Original article:

Arterial arcades of Pancreas and their variations
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Abstract:

Introduction: Pancreas is a highly vascular organ supplied by number of arteries and arterial arcades which provide blood supply to the organ. Arteries contributing to the arterial arcades are celiac and superior mesenteric arteries forming anterior and posterior arcades. These vascular arcades lie upon the surface of the pancreas but also supply the duodenal wall and are the chief obstacles to complete pancreatectomy without duodenectomy. Knowledge of variations of upper abdominal arteries is important while dealing with gastric and duodenal ulcers, biliary tract surgeries and mobilization of the head of the pancreas, as bleeding is one of the complications of these surgeries. During pancreaticoduodenectomies or lymph node resection procedures, these arcades are liable to injuries.

Material and methods: Study was conducted on 50 specimens of pancreas removed enbloc from cadavers to study variations in the arcade.

Observation and result: Anterior arterial arcade was present in 98% specimens and absent in 2%. It was formed by anterior superior pancreaticoduodenal artery (ASPDA) and anterior inferior pancreaticoduodenal artery (AIPDA) in 92%, Anterior superior pancreaticoduodenal artery (ASPDA), Anterior inferior pancreaticoduodenal artery (AIPDA) and Right dorsal pancreatic artery (Rt.DPA) in 2%, Anterior superior pancreaticoduodenal artery (ASPDA) only in 2%, Anterior superior pancreaticoduodenal artery (ASPDA) and Posterior inferior pancreaticoduodenal artery (PIPDA) in 2%, Arcade was absent and Anterior superior pancreaticoduodenal artery (ASPDA) gave branches in 2%. Similarly posterior arcade also showed variations with presence in only 98% specimens.

Conclusion: Wide range of statistical records of arterial supply of pancreas, show that it is an organ that lies in three peripancreatic interlocking arterial circles with varying degree of variations making it difficult to differentiate and classify normal, variant and anomalous. It shows that developmental probabilities and possibilities associated with two pancreatic buds approaching each other, enlarging and invading into a meshwork of blood vessels are many.

Key words: Arcades, variations, surgical importance

Introduction
Pancreas is second largest of digestive glands of the human body having glandular tissue of two different types for accomplishing two different functions. The major part is an exocrine gland secreting enzymes for digestion of ingested food and the other is an endocrine part for glucose homeostasis and gastrointestinal motility.

Pancreas is an organ that develops at the boundary between foregut and midgut. The area of foregut is
supplied by the celiac trunk and the midgut by superior mesenteric artery. This explains the description of classical anatomy of the area that the blood supply of second part of duodenum and the head of pancreas originates from several arteries that spring from the celiac axis and the superior mesenteric artery. The pancreaticoduodenal arcades which are located anterior and posterior to the pancreatic head, are major source of blood supply of pancreatic head and the second part of the duodenum. Extensive interference with the pancreaticoduodenal arcades in the course of a 95% pancreatectomy may compromise the blood supply of the duodenum because of the shared blood supply of the duodenum and pancreatic head. In addition, because the duodenojejunal flexure and the first part of the jejunum may derive their blood supply from branches of the inferior pancreaticoduodenal artery or the pancreaticoduodenal arcades, ligation of these vessels in the course of a resection may render the proximal jejunum ischemic. Typically, the posterosuperior pancreaticoduodenal artery arises from the gastroduodenal artery and passes to the right, anterior to the common bile duct, forming a major source of blood supply to common bile duct. This relation is of surgical importance in case of operation involving mobilization of the lower end of the common bile duct.

There are variations in this arcades like; it may be doubled or tripled. The posterior arcade may also anastomose with an aberrant right hepatic artery from the superior mesenteric artery and also there are variations in the origins of arteries forming arcade. So the study was conducted to study the pattern of arterial arcades supplying pancreas and the variations in arterial arcades of pancreas and to compare the findings with available literature to establish a data for this region.

**Material and methods**

The study was carried out on 50 specimens removed enbloc from the cadavers, available in the department of Anatomy of Rural Medical College, Loni, Maharashtra. The approval of the Institutional Ethical and Research Committee was sought before beginning the study.

**Inclusion criteria**: Formalin embalmed adult cadavers with normal anatomy of pancreas irrespective of sex were used in this study. These were the cadavers meant for utilization by first year medical students for routine dissection.

**Exclusion criteria**: The cadaveric specimens with obvious abdominal pathology or operative procedures were excluded from the study.

The enbloc removal, along with pancreas included the duodenum, the spleen, the related part of the abdominal aorta and portal vein. The dissection necessary to study the arterial supply of different parts of the pancreas was carried out. A hand lens was used wherever necessary. Each and every specimen thus dissected was documented with the help of line drawing and photograph.

After removal and cleaning the dissected specimen all parameters such as origin of arteries forming arcade, distance of arcade from duodenum, number of arcades and number of branches were noted. The data collected was analyzed and expressed as percentage. Wherever required the data was subjected to statistical analysis. Other incidental observations in the course of study were recorded and discussed in the light of existing literature.

**Abbreviations** - (AA- Abdominal Aorta, CT- Celiac trunk, CHA- Common Hepatic Artery, HA- Hepatic Artery Proper, GDA- Gastroduodenal Artery)
ASPDA- Anterior Superior Pancreaticoduodenal Artery  PSPDA-Posterior Superior Pancreaticoduodenal Artery, RGEA- Right Gastroepiploic Artery , IPDA- Inferior Pancreaticoduodenal Artery , AIPDA- Anterior Inferior Pancreaticoduodenal Artery, PIPDA- Posterior Inferior Pancreaticoduodenal Artery, APAr- Anterior Pancreaticoduodenal Arcade/Anterior arcade, PPAr- Posterior Pancreaticoduodenal Arcade /Posterior arcade

Observation

1. Anterior Pancreaticoduodenal Arcade (APAr):

Two major arterial arcades were identified i.e. anterior and posterior. Anterior arcade is formed by anterior superior pancreaticoduodenal and anterior inferior pancreaticoduodenal arteries and posterior arcade is formed by posterior superior pancreaticoduodenal and posterior inferior pancreaticoduodenal arteries, mostly. Anterior arcade was present in 98% (49/50) specimens and absent in 2%.

Arteries of origin are shown in table 1 (figure 1 and Photograph 1,2,3,4).

Table 1: Showing origin of Anterior Pancreaticoduodenal Arcade

<table>
<thead>
<tr>
<th>Origin</th>
<th>No.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior superior pancreaticoduodenal artery (ASPDA) and Anterior inferior pancreaticoduodenal artery (AIPDA)</td>
<td>46/50</td>
<td>92%</td>
</tr>
<tr>
<td>Anterior superior pancreaticoduodenal artery (ASPDA), Anterior inferior pancreaticoduodenal artery (AIPDA) and Right dorsal pancreatic artery (Rt.DPA)</td>
<td>1/50</td>
<td>2%</td>
</tr>
<tr>
<td>Anterior superior pancreaticoduodenal artery (ASPDA) only</td>
<td>1/50</td>
<td>2%</td>
</tr>
<tr>
<td>Anterior superior pancreaticoduodenal artery (ASPDA) and Posterior inferior pancreaticoduodenal artery (PIPDA)</td>
<td>1/50</td>
<td>2%</td>
</tr>
<tr>
<td>Arcade absent and Anterior superior pancreaticoduodenal artery (ASPDA) gives branches</td>
<td>1/50</td>
<td>2%</td>
</tr>
<tr>
<td>Total</td>
<td>50/50</td>
<td>100%</td>
</tr>
</tbody>
</table>
Figure 1: Showing arteries of origin for Anterior Pancreaticoduodenal Arcade

Distance of arcade from duodenum: The distance of arcade from duodenum ranged from 0(at pancreaticoduodenal junction) to 3 cm with mean 0.54 and standard deviation of 0.68.

In 20 specimens the arcade was hidden by pancreatic tissue (40%).

Number of Arcade: In all specimens only single arcades were found.

Number of branches by arcade: Average number =8; Range =6 - 10

2. Posterior pancreaticoduodenal arcade (PPAr):
This arcade was present in 98% and absent in 2% specimens. Arteries of origin are shown in table 2 (Figure 2 and Photograph 5,6,7,8,9,10)
**Table 2:** Showing origin of Posterior Pancreaticoduodenal Arcade

<table>
<thead>
<tr>
<th>Origin</th>
<th>No.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posterior superior pancreaticoduodenal artery (PSPDA) and Posterior inferior pancreaticoduodenal artery (PIPDA)</td>
<td>43/50</td>
<td>86%</td>
</tr>
<tr>
<td>Posterior superior pancreaticoduodenal artery (PSPDA), Posterior inferior pancreaticoduodenal artery (PIPDA) and extra branch from superior mesenteric artery (SMA)</td>
<td>2/50</td>
<td>4%</td>
</tr>
<tr>
<td>Posterior superior pancreaticoduodenal artery (PSPDA), Posterior inferior pancreaticoduodenal artery (PIPDA) and extra branch from abdominal aorta (AA)</td>
<td>1/50</td>
<td>2%</td>
</tr>
<tr>
<td>Posterior superior pancreaticoduodenal artery (PSPDA) only</td>
<td>1/50</td>
<td>2%</td>
</tr>
<tr>
<td>Anterior inferior pancreaticoduodenal artery (AIPDA) and Posterior superior pancreaticoduodenal artery (PSPDA)</td>
<td>1/50</td>
<td>2%</td>
</tr>
<tr>
<td>Arcade absent and Right hepatic artery (RHA) gives branches</td>
<td>1/50</td>
<td>2%</td>
</tr>
<tr>
<td>Posterior superior pancreaticoduodenal artery (PSPDA), Posterior inferior pancreaticoduodenal artery (PIPDA) and Anterior inferior pancreaticoduodenal artery (AIPDA)</td>
<td>1/50</td>
<td>2%</td>
</tr>
<tr>
<td>Total</td>
<td>50/50</td>
<td>100%</td>
</tr>
</tbody>
</table>

![Diagram 1](image1.png)

![Diagram 2](image2.png)
Figure 2: Showing arteries of origin for Posterior Pancreaticoduodenal Arcade

PSPDA, PIPDA and Extra branch from SMA 2/50 (4%).

(Photograph 5)

PSPDA, PIPDA and extra branch from AA 1/50 (2%).

(Photograph 6)

PSPDA only forms arcade 1/50 (2%).

(Photograph 7)

PSPDA and AIPDA 1/50 (2%).

(Photograph 8)

PPAr is absent and RHA gives branches 1/50 (2%)

(Photograph 9)

PSPDA, PIPDA and AIPDA 1/50 (2%).

(Photograph 10)
Distance from duodenum: The distance of arcade from duodenum ranged from 0 (at pancreaticoduodenal junction) to 2.9 cm, with a mean 1.36 and standard deviation of 0.52. There was a statistically significant difference (p value < 0.05) between the mean distance of anterior arcade and mean distance of posterior arcade from pancreaticoduodenal junction.

Number of arcades - arcade was single in all cases.

Number of branches by arcade: Average number = 7; Range = 6 - 10.

Discussion

Anterior Pancreaticoduodenal Arcade (APAr): An arcade of an artery supplying branches to anterior surface of both duodenum and head of pancreas is present in 98% cases in this study; same was present in all cases studied by Kimura W et al.\textsuperscript{16} In 92% cases this arcade is formed by anterior superior pancreaticoduodenal artery and anterior inferior pancreaticoduodenal artery; whereas same is noted in all cases studied by Kimura W et al.\textsuperscript{16} In 40% cases the lower 2/3\textsuperscript{rd} arcade was found to be partly embedded within pancreatic tissue; this occurrence finds no mention anywhere in the available literature. On an average we found eight branches arising from anterior arcade supplying only the duodenum. Smaller delicate branches arising from the arcade sunk directly into substance of pancreas (Photograph No.11).

Photograph 11: Anterior arcade embedded within pancreatic tissue.

Posterior Pancreaticoduodenal Arcade (PPAr): Another arcade artery supplying posterior surface of duodenum and pancreas is present in 98% of cases in this study, in all the cases studied by Michel NA et al\textsuperscript{9}, and 88% of cases studied by Kimura W et al.\textsuperscript{16} Variable origin of the two source arteries for arcade was noted in this study; arcade formation by posterior superior pancreaticoduodenal artery and posterior inferior pancreaticoduodenal artery was seen in 86% cases. Similar combination is seen in 78% by Van Damme et al\textsuperscript{8}, and in 88% cases studied by Kimura W et al.\textsuperscript{16} Location of this arcade was farther away from duodenum as compared to anterior arcade. On an average we found seven branches arising from posterior arcade supplying duodenum (2\textsuperscript{nd} part) along with common bile duct. Smaller delicate branches arising from the arcade sunk into posterior surface of head of pancreas.

There are anastomoses at all levels of pancreas. This extensive arterial network of the pancreas is an important source of collateral blood supply in cases of occlusion of celiac axis, superior mesenteric or splenic arteries. The existence of individual differences, development of arterial–arterial anastomosis asks for obligatory preoperative supraselective angiography which enables insight into distribution of blood vessels.\textsuperscript{17} It is into this meshwork of vessels the pancreatic buds sprout from two opposite sides i.e. dorsal and ventral of the second part of duodenum (Picture No.1).
Dorsal bud sprouts and enlarges on the left side of the network of vessels in the dorsal mesentery of duodenum. Hence after rotation and fixation of the duodenal loop the blood vessels for body and tail of pancreas are seen to be located on posterior surface only. Ventral bud along with bile duct and network of vessels on its both side rotates and fuses with dorsal bud, hence the presence of blood vessels in the form of arcade is seen on both surfaces of head of pancreas. In a general way, this explains the existence of three peripancreatic, interlocking arterial circles; the variations among the pancreatic vessels in different individuals; and the varying calibers of vessels. Thus pancreatic arteries may have variable origins as well as variable caliber. Arteriography can outline most of the arteries of the pancreas, so it is advisable to obtain preoperative angiograms to provide more orderly intraoperative identification and control of the arterial blood.

**Summary and conclusion**

All the arteries supplying different parts of pancreas were studied with respect to their origin, termination, length, and parts of pancreas supplied. We found that pancreas is an organ that lies in three peripancreatic interlocking arterial circles with varying degree of variations often making it difficult to differentiate and classify normal, variant and anomalous.

- All the arteries supplying arcades of pancreas were found to have a variable origin, length and termination.
- Different studies on the arterial supply of pancreas came up with a wide range of statistical records. No one particular reason can satisfactorily explain occurrence of such variations in arteries supplying pancreas.
- These studies are from different region of the world. Food type, bodily habitus, and the habitat vary from region to region leading to variation in morphology of organs associated with alimentary system and consequent rearrangement of vessels.
- The reason for variations being found in the same geographical region may lie in the many developmental probabilities and possibilities associated with two pancreatic buds approaching each other, enlarging and invading into a meshwork of blood vessels.
- One should have precise knowledge regarding the anatomy of the pancreaticoduodenal region (pancreaticoduodenal
arteries) which provide blood to the duodenum.

- There is a need to preserve the pancreaticoduodenal arteries to avoid duodenal necrosis
- Preservation of the pancreaticoduodenal arteries would provide a better supply of blood to the duodenal wall.
- Distance of posterior arcade from duodenojejunal junction was found to be significantly more than the distance of anterior arcade which is most probably due to presence of common bile duct between posterior arcade and duodenum.
- In 40% specimens the arcade was hidden by pancreatic tissue.

One thing that became apparent in this study was need to include a larger sample size in view of the quantum and spectrum of variations that we came across in a relatively small sample size. Study in a larger sample size was not possible due to constraints with respect to time and availability of specimens for study.

A thorough search of literature did not yield any publication related to study of arteries of pancreas from our region. This was probabaly the first attempt in our region to study and document arteries of pancreas in detail. The knowledge of the vascular anatomy of pancreatic region is an important prerequisite for planned surgical intervention. The awareness of the existing vascular anomalies enhances the insight of any region and thus the chances of successful outcome.

Bibliography
