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Computerized tomography–based anatomic description of the porcine liver

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ABSTRACT

Background: The knowledge of the anatomic features is imperative for successful modeling of the different surgical situations. This study aims to describe the anatomic features of the porcine using computerized tomography (CT) scan.
Methods: Thirty large, white, female pigs were included in this study. The CT image acquisition was performed in four-phase contrast study. Subsequently, analysis of the images was performed using syngo.via software (Siemens) to subtract mainly the hepatic artery and its branches. Analysis of the portal and hepatic veins division pattern was performed using the Myrian XP-Liver 1.14.1 software (Intrasense).
Results: The mean total liver volume was 915 ± 159 mL. The largest sector in the liver was the right medial one representing around 28 ± 5.7% of the total liver volume. Next in order is the right lateral sector constituting around 24 ± 5%. Its volume is very close to the volume of the left medial sector, which represents around 22 ± 4.7% of the total liver volume. The caudate lobe represents around 8 ± 2% of the total liver volume.The portal vein did not show distinct right and left divisions rather than consecutive branches that come off the main trunk. The hepatic artery frequently trifurcates into left trunk that gives off the right gastric artery and the artery to the left lateral sector, the middle hepatic artery that supplies both the right and the left medial sectors and the right hepatic artery trunk that divides to give anterior branch to the right lateral lobe, branch to the right medial lobe, and at least a branch to the caudate lobe. Frequently, there is a posterior branch that crosses behind the portal vein to the right lateral lobe. The suprahepatic veins join the inferior vena cava in three distinct openings. There are communications between the suprahepatic veins that drain the adjacent sectors. The vein from the right lateral and the right medial sectors drains into a common trunk. The vein from the left lateral and from the left medial sectors drains into a common trunk. A separate opening is usually encountered draining the right medial sector. The caudate lobe drains separately into inferior vena cava caudal to the other veins.
Conclusions: Knowledge of the anatomic features of the porcine liver is crucial to the performance of a successful surgical procedure. We herein describe the CT-depicted anatomic features of the porcine liver.

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Background

Complications after liver surgery might be drastic.[1] To reduce the risk of complications, particularly after major liver resection, swine has been in use as a surgical model to better study and understand the different surgical situations for a long time.[2] This is particularly true because the animal is readily available at a reasonable price and that the anatomy is to an extent similar to human anatomy.[3] Experiments on liver regeneration after different percentages of partial hepatectomy have been performed to simulate situations with small-for-size syndrome.[4]

One of the key factors on which the success and the reproducibility of the experimental model are based is the precise knowledge of the normal anatomy along with its variations. In humans, an aberrant right hepatic artery originating from the superior mesenteric artery or a right bile duct originating from the left bile duct could change the outcome. Despite that the swine model has been in use for decades, little information on the detailed anatomic features of the porcine liver is available in the literature.[3]

Few studies have concentrated on the ultrastructure of the hepatic microarchitecture,[5] others based their studies on casting.[3] Furthermore, detailed descriptive data from computerized tomography (CT) scan do not exist. This study aimed at describing the normal porcine liver anatomy based on CT scan.

Methods

Ethical approval

The study was approved by the regional committee of ethics in animal research and by the ministry of higher education and scientific research and ministry of agriculture and fishing according to the European Union directives.

Study setting

Surgeries were performed at the CIRE platform, INRA Centre Val de Loire, Nouzilly, France.

Animals

Thirty large, white, female pigs were included in this study. Females were chosen to neutralize the potential influence of gender on regeneration because these animals were subsequently used for that purpose. Besides, laparotomy in female pigs was relatively easier because urine leak from the male penis located within the umbilical stalk has an extremely unpleasant odor. The average age of the included animals was 3 mo ± 10 d and their mean weight was 35.3 ± 5 kg. Animals were kept under strict protocol. There was a period of conditioning before surgery varying from 4 to 6 d. The pigs were housed in individual pens with temperature regulated at 23 ± 1°C at ambient humidity. Lighting was natural through close to ceiling wide windows.

Anesthesia

All animals were subjected to overnight fast before anesthesia and before imaging that was performed under general anesthesia as well. Each pig received 100 mg of xylazine 2% (Rompun; Bayer Healthcare) with750 mg ketamine for anesthesia induction followed by tracheal intubation (6-7 mm in size, Portex; France). Subsequently, inhalational anesthesia Q9 was started using a 60% FiO_2 with 2% isoflurane (Isoflurane, Q8 Belmont, France) in assisted ventilation. The ventilator was set up on volume control mode delivering 350-400 mL at a rate of 17-20 cycles per minute. Crystalloid fluids were given at a rate of 2 mL/kg/h fasting. During imaging, animals were covered with blankets.

Abdominal CT scan and volumetric study

Abdominal CT scan was conducted in every animal. On average, an 80 mL (2 mL/kg) of iodinated contrast (Omnipaque; GE healthcare, Carrigtohill, Ireland) was injected through an intravenous catheter with a rate of 4 mL/s. CT scans were performed with a Somatom (Definition AS; Siemens, Forchheim, Germany). The CT image acquisition was performed Q10 in four contrast phases, arterial at 15 s of injection, the early portal at 35 s, portal venous at 55 s of injection, and at 75 s after the injection, the hepatic venous phase was done.

Syngo.via software (Siemens healthcare global) was used in a cardiac analysis module to subtract mainly the hepatic artery and its branches. On launching the module, cropping of the volume, limiting the display from the diaphragm to the celiac trunk was performed. Then, the image display parameters were adapted to the hepatic artery. Image cropping was further performed from ventral and dorsal aspects to remove the parietal vessels if necessary.

Volume analysis was performed using the Myrian XP-Liver 1.14.1 software (Intrasense, Montpellier, France). Segmentation of the portal venous branches as well as the hepatic venous branches was performed initially. Subsequently, the liver parenchyma was segmented. To segment the different hepatic sectors, each sector was segmented based on the supplying portal vein, the draining hepatic vein, and the fissure boundary with the adjacent sector. Images were segmented most successfully in the 75-s hepatic venous phase.

Verification of the segmentation was performed in CT scan performed in two distinct postresection situations. The first was after resection of the three left hepatic sectors, and the second was after resection of the four sectors leaving behind only the caudate lobe in place. This was performed to verify the segmentation of the right lateral sector and the caudate lobe. All animals have been submitted to different percentages of hepatic resection.

Results

Artery

The proper hepatic artery originates from the common hepatic artery after it gives off the gastroduodenal artery. It then