Pancreas elastography can be obtained by using two main techniques: first is strain elastography (SE); second is shear wave elastography (SWE), which in turn includes transient elastography (TE), point SWE, 2D-SWE and 3D-SWE, and acoustic radiation force impulse (ARFI), the most recent technique introduced [(8)]. Through a colour or a grey scale map, a qualitative evaluation of the elastic properties of tissues is provided by the strain elastography, giving the opportunity that isoechoic lesions, which are undetectable at conventional B-mode ultrasound, might be identified at elastography studies. Shear wave imaging, on the contrary, allows both qualitative and quantitative evaluations. The ARFI ultrasound technique permits the evaluation of mechanical strain properties of deep tissues without the need of external compression, allowing both a qualitative and a quantitative evaluation of the tissue stiffness: in the qualitative one it creates a static map of the relative tissues stiffness; whereas in the quantitative one the speed of the wave through the tissue is calculated in m/s and the stiffer the tissue is, the

greater the shear wave velocity [(8)]. The healthy pancreas appears as intermediately soft tissue, characterized by a homogeneous soft tissue green area at elastographic imaging; with the adipose tissue accumulation during the years and fibrosis degeneration of parenchyma, the elastographic image becomes heterogeneous, due to different colour areas within the gland. The mean wave velocity value obtained in a healthy pancreas with ARFI technique is about 1.40 m/s, as reported in literature [(8-10)].

Contrast-enhanced ultrasonography is a relatively new tool of conventional ultrasound that significantly increases the accuracy of the first line examination in characterizing focal solid and cystic lesions. Administration of ultrasound contrast agents allows an accurate evaluation of macro- and microcirculation, in and around a focal mass, giving more detailed and advanced results than color-Doppler study thanks to its high spatial, contrast and temporal resolution. Due to the rich vascular gland supply, enhancement of the pancreatic gland begins almost at the same time as aortic enhancement. After this early phase (arterial/pancreatic, from 10 seconds to 30 sec), there is the venous phase (from 30 to approximately 120 sec) and the late phase (about 120 sec after injection. Ultrasound contrast agents have a purely intravascular distribution without any interstitial phase, which is an important distinctive feature from contrast media used in CT and MRI studies [(4)].

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