SEGMENTAL ANATOMY OF THE PANCREAS AND ITS DEVELOPMENTAL VARIANTS

Gustavo Raichholz, Sebastián Giménez, Santiago Dumoulin, José Luis Sañudo

Resumen

La organogénesis del páncreas es un proceso complejo, en el que se pueden producir una serie de errores embriológicos dando como resultado anomalías del desarrollo. Las más frecuentes son el páncreas divisum, el páncreas anular y el páncreas ectópico. Generalmente estas anomalías son un hallazgo incidental en estudios de imagen realizados a individuos asintomáticos o por otro motivo, pero en ocasiones pueden dar manifestaciones clínicas importantes que requieren de un tratamiento médico especializado. El conocimiento de la anatomía segmentaria del páncreas permite una correcta localización de las lesiones pancreáticas y una buena planificación quirúrgica.

Palabras clave: Páncreas divisum, páncreas anular, páncreas ectópico.

Abstract

Pancreatic organogenesis is a complex process, which can produce a series of embryological errors resulting in development anomalies. The most common ones are pancreas divisum, annular pancreas and ectopic pancreas. Usually these anomalies are incidental findings in imaging studies performed for other reasons on asymptomatic individuals, but sometimes they can provide important clinical manifestations that require specialized medical treatment. Knowledge of the segmental anatomy of the pancreas permits a proper localization of pancreatic lesions and a good surgical planning. The pancreas is divided into right, left and central pancreas or pancreatic isthmus.

Key words: Pancreas divisum, annular pancreas, ectopic pancreas.

Contact information:
Gustavo Raichholz.
Diagnóstico por Imágenes Junín - Santa Fe capital.
E-mail: raichholz-gustavo@hotmail.com

Recibido: 25 de agosto de 2015 / Aceptado: 13 de marzo de 2016

Received: August 25, 2015 / Accepted: March 13, 2016
Introduction

Knowledge about segmental anatomy of the pancreas is essential for a correct imaging interpretation as well as a proper surgical exploration. For a long time, the pancreas was difficult to explore radiologically and surgically due to its retroperitoneal location in the upper part of the abdomen. Now, modern imaging methods contribute to determining the exact variants of pancreatic development, its morphology, its anatomic relationships, and to having a better localization of the pancreatic pathology. The purpose of the following article is to describe the main aspects of the segmental anatomy of the pancreas and its developmental variants.

Descriptive anatomy

The pancreas develops from the primitive intestine thanks to the ventral and dorsal pancreatic buds. It is an accessory gland of the digestive system with mixed exocrine and endocrine functions. Macroscopically, it has a lobulated aspect and a pale yellow color. It weighs from 85 to 100 gr and is 12 to 15 cm long. It has 1 to 3 cm anteroposterior diameter and it is 4 to 8 cm of height, with its maximum at the head. It is 71% water and 13% proteins, and its fat component is variable and can range from 3 to 20% (1).

The pancreas is located across the retroperitoneum between the duodenum to the right and the spleen to the left at the level of L1-L2. It is related with the transcavity of the omentum on top, the transverse mesocolon in its front and the major omentum below. Anatomically it is divided in 4 sections: head, neck, body, and tail. It can also be divided into right pancreas, central pancreas, and left pancreas.

The right pancreas includes the head and the uncinate process or Winslow pancreas. To determine its limits radiologically it is necessary to identify the gastroduodenal artery, which runs through the anterior edge of the pancreas and the superior mesenteric vein (Figure 1). An imaginary line that goes through the right side of the gastroduodenal artery and the right side of the superior mesenteric vein (Figure 2) divides the pancreas into right and central pancreas. The central pancreas or pancreatic isthmus is located immediately anterior to and slightly towards the right of the superior mesenteric vein. The left pancreas, made up of the body and the tail, is located next to the imaginary line at the left, and passes through the left edge of the superior mesenteric vein (Figure 2). Another radiological way of recognizing the left pancreas is to identify the splenic vein, since the head and the tail of the pancreas is always located immediately anterior to the splenic vein in humans. It is important to remember that due to the oblique position of the organ, sectional views in tomographic and magnetic resonance images only show partial small segments of the pancreas in each section.

The head of the pancreas has an extension in its inferior and left extremity, which is the hook (uncus or small pancreas of Winslow). It is located behind the superior mesenteric vein. In 41% of the cases, it does not reach the vein, in 32% of the cases it reaches the gap between the artery and the superior mesenteric vein, in 15% of the cases it extends towards the back of the superior mesenteric vein (Figure 3), and in 12% of the cases, it reaches the aorta (1). A dense connective lamina connects the uncinate process of the pancreas to the superior mesenteric artery and to the aorta. In that lamina, known as retroportal lamina (Figure 4), there are nervous and lymphatic elements, the initial segment of the posterior pancreaticoduodenal artery, and almost all the nervous laminas derived from the trigeminal ganglion, the pre-aortic plexus and the mesenteric plexus. During cephalic pancreatectomy, the surgeon must pay special attention to this lamina since the aberrant right hepatic artery, branch of the superior mesenteric artery runs through it (Figure 5). It is also a specific place that helps with the decision to perform a surgical resection with healthy margins (1, 2, 3). The retroportal lamina is a key site of locoregional invasion of pancreatic cephalic tumors and must be analyzed thoroughly during a magnetic resonance scan of the pancreas (Figure 5). The pancreas does not have a fibrous capsule but it is enclosed by a fatty lamina that is individualized in images and through which vascular and nervous structures happen.

The pancreas receives its irrigation through the celiac trunk and the superior mesenteric artery. Once they have penetrated the arteries of the pancreas, they are interconnected through a rich net of arterial anastomosis, which makes the pancreas an organ that is particularly resistant to ischemia. The head
is irrigated by superior pancreaticoduodenal arteries, branch of the gastroduodenal artery and by the inferior pancreaticoduodenal artery, branch of the superior mesenteric artery. Both pancreaticoduodenal arteries are divided into anterior and posterior branches that anastomose with each other and create the anterior and posterior arterial arcades. The body and the tail of the pancreas are irrigated by the dorsal pancreatic artery. Its origin is variable, it can be the branch of the splenic artery (40%), of the celiac trunk (22%), of the superior mesenteric artery (14%) or of the common hepatic artery (12%). The veins of the pancreas drain in the portal system through the splenic vein, the superior mesenteric vein, the inferior mesenteric vein, and the portal vein. Generally, the pancreatic veins run parallel to arteries (1).

Figure 1. Segmental anatomy of the pancreas. Computed Tomography (CT) scan of the abdomen with intravenous contrast in peripancreatic phase. Gastroduodenal artery (long arrow) running through the anterior edge of the pancreas. Superior mesenteric vein (short arrow) located posteriorly to the pancreas.

Figure 2. Segmental anatomy of the pancreas. CT scan that shows the division between the right section of the pancreas (D), the central section of the pancreas (C) and the left section of the pancreas (I) after drawing an imaginary line that goes through the gastroduodenal artery to the right and the superior mesenteric vein, and an imaginary line that runs through the superior mesenteric vein to the left.
Figure 3. Anatomical variants of the uncinate process.
Abdominal CT with intravenous contrast injection. Uncinate process extending behind and going beyond the superior mesenteric vein.

Figure 4. Retroportal lamina.
Focalized CT in topography of the right section of the pancreas (P) and superior mesenteric vessels (artery [AMS] and vein [VMS]). The fatty tissue located between the right section of the pancreas and the superior mesenteric artery is known as retroportal lamina.

Figure 5. Retroportal lamina and right hepatic artery.
Abdominal CT with intravenous contrast injection. Note the presence of the right hepatic artery (AHD) originating in the superior mesenteric artery (AMS) and going through the retroportal lamina. The retroportal lamina is dense due to the invasion of an adenocarcinoma of the right section of the pancreas.

Figure 6. Pancreas and Ultrasound Scans.
Transabdominal ultrasound of the superior retroperitoneum that shows a homogeneous and slightly hypoechogenic pancreatic gland (arrows). Superior Mesenteric Vein (VMS) and Splenic Vein (VE).
Pancreas and ultrasound scans
The ultrasound scan of the pancreas does not require specific preparation. Fasting is recommended to eliminate gastrointestinal gases. Simple maneuvers can help to locate the pancreas. One of them is the forced and blocked inspiration, which lowers the liver creating a good acoustic window through the left lobe. In spite of this trick, the proper visualization of the pancreas by means of ultrasound scans can be difficult. Although the head is visible in 90% of the cases in different series, the tail can only be seen in 50% to 60% of the cases (4). In ultrasound scans, the pancreatic parenchyma is homogeneous, composed by thin and regular echoes. Its echogenicity is similar to the normal liver. Pancreatic edges are regular, smooth and well individualized in adjacent planes (Figure 6).

Pancreas and tomography scans
Tomography scans are still the technique of choice to study the pancreas. With the CT it is possible to study the parenchyma, the vessels and the extension of pancreatic pathologies. The exploration implies series without intravenous contrast when searching for calcifications and hemorrhages, and series with i.v. contrast in a pancreatic arterial phase and a venous phase. It is recommended to perform the pancreatic arterial phase 45 seconds after the contrast injection has started, while the venous phase should be performed 75 seconds after the injection has started (4). The density of the parenchyma is similar to the muscle in the series without contrast. After the intravenous injection of iodine contrast, the maximum enhancement of the pancreatic parenchyma is obtained slightly from the portal hepatic phase, around 45 seconds after the injection has started (Figure 7). The enhancement is homogeneous over the pancreatic gland and peripheral lobulations are better seen when the peripancreatic fatty pseudo-capsule is well developed.

Pancreas and magnetic resonance imaging scans
Two technological progresses made possible a proper study of the pancreas by MRI. They are fast sequences and sequences with fat suppression (4). The study of the pancreas must include T1 and T2 weighted sequences. T1 gradient echo sequences with fat saturation make possible a dynamic study after the administration of Gadolinium i.v. The study of the biliary ducts or Magnetic Resonance Cholangiopancreatography (MRCP) or even Cholangio-MRI uses T2 fast spin echo (FSE) sequences. They are short duration sequences (2.5 seconds) involving a single shot (4). In T1 weighted sequences, the pancreas has an intermediate signal, equal to or slightly inferior than the liver. In the sequences with fat suppression, there is a hyper signal due to the presence of aqueous protein in the acini. In T2 sequence, the signal of the pancreas is equal to the liver. After intravenous injections of Gadolinium chelates, it is enhanced intensely and homogenously, and there is hyper signal compared to the liver (Figure 8).

Variants in the appearance and development of pancreas
There are several variations in the shape, size and edges of the pancreatic parenchyma. The left pancreas is located in the pancreatic splenic omentum. According to the development of this omentum and its communication with the splenic gastric omentum, the tail of the pancreas can be more or less mobile and occupy variable spaces into the left hypochondrium. This will create original shapes: flat pancreas, an inferior concavity, anterior or posterior hook, etc. There are even cases of bifid pancreas. These three pancreatic congenital anomalies that can have a clinical translation are pancreas divisum, annular pancreas, and ectopic pancreas.

Pancreas divisum
Pancreas Divisum (PD) is the most frequent anatomical anomaly of the pancreas. It was reported in 4 to 10% of the general population (1-14% in the autopsy series) (5). This anomaly is the result of a failure in the fusion of ducts in the ventral and dorsal pancreas during the development of embryos in the 6-8 week of gestation. The main pancreatic drainage (superior head, body and tail) is performed through the dorsal duct (Santorini) into the minor papilla. The inferior
part of the head and the uncinate process is drained by the ventral duct (Wirsung duct) into the major papilla (5, 6). The clinical meaning of PD is subject of discussion. It is usually asymptomatic; however, some authors observed that the incidence of PD is slightly greater (12-26%) in patients with idiopathic acute pancreatitis (5, 7, 8). It has been stated that the major papilla is too narrow to allow a proper drainage of pancreatic secretions, which leads to an increase in the ductal resistance and tension causing an obstruction of the relative pancreatic juice flow of the dorsal pancreas and a secondary pancreatitis (in post-mortem series, changes secondary to pancreatitis are limited mainly to the dorsal pancreas). These observations lead to consider that the PD could be a risk factor for pancreatitis. The final diagnosis of PD is reached with endoscopic retrograde cholangiopancreatography (ERCP) (5). Chlangio-MRI proved to have a high sensitivity and specificity for diagnosis (Figure 9) (5-9). PD can be diagnosed with CT as well as with MRI, when the main pancreatic drainage duct (dorsal duct or Santorini duct) is seen draining directly into the duodenum without fusing with the common bile duct (Figure 10). A related radiological sign is santorinicele (Figure 9), a cystic focal dilatation of the dorsal pancreatic duct or the Santorini duct at the minor papilla. Although there is controversy over its origin, it is believed that the increased pressure at the minor papilla helps in its formation and that it also contributes to the obstruction of the relative flow; therefore, it is related to repeated episodes of pancreatitis (10).

Annular pancreas

Annular pancreas (AP) is a rare congenital anomaly (0.05% of incidence) in which a ring of pancreatic tissue encircles the descending portion of the duodenum (4, 11). AP is related to anomalies in the rotation of embryonic buds. The ventral bud is formed by two components that, in normal conditions, fuse together and rotate around the duodenum in a way that places them below the dorsal bud. However, sometimes that right portion of the ventral bud emigrates following its normal path, but the left portion goes in the opposite direction forming an annular pancreas. Symptoms of annular pancreas can appear at any age, from the neonatal period to adulthood, although it is estimated that almost two thirds of patients with annular pancreas experience no symptoms throughout their lives. The age in which symptoms appear depends on the degree of duodenal constriction. The periods of greater clinical incidence are the neonatal period and adulthood (4). In the neonatal period, the clinical presentation is a duodenal stenosis that can be more or less severe. In adults, the symptoms are abdominal pain, nausea, vomiting, complications such as duodenal ulcer, chronic or acute pancreatitis, and less likely, biliary obstruction. AP can be diagnosed by means of CT or MRI scans that reveal a ring of pancreatic tissue and an annular duct surrounding the descending duodenum (4, 11) (Figure 11).

Ectopic pancreas

Ectopic pancreas (EP) is defined as pancreatic tissue without anatomical or vascular continuity with the main body of the gland. It is originated in the embryonic period from the embryonic vesicles. The most frequent location of ectopic pancreas is the stomach (26-38% of the cases), the duodenum (28-36% of the cases) and the proximal jejunum (16% of the cases) (5). However, there are cases reported in the ileum, Meckel’s diverticulum, gallbladder, biliary tract, spleen, omentum, mesentery or even the mediastinum. The frequency of ectopic pancreas is estimated in 0.6% to 13.7% of diverse series of autopsies (12). The measure of the ectopic tissue ranges from 0.5 to 2 cm and it is located in the submucosa in approximately 50% of the cases (5). In most patients, ectopic pancreas is an incidental finding without symptoms and it is revealed incidentally in imaging scans, during exploratory laparotomies or in autopsy. If there are symptoms, the most common are abdominal pain (epigastric pain), dyspepsia and GI bleeding. All the pathologies affecting the orthotropic gland can also affect the ectopic pancreas, such as pancreatitis, cystic dystrophy and even cancer. Radiologically, they have different presentations. The most common is the thickening of the duodenal or gastric wall with a solid formation in the submucosa, located in the internal wall of the duodenum generally close to the head of the pancreas. In the stomach, it is located in the antro-pyloric mucosa in 85-95% of the cases.
In CT scans, the enhancement patterns of the lesion are variable. They can present similar enhancement as the normal pancreas (Figure 12), have a decreased enhancement or show lack of uptake. The cystic transformation of the ectopic pancreas, known as “cystic dystrophia” (13, 14), is seen as a thickening of the duodenal wall with cystic lesions in its interior (Figure 13).

**Figure 7. Pancreas and Computed Tomography Scans.**
A) CT scan in pancreatic arterial phase (45 seconds after the contrast injection had started). The quality criterion used in this phase is the opacification of the superior mesenteric vein and of the splenic vein. B) CT scan in venous phase (75 seconds after the contrast injection had started). The quality criterion used is the opacification of the suprahepatic veins. Pancreas (arrows). Superior Mesenteric Veins (VMS). Splenic Veins (VE). Median Suprahepatic Vein (VSM).

**Figure 8. Pancreas and MRI Scans.**
A) MRI scan with T2 sequences. The left section of the pancreas is seen as hypointense with a signal similar to the liver (arrow). B) MRI T1 sequences with fat suppression. The intensity of the relative signal of the pancreas increases significantly and appears as markedly hyperintense (arrow) and therefore, this organ becomes the brightest soft tissue in the superior abdomen. C) MRI T1 sequences with fat suppression and Gadolinium. Marked homogeneous enhancement of the pancreas after the administration of Gadolinium chelates and acquisition of images in pancreatic arterial phase (arrow).
**Figure 9. Pancreas Divisum.**
MRI Cholangiopancreatography. The dorsal pancreatic duct (DP) goes through the common bile duct (C) to drain into the expected site of the major papilla. Minimum focal cystic dilatation of the dorsal duct or Santorini duct at the papilla, known as Santorinocele (S).

**Figure 10. Pancreas Divisum.**
Computed Tomography (A) and Magnetic Resonance Imaging (B) scans showing the dorsal pancreatic duct (CPD) crossing in front of the common bile duct (C) and reaching the duodenum.

**Figure 11. Annular Pancreas.**
Abdominal CT scan with intravenous contrast showing the presence of pancreatic tissue completely surrounding the second section of the duodenum, which is visible in two successive views of computed tomography scans.
Conclusion
Knowledge of the segmental anatomy of the pancreas permits a proper localization of pancreatic lesions and a good surgical planning. Anomalies in the development of the pancreas can be recognized with diverse diagnostic methodologies and it is essential to differentiate them from other pancreatic or GI tract pathologies.

Figure 12. Ectopic Pancreas.
Abdominal CT scan with intravenous contrast in arterial phase (A) and portal venous phase (B). Solid nodular formation with the same tomodensitometric characteristics as the orthotropic pancreas, located at the level of the anterior duodenal wall (arrow).

Figure 13. Ectopic Pancreas and Cystic Dys trophya.
Computed Tomography (CT) scan with axial views and intravenous contrast in arterial phase. There is a confirmation of displacement and decrease of the light in the second duodenal section (thin arrow) due to a medial parietal thickening at the expense of the ectopic pancreas (thick arrow), associated with liquid-like formations (asterisk). There is a proper differentiation of the process with respect to the head of the pancreas (double arrow).
Bibliography


