Uttar Pradesh Journal of Zoology

Volume 45, Issue 21, Page 179-185, 2024; Article no.UPJOZ.4295
ISSN: 0256-971X (P)

The Morphology and Topography of Portal Vein Root and Tributaries in Pig

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.56557/upjoz/2024/v45i214627

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://prh.mbimph.com/review-history/4295

Original Research Article

Received: 08/09/2024
Accepted: 12/11/2024
Published: 20/11/2024

ABSTRACT

The study of the circulatory system in pigs is of major concern for anatomists, as the swine model is widely used in experimental cardio-vascular surgery. Although the vascularization of the cavities it is not a totally unknown „territory", we noticed that any morphological study on the vasculature of the abdominal cavity and especially of the liver, offered new elements, appreciated by those who focus on the therapy of cardio-vascular diseases. The study was conducted within the Anatomy

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Cite as: *Zagrai, G., I. Dumitrescu, Sorina Andreea Mihai, Elvira Gagniuc, Aureliana Grama, C. Belu, and A. Damian. 2024. "The Morphology and Topography of Portal Vein Root and Tributaries in Pig". UTTAR PRADESH JOURNAL OF ZOOLOGY 45 (21):179-85. https://doi.org/10.56557/upjoz/2024/v45i214627.*

Laboratory of the Faculty of Veterinary Medicine in Bucharest. The research was conducted on approximately one-month old piglets, using the method of injecting the vessels with a contrast substance. This substance named Latex FDS195, has been used for the first time in our lab, and has been considered very efficient. As a result of the study, individual variants which have not been mentioned in specialized literature were described: the jejunal veins form structures in the shape of networks of fine vessels where the venous formations intertwine with the arterial ones. These aspects have not been described in detail in other scientific works. Recommendations of practical importance were also specified (the role of the networks on the jejunal artery route and the importance of knowing the topography of the caudal mesenteric artery for intrarectal administration of substances). Our results show that detailed knowledge of normal anatomy is crucial to avoid complications and ensure the success of liver surgery. Thus, we recommend that surgeons pay special attention to this aspect and be prepared to manage the variations of the hepatic pedicle properly. It is important that this knowledge is integrated into surgical training and practice to ensure the safety and success of interventions in the liver area

Keywords: Portal vein; swine; liver; cranial mesenteric vein.

1. INTRODUCTION

The term „animal model" in medicine generally refers to a living non-human animal in which a parentally transmitted, naturally acquired or induced pathological process or lesion is to be investigated. The purpose of its use is to solve a hypothesis to investigate a similar condition in the target human species (Crisóstomo et al., 2016; Dard, 2020).

Over time, many animal species have served as experimental models. Rodents are known to be highly advantageous species, making them some of the most favourable in biomedical research. Although cardiovascular biology has benefited from an immense amount of information, especially from the molecular and cellular segment of biology, the limitation of using rodents has been due to the intrinsic differences between rodents and humans in heart rate, adrenergic receptor ratio, oxygen consumption loss response, and other physiological processes such as the absence of plateau phase and contractile protein expression critical for the excitation-contraction coupling process, as well as spontaneous reversal of experimentally induced ventricular fibrillation in normal sinus rhythm, which make the use of rodents and extrapolation of data derived from these models problematic (Haacke et al., 2011; Tumbleson and Scook L.1996). Over the last two decades, researchers have agreed that of the animal species suitable for use as experimental models, the closest in cardiovascular anatomy and physiology is the swine model (Haacke et al., 2011; Michael et al.,1998; Nykonenko et al,2017; Ntonas et al.,2020; Shah et col. 2022). Investigation of the vascular system has been particularly compelled by advances in liver surgery, which has opened up new possibilities in the surgical treatment of liver disease. Experimental surgeries on pig liver are absolutely necessary to improve the relatively new surgical techniques (Haacke et al., 2011). Even though research on the vascular system in swine is an unexplored „territory" (Barone, 1996; Dumitrescu et al., 2016; Lelovas et al., 2014; Spalding et al., 1987; Swindle, 1998, 2007), we believe that any study regarding the vascularisation of the pig liver may provide new information, which will be of great importance for specialists involved in the therapy of cardiovascular diseases, which is the reason for the present study. The aim of our study was to evaluate the anatomical and functional characteristics of pig and human liver, and to highlight the importance of knowing them in surgical practice. It is important that this knowledge be integrated into surgical training and practice to ensure the safety and success of interventions in the liver area (Michels, 1953; Vandamme et al., 1969; Marin et al., 2001; Covey et al., 2002; Prabhasavat and Homgade, 2008).

2. MATERIALS AND METHODS

The present study was conducted at the Department of Anatomy of the Faculty of Veterinary Medicine Bucharest from February 2024 to September 2024. To undertake the present investigations, ten carcasses of Large White pigs, of both sexes and weighing about 20-25 kg, apparently healthy, freshly slaughtered from the local slaughterhouse, were used. The materials used for anatomical investigations were: scalpel, tweezers, scissors, gloves, magnifying glass, catheters. Equipment used:

Nikon D3400 digital camera, for macroscopic photography. For anatomical investigations, the abdominal cavity was opened, making a section on the white line and another perpendicular to the first, in the flank region. The lumen of the large vessels in the abdominal cavity (aorta, vena cava, portal vein) was cleaned with saline solution. To obtain preparations with arterial vascularization of the liver, after bleeding was injected into the portal vein near the hepatic hilum, a substance based on natural latex with blue pigment was also injected into the biliary system through the gallbladder and into the system of pancreatic ducts through the duodenum, which, in both cases, had been previously bound. After injection, the corpses were kept at a temperature of -14°C for 24-48 hours, allowing the latex to solidify. After solidification the left lateral abdominal wall was removed, the arterial blood vessels were prepared and photographed with a digital camera, and the venous structures were traced and described, according to Nomina Anatomica Veterinaria, 2017.

3. RESULTS AND DISCUSSION

3.1 Portal Vein Roots and Tributaries

In the pig, the only roots of the portal vein are the cranial mesenteric and caudal mesenteric veins, which meet in the plane of the first lumbar vertebra. The portal vein passes through a complete ring formed by the pancreas. In the pig, the splenic vein is the first tributary of the portal vein. The second tributary is the gastroduodenal vein and in this species it has always been observed that the right gastric vein remains isolated, constituting the third tributary of the portal vein.

The caudal mesenteric vein (*V. mesenterica caudalis*) is relatively thin. It has **the cranial rectal vein** (*V. rectalis cranialis*) as its only root (Fig. 1). Odd and satellite of the homonymous artery, it exchanges anastomoses on the lateral sides of the rectum with the middle and caudal rectal veins, apparently also tributary to the caudal vena cava. This arrangement has an important consequence: substances administered rectally are almost entirely absorbed through the veins of the systemic circulation, only a small amount passing through the portal vein of the liver. The caudal mesenteric vein passes together with the artery in contact with the descending colon. It is thin, which is why some authors consider it a mere tributary of its cranial homologue. It continues a reduced cranial rectal vein, then joins the descending colon, from which it receives numerous and reduced tributaries. The segment associated with the descending colon, which reaches the origin of the **caudal mesenteric artery**, can be considered the left colic vein. In the specimens studied the **middle colic vein** is placed in the concavity of the transverse colon and anastomoses at both ends with the right colic vein.

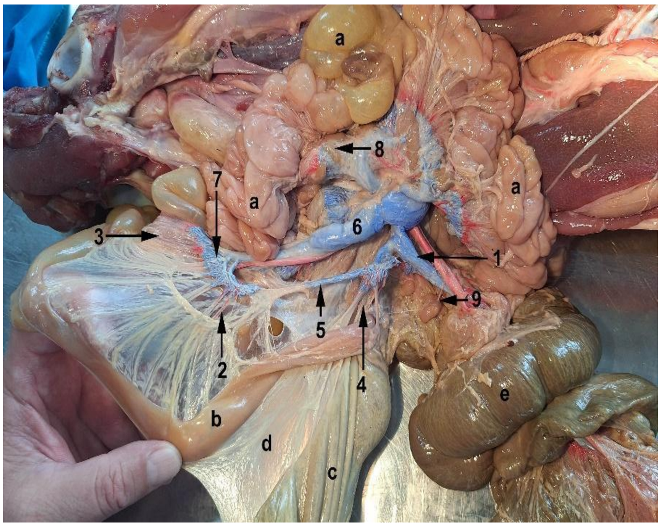

Fig. 1. Cranial mesenteric vein in pig (original)

1-colic root of the cranial mesenteric vein; 2-ileonic veins; 3-jejunal veins; 4-caecal vein; 5-mesenteric ileonic vein; 6-jejunal root of the cranial mesenteric vein; 7-superposed venous arches; 8-jejunal lymph nodes; 9-colic lymph nodes at the origin of the mesocolon; a-jejunal circumvolutions; b-ileon; c-cecum; d- ileocaecal ligament; e-ascending (helical) colon

The cranial mesenteric vein (*V. mesenterica cranialis*) is a voluminous vessel whose disposition is similar to the corresponding artery and its branches. It has two roots, one jejunal and one ileocolic.

The jejunal root starts through a series of **ileal veins** (*Vv. ileales*) and then discharges **jejunal veins** (*Vv. jejunales*). These arise from superimposed arches, which receive in the middle of the jejunum a very large number of straight veins accompanying arterial branches of the same order. The superposed arches take the form of venous networks located near the jejunal roots of the portal vein, in which these networks discharge through multiple jejunal veins. Their volume and length increase progressively towards the terminal part of the jejunal root. These venous networks consist of numerous relatively fine and dense branches, which give them a relatively spongy appearance. They interweave strongly at both the ventral and dorsal edges of the network and overlap the homonymous arterial networks. The main collecting trunk of the jejunal arteries joins at the origin of the mesentery with a strong **ileocolic vein** (*V. ileocolica*). This arises from three confluent veins: 1) a very well represented **cecal vein** (*V. caecalis*), which discharges numerous tributaries from the cecum but also from the antemesenteric border of the ileum; 2) a **colic root** (*R. colicus*), which drains the initial and spiral portion of the ascending colon and a mesenteric ileonic vein anastomosed with the first ileonic veins; and 3) a **right colic vein** (*V. colica dextra*), more reduced, which receives in all specimens the **middle colic vein** (*V. colica media*).

In 50% of cases a distinct, relatively well-represented branch was identified, rooted at the ileocaecal junction. This branch joins the ileocolic vein approximately 2 cm from where the colic branch connects with the ileocolic vein.

Once formed, the cranial mesenteric vein receives the **caudal pancreaticoduodenal vein** (*V. pancreaticoduodenalis caudalis*), which is not very well developed. This vein, located in the company of the homonymous artery, discharges blood from the caudal half of the duodenum. After about 1 cm, the pancreaticoduodenal vein bifurcates. One of the branches orients to the small curvature of the descending portion of the duodenum and the second discharges venous blood from its ascending portion.

The splenic vein (*V. lienalis*) has two roots: an **epiploic branch** (*R. epiploicus*) situated in the thickness of the greater omentum, distal to the great curvature of the stomach, and a **splenic branch** (*R. lienalis*) originating at the distal end of the spleen (Fig. 2). The two roots converge about 4 cm from the distal end of the organ, the level at which the splenic vein engages the hilum of the spleen.

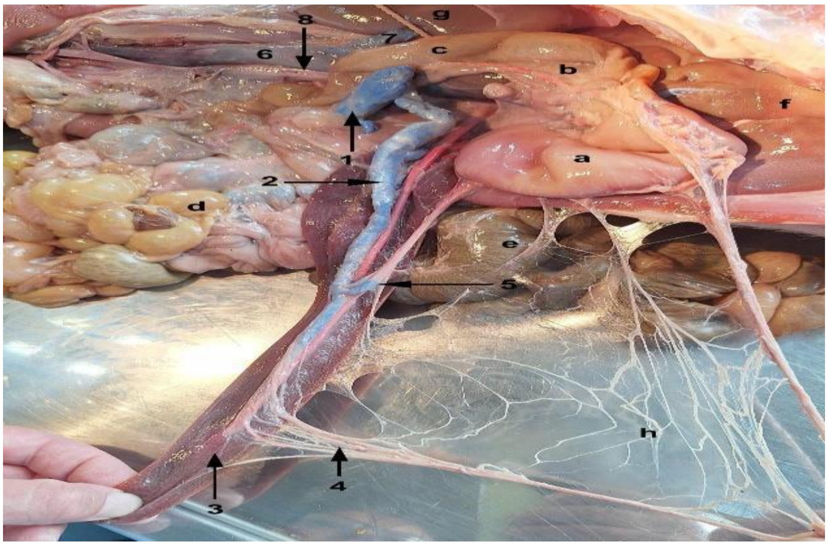

Fig. 2. Splenic vein in pig (original)

1- portal vein; 2- splenic vein; 3- splenic root of the splenic vein; 4- epiploic root of the splenic vein; 5- left gastroepiploic vein; 6- left gastroepiploic vein; 6- caudal vena cava; 7- right renal vein; 8- right renal vein; 8-aortic artery; a- stomach; b-pilor; c-duodenum; d-jejunal loops; e- ascending (helical) colon; f- right lobe; g- right kidney; h- greater omentum

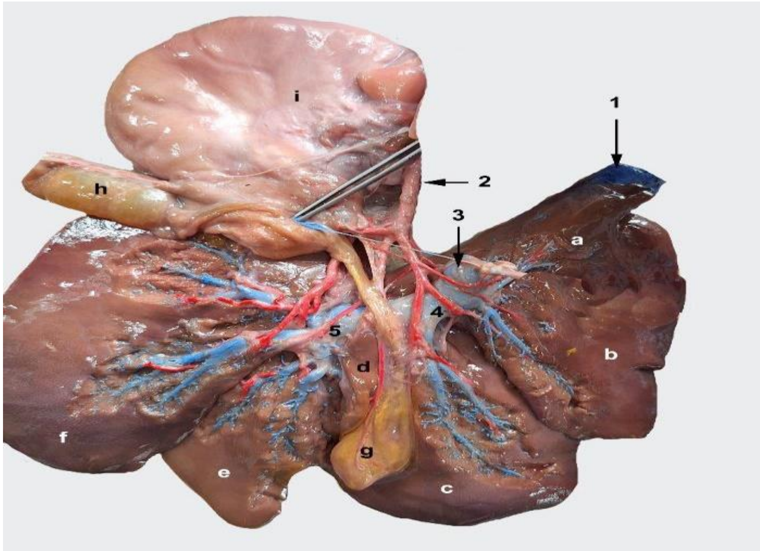

Fig. 3. Terminal branches of the portal vein in the pig (original)
1-caudal vena cava; 2-hepatic artery; 3-portal vein; 4-right branch of the portal vein; 5-left branch of the portal vein; a-caudate lobe; b-right lateral lobe; c-right medial lobe; d-right medial lobe; d-quadrate lobe; e-left medial lobe; f-left lateral lobe; g-biliary vein; h- descending portion of the duodenum; i- fundus of the stomach

The splenic vein then follows proximally the spleen hilum to the upper third of the spleen, from where it progressively distends from the deep face of the spleen. As it travels along the hilum, the vein discharges blood from the spleen through numerous branches. These branches increase in length and volume towards the proximal end of the organ. Approximately halfway down the hilum the splenic vein receives in 70 % of cases two strong tributaries that proximally and distally frame the left gastro-epiploic artery, up to the vicinity of the great curvature of the stomach. At this level the distal branch follows the great curvature of the stomach to the right side and the proximal branch is orientated towards the left end of the great curvature. By topography and configuration these branches correspond to the **left gastroepiploic vein** (*V. gastroepiploica sinsitra*). In 30% of cases the vein was unique.

Once formed, the portal vein is initially located in the neighbourhood of the caudal vena cava, running cranially and slightly to the right. It arrives at the dorsal aspect of the pancreas, from where it will pass through a complete ring formed at this level by the uncinate process, then crosses the dorsal aspect of the duodenum and is placed in the right border of the lesser omentum, where it occupies the ventral border of the omental foramen. On reaching the dorsal and right side of the hilum, it joins the hepatic artery with which it enters the hilum, dorsal to the choledochal duct.

At the level of the hepatic hilum the portal vein divides. The two branches are strong and divergent. The **right branch** (*Ramus dextra*) is the smaller branch, distributed to the right lateral lobe and caudate process. The **left branch** (*Ramus sinister*) directly extends the portal vein to the left lobe. Its two segments are the **transverse portion** (*Pars transversa*) and the **umbilical portion** (*Pars umbilicalis*) (Fig. 3). The umbilical vein twists around the round ligament and in the foetus it extends the umbilical vein, the extrahepatic portion of which, closed after birth, becomes the **round ligament of the liver** (*Lig. teres hepaticus*). The demarcation between the two portions of the left branch is marked by the fibrous vestige of the **venous canal** (*Ductus venosus*), which in the foetus joins the umbilical vein to the caudal vena cava.

4. CONCLUSIONS

1. In the pig, the portal vein only has two roots: the cranial mesenteric vein and the caudal mesenteric vein.
2. In the case of the cranial mesenteric vein, we found that the jejunal veins form a series of superimposed arches, in which fine venous branches intertwine with arteries of the same calibre. As no detailed descriptions of these formations were found in literature, we believe that further investigation of these formations may

provide new insights into their physiologic role.

3. Odd and satellite of the homonymous artery, the caudal mesenteric vein exchanges anastomoses on the lateral sides of the rectum with the middle and caudal rectal veins, apparently also tributary to the caudal vena cava. This arrangement seems to have an important consequence: substances administered rectally are almost entirely absorbed through the veins of the systemic circulation, only a small amount passing through the portal vein of the liver.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

ETHICAL APPROVAL

The experiment benefited from the approval of the Ethics Commission of the Faculty of Veterinary Medicine in Bucharest, and/or met the conditions required by EU Directive 63/2010.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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