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Anatomical, Radiological, and Corrosion Casting of the Liver, Gallbladder, and Biliary Duct System of Local Breed Cattle (Bos ttaurus)

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ABSTRACT: Local breed cattle's liver, reddish-brown, occupies the right hypochondriac region with 35.2 ± 3.24 cm long and 5.5 ± 0.5 kg weight. Connected by left and right triangular ligaments; and falciform ligaments with the diaphragm, and hepatorenal ligament with the right kidney. While the coronary ligament encompassing the caudal vena cava divides into dorsal and ventral branches, enclosing the nuda region. The round ligament connects the umbilical fissure to the umbilicus. The lesser omentum on the liver's visceral surface connects the stomach and duodenum through hepatogastric and hepatoduodenal ligaments, respectively. The liver has, parietal and visceral surfaces; right, left, ventral, and dorsal borders; and left, right, caudate, and quadrate liver lobes that are not clearly separated, except for the caudate. The gallbladder has a dark green color and pear-shaped morphology, measures 16 ± 1.5 cm, and is located in a shallow cystic fossa. Consisting of the neck, forms an inverted funnel shape, body, and fundus. The diameters were 2 ± 0.3, 6 ± 1.2, and 4 ± 1.3 cm, respectively. The biliary tract consists of extrahepatic and intrahepatic ducts. The extrahepatic ducts have a left duct of 3 ± 0.5 cm and a right duct of 2 ± 0.25 cm. Converging to form a common hepatic duct 8 ± 0.5 cm. The cystic duct is 3± 0. cm, joins with the common hepatic duct ventrally. The intrahepatic ducts consisted of primary, secondary, tertiary, interlobular, intralobular, and intercalated ducts. The left hepatic duct received 9 ± 1 of dorsal primary ducts and 8 ± 2 ventral primary ducts. The right hepatic duct receives 4 ± 1 dorsal ducts and 2 ± 1 ventral ducts.

Keywords: liver, extrahepatic, lobe, quadrate, intrahepatic

1. INTRODUCTION

Bos taurus, often known as the domestic cow, has a wide distribution over several regions of the globe, including northern Africa, Europe, and southern Asia. This species displays significant diversity within its population. These cattle are produced and raised on vast rangelands, tracing their origins back to indigenous ancestors. Bos taurus has notable attributes in terms of its considerable dimensions and sturdy anatomical structure, displaying a diverse spectrum of colors and varying sizes. The necks of these organisms are characterized by their shortened length, which is accompanied by the presence of drooping skin folds known as dewlaps, hollow horns, and a lengthened tail adorned with tufts of hair. [1], [2]. A multitude of hepatic disorders remain undetected as a result of symptoms that are ambiguous or lack specificity [3]. The effectiveness of hematology and serum biochemistry has been

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called into question by [4], [5], necessitating the use of additional auxiliary tests as suggested by [6]. The use of ultrasonographic and radiographic methods for liver exams has been shown to provide comprehensive data on the liver's dimensions, positioning, and parenchymal composition [7], [8], [9]. Nevertheless, the evaluation of the liver for potential abnormalities relies on the analysis of radiographic alterations in its size, shape, location, and opacity. The existence of liver disease cannot be excluded solely based on a normal liver size; nonetheless, assessing liver size is valuable for the purposes of screening and establishing a differential diagnosis for liver illnesses conditions related to bile duct injuries, cirrhosis, as well as many infestations [10], [11].
According to [12], [13], [14], In modern times, polymers and resins are often used because they are easy to work with, make things safer, dry to a good hardness, and don't shrink or change shape compared to how they were cast. According to [15], The use of injection and corrosion techniques has shown considerable efficacy not only in the realm of anatomy instruction but also in the field of research. This technique enables the examination of the intricate organization and structure of the microvasculature and even allows three-dimensional observation [16]. Furthermore, it contributes to the accurate interpretation of diagnostic pictures in medical practice [17]. Our study aimed to investigate the main macroscopic and characteristic liver, gall bladder, and biliary duct systems in cattle through observation of the gross anatomy of the liver and cast-forming and contrast radiography.

2- METHEDOLOGY

2-1 Morphological study

A total of twenty seemingly healthy adult cattle, irrespective of their gender, were chosen from the slaughterhouse. The geographical position, size, and anatomical associations of the liver, as well as its interconnections with other organs, were documented. Subsequently, the liver was excised in conjunction with a portion of the diaphragm, the abomasum, and a segment of the duodenum. Then, general anatomical characteristics of the liver and its biliary duct system, including their measurements, were documented and conducted utilizing precision instruments such as a vernier caliper, a ruler, and a very accurate scale.

2.2 RESIN CASTING

Veracril® / Opti-Cryl® Self-curing Acrylic is a veined acrylic resin (polymer) in different tones of rose color and transparent, used for the reparation and elaboration of base plates, individual trays, and, orthodontic and orthopedic appliances. Chosen for its consistent size, favorable viscosity at room temperature, and ability to flow through microchannels effectively. Its high hardness is crucial for maintaining organ structural integrity during maceration [18], [19]. After confirming the absence of pathological lesions and congenital abnormalities, a plastic catheter was inserted and securely fastened to prevent resin leakage. And evacuate the gall bladder and extrahepatic duct from the bile through the common bile duct opening. Then distilled water injections and milking procedures were performed to eliminate bile accumulated inside the bile ducts. The resin was manually injected using a 20-ml syringe, and the liver was held in its prescribed position for 48 hours to ensure full solidification. A solution of 40% potassium hydroxide was used to completely immerse the liver. After complete maceration, the tissues affixed to the cast were thoroughly eliminated by rinsing with continuously flowing water. [19], [20], [21], [22], [23], [24]

2.3 RADIOLOGY

The radiography used Only fresh, healthy livers with typical architecture to demonstrate the extra- and intrahepatic views of the biliary duct system. And remove bile from the gallbladder and extrahepatic duct through the common bile duct opening. Then distilled water injections and milking were performed to eliminate bile accumulated inside the bile ducts by a syringe via a polyethylene catheter inserted into the duodenal orifice of the common hepatic duct using JPI's DirectVet veterinary digital X-ray system using a +ve contrast media (Opaxol 350 mg/mL IA/IV solution for injection, non-ionic, monomeric, x-ray contrast agent). The catheter was connected to a 10-ml syringe, and contrast media was steadily injected [25]. At five, fifteen, twenty-five, and finally forty ml, digital images were taken sequentially as the injection was administered slowly.

2-4 Ethical approval

The Research Ethics Committee of the University of Baghdad's College of Veterinary Medicine provided research ethical permission, number P.G/94

3- RESULTS

In the present investigation, the liver of the local breed cattle is seen to possess a reddish-brown color. Situated in the thoracic part of the abdominal cavity, the organ of concern mostly occupies the right hypochondriac region, positioned directly posterior to the diaphragm (Fig.1). The longitudinal axis spans from the right to left lobes in an oblique direction in the abdominal cavity, in a cranioventral direction, ranging from the 13th rib to the 6th intercostal space, with an average length of 35.2 ± 3.24 cm and a mean weight of 5.5 ± 0.5 kg and 1.5% relative weight.

The cattle liver is fixed in place by several ligaments and the pressure of the adjacent organs. The left triangle ligament is a small, thick structure that connects the tendinous portion of the diaphragm to both the parietal and visceral sides of the dorsal border of the left lobe (Fig.1). While the elongated, thin, and wide right triangular ligament spans from the ventral, right, and dorsal borders of the parietal side of the right lobe, which connects with the inner wall of the thoracic area of the abdominal cavity and the muscular portion of the diaphragm, in addition, the hepatorenal ligament extends from the caudate process to the ventral surface of the right kidney (Fig.1).

Moreover, the coronary ligament encompasses the caudal vena cava, extending along its groove on the dorsal border of the liver from the vena cava foramen to the right triangle ligament. It divides into two branches, a dorsal and a ventral, enclosing the region known as the nuda. The dorsal branch of the coronary ligament remains connected to the right triangular ligament. The falciform ligament (Fig.2 B) extends from the coronary ligament, dorsally directed, to the ventral cleft (of the round ligament) between the quadrate and left lobes. This ligament serves to link the parietal surface of the liver with the tendinous portion of the diaphragm, and there is a slightly thickened caudal free edge representing a round ligament that connects the umbilical fissure of the liver to the umbilicus (Fig.2A&B). Furthermore, the lesser omentum serves as a connecting structure between the stomach and duodenum, establishing a connection with the visceral surface of the liver via the hepatogastric and hepatoduodenal ligaments.

The liver in this work has two surfaces, two borders, and four lobes. The convex and smooth parietal surface (diaphragmatic) corresponds to the diaphragm, divided into left and right lobes by the falciform ligament (Fig.2B). Due to the oblique direction of the liver, this surface faces dorsally, cranially, and to the right. Most of this surface is molded to hollow the right half of the diaphragm, and a small part of the diaphragmatic surface contacts the last two or three ribs.
Further, the concave visceral surface corresponding to the stomach has a porta hepatis bounded by the papillary process, caudate process, and area of adhesion of the pancreas, and it also contains the gallbladder fossa (cystic fossa), which extends from the porta hepatis to the ventral border of the liver (Fig.2A). A fissure extends transversely across this surface from the notch for the round ligament. This surface also shows the attachment of the lesser omentum, and there are omasal, reticular, abomasal, and cystic impressions.

Besides, the right border is comparatively short and thick. It possesses a renal impression. In contrast, the left border is thin and smoothly curved (Fig.2A&B).
Likewise, the thin and long ventral border presents the fossa for the gallbladder and a notch for the round ligament, and the dorsal border is median in position and possesses a wide groove that passes the caudal vena cava (Fig.2A&B).
Concerning liver lobes, they are not clearly separated from each other (except the caudate). And not find any fissure that divides. The largest left lobe is ventral and left in position in the thoracic part of the abdominal cavity (Fig.1). The cranial border of this lobe is at the level of the sixth intercostal space. Nevertheless, the right lobe is very short and thick dorsal and right in position in the thoracic part of the abdominal cavity. However, the caudate lobe (Fig.2A)lies between the right and left lobes at the visceral surface, consisting of the larger and elongated caudate process that extends to the right of the median plane and may protrude out the liver mass, which covers most of the area of the visceral surface of the right lobe and forms the deep renal impression with the right lobe for the right kidney, and a small flab-like papillary process found between the vena cava dorsally and the left branch of the portal vein ventrally. In addition, the quadrate lobe (Fig.2A) is indistinct and found between the left and right lobes at the ventral border. The notch of the round ligament separates it from the left lobe.
The current investigation provided evidence that the gallbladder (Fig.2A&B) exhibits a dark green coloration and has a narrow, elongated, pear-shaped morphology. The length of the gallbladder was found to be around 16 ± 1.5 cm, while it is situated inside a shallow cystic fossa measuring approximately 6 ± 0.5 cm in length and 4 ± 0.7 cm in breadth.
The gallbladder is comprised of three distinct components (Fig.3). The uppermost section is referred to as the neck, which takes on an inverted funnel shape. The neck extends upwards to create the cystic duct and downwards to constitute the biggest portion of the gallbladder, known as the body. The body is situated in the center and terminates with the fundus, which protrudes beyond the liver mass. The diameters of the three components were measured to be (2 ± 0.3), (6 ± 1.2), and (4 ± 1.3) cm, respectively.
The biliary tract is largely divided into two parts: the extrahepatic and intrahepatic ducts. The former ducts are very small, tree-like branches in the liver tissue. The extrahepatic biliary system (Fig.2A) is typically located outside of the liver tissue, as its name suggests. The extrahepatic biliary duct is the trunk of the biliary tree; thus, it connects all bile flows from the intrahepatic duct and pours them into the duodenum. Thus, the findings of this research indicate that upon gross inspection, the extrahepatic ducts exhibit a distinct separation into

two distinct entities: a left duct measuring approximately 3 ± 0.5 cm and a right duct measuring approximately 2 ± 0.25 cm at the porta hepatis, which promptly converge to create the common hepatic duct, which ventrally courses, measures about 8 ± 0.5 cm. The solitary, shortened 3± 0.6 cm cystic duct rans upward along the lesser omentum, then converges the common hepatic duct ventrally before trajectory through the duodenal wall as an intramural segment 3 ± 0.4 cm, then opens in the duodenum by a major duodenal papilla, located around 20 ± 2 cm distant from the pylorus.

The examination of the intrahepatic ducts included the use of a resin cast (Fig.4) and radiography (Fig.5). The left and right hepatic ducts are created through the merging of the primary lobar ducts originating from the dorsal and ventral areas of the liver tissue. These primary ducts are formed by the combination of numerous secondary ducts that branch within the hepatic lobes, which in turn are formed by the convergence of smaller tertiary ducts. The latter outcome arises from the convergence of smaller interlobular ducts, which originate from the intralobular ducts and terminate in the intercalated ducts. The left hepatic duct, measuring around 21.4 ± 1.6 cm in length, is responsible for receiving a variable number of dorsal ducts, estimated to be around 9 ± 1. Among these ducts is the papillary duct, which spans approximately 9.2 ± 1.4 cm. The other dorsal ducts are spread along the path leading to the dorsal part of the left lobe. There are ventral ducts, with a range of 8 ± 2. These ducts include the quadrate duct, measuring approximately 10 ± 0.5 cm, and the other ducts are spread towards the ventral part of the left lobe. In contrast, the right hepatic duct, which has an average length of 12.4 ± 2.3 cm, is the recipient of about 4 ± 1 dorsal duct. These ducts include the caudate process duct, which has an average length of 11.4 ± 0.5 cm, as well as the other ducts originating from the lateral part of the right lobe. There are three ventral ducts, with a potential variation of one, including the ventral part of the right lobe and the remaining ducts originating from the ventral part of the right lobe

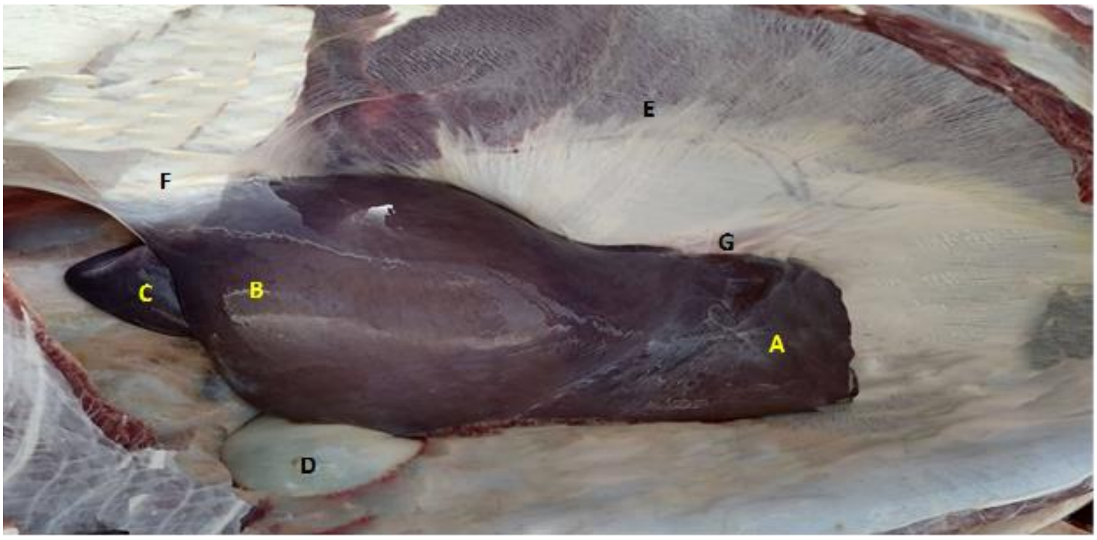

Fig. (1): Parietal surface of liver in cattle (in situ) demonstrating: A- Left lobe. B- Right lobe. C- Caudate process. D- Gallbladder. E- The diaphragm. F- Right triangular ligament. G- Left triangular ligament.

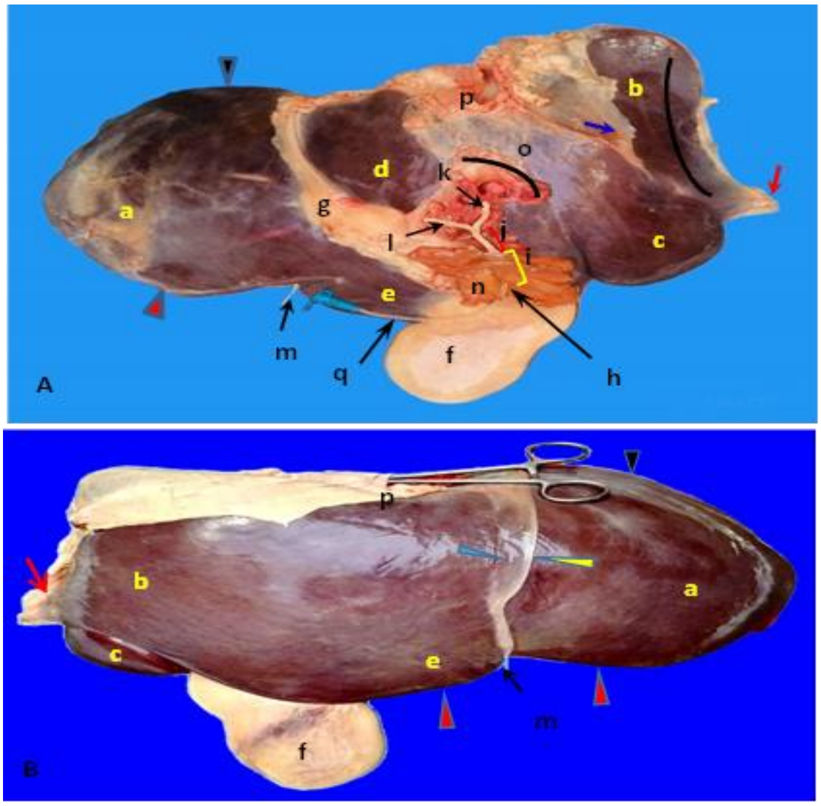

Fig. (2): Visceral (A) and parietal (B) surfaces of liver in local breed cattle demonstrating:
a- Left lobe. b- Right lobe.
c- Caudate process. d- Papillary process.
e- Quadrate lobe. f- Gallbladder.
g- Lessor omentum. h- Major duodenal papilla.
i- Common hepatic duct (itramural part).
j- Common hepatic duct (retroduodenal part).
k- Right hepatic duct. l- Left hepatic duct.
m- Round ligament. n- Duodenum.
o- Porta hepatis. p- Caudal vena cava.
q- Catheter. Dorsal border (black head of arrow). Ventral border (red head of arrow). Renal impression (black curved line). Hepatorenal ligament (blue arrow). Right triangular ligament (Red arrow).

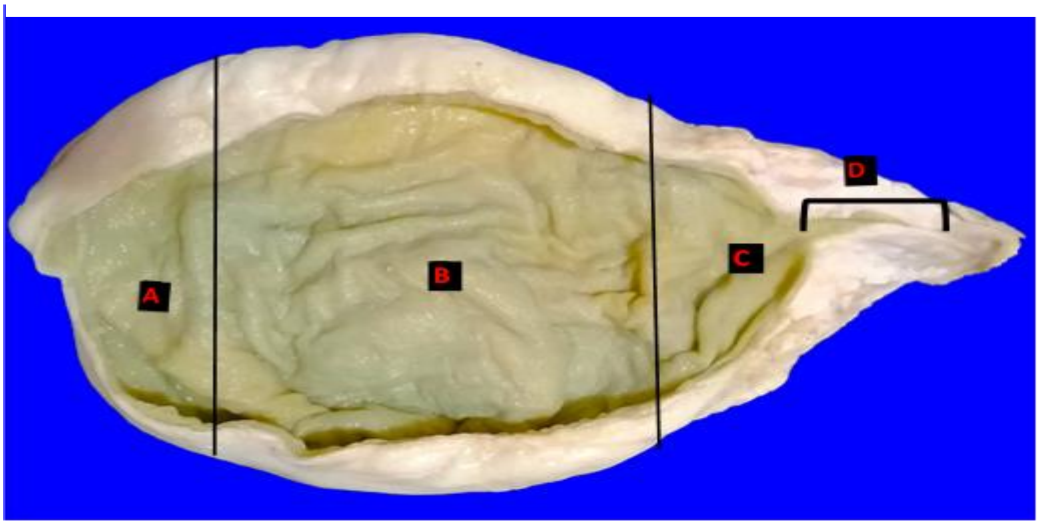

Fig. (3): Internal surface of gallbladder in cattle illustrated the folds: A- Fundus. B- Body. C- Neck. D- Cystic duct.

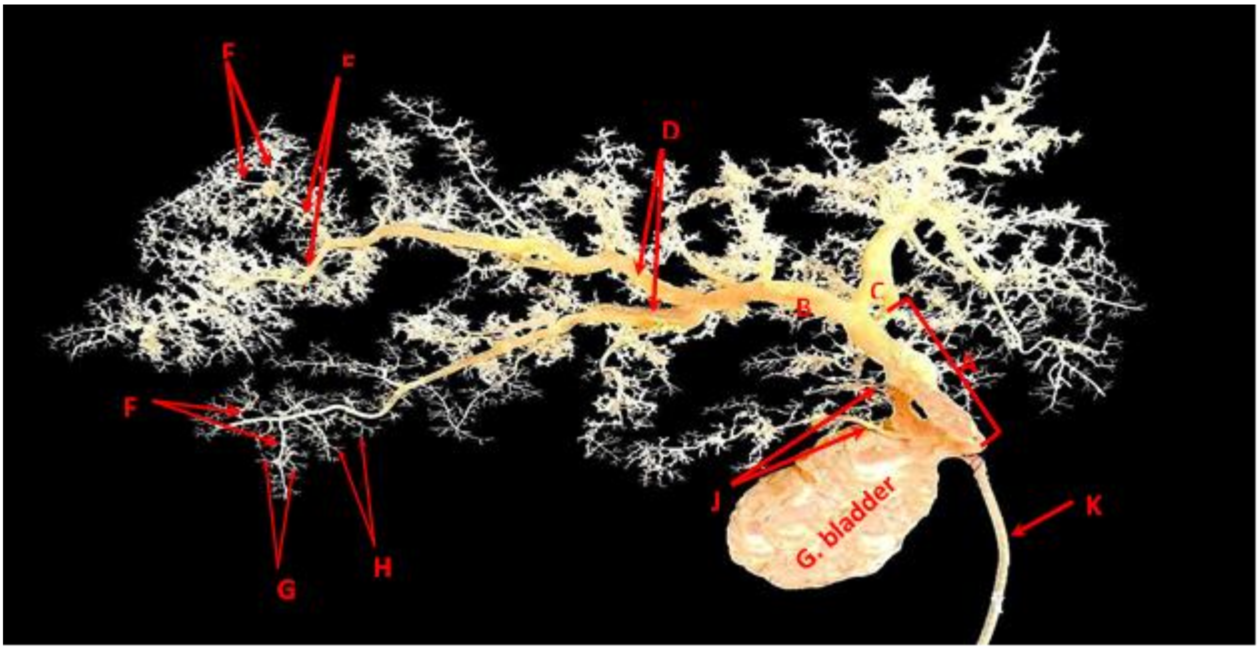

Fig. (4): Resin cast illustrated the biliary duct system for liver in cattle: A- Common hepatic duct. B - Left hepatic lobar duct. C- Right hepatic lobar duct. D- Primary duct. E- Secondary duct. F- Tertiary duct. G- Inter lobular duct. H- Intra lobular duct. I- Cystic duct. J- Hepatocystic ducts. K- Catheter.

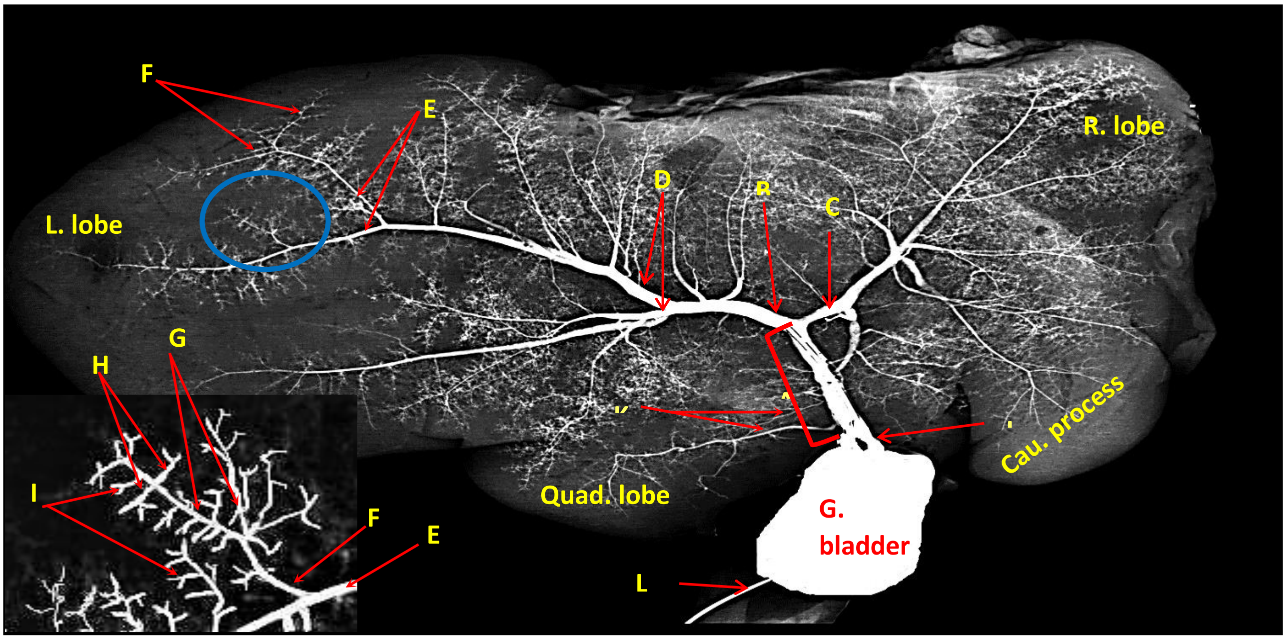

Fig. (5): Contrast radiograph illustrated the biliary duct system for liver in cattle (40 ml contrast media injected): A- Common hepatic duct. B - Left hepatic lobar duct. C- Right hepatic lobar duct. D- Primary duct. E- Secondary duct. F- Tertiary duct. G- Inter lobular duct. H- Intra lobular duct. I- Intercalated duct. J- Cystic duct. K- Hepatocystic ducts. L- Catheter.

4- DISCUSSION

The spatial positioning of the liver in ruminant animals aligns with the observations made by [26]. In several breeds, the liver exhibits a rightward deviation along the median line, perhaps attributed to the anatomical configuration of the stomach and intestines in ruminants, resulting in a pronounced rightward displacement of the liver [26], [27], [28], [29].

The hepatic extension seen in local cattle coincides with the findings reported by [30] in ruminants and [8] in goats. While it varies among different animal species, previous studies have reported specific ranges for certain animals. For instance, [31], [32] found that hepatic extension in one-humped camels occurred between the 5th and 11th ribs, while [33] observed it between the 5th and 12th ribs. In goats, [34] reported hepatic extension between the 8th and 12th ribs. Similarly, [35], [36] found that hepatic extension in gazelles was located between the 8th rib and the first lumbar vertebra.

Furthermore, the findings of [37] contradict the aforementioned statement, since they reported different extension ranges in various animals, namely 10^{th}-12^{th} ribs in cattle, 9^{th}-10^{th} ribs in sheep, 7^{th}-9^{th} ribs in goats, and 6^{th}-11^{th} ribs in camels.

The present study has extensively validated the existence of the right and left triangular, falciform, and hepatorenal ligaments, as well as the lesser omentum, as supported by previous research conducted on camels [27], [29], [38], [39]. However, the round ligaments were not specifically mentioned in these studies.

The ligaments play a significant role in maintaining the position of the liver and regulating its mobility, as well as exerting pressure on the internal organs, resulting in visible imprints on the surface of the liver. The robust and expansive right triangular ligament, together with the hepatorenal ligament, provides substantial reinforcement for the connection to the inner wall of the abdominal cavity. Additionally, the shorter and thicker left triangular and falciform ligaments, and the lesser omentum allow the organ to exhibit a greater degree of curved motion on the right side compared to the left side. [40]

Based on our research findings, it can be seen that the relative liver weight in herbivores aligns well with the information provided by [41], however, it deviates from the relative liver weights observed in pigs, which fall within the range of 2%–3%. And according to [42], equines have a reported liver weight of 5 kg, whereas bovines have a liver weight ranging from 3 to 4 kg.

In contrast, the weight of the target organ exceeds that of a native gazelle of 275.40 ± 0.21 grams, with a smaller relative liver weight of 1.7%. [35], [43]. According to the studies, the weight of camel liver was found to be much greater than that of cattle. Specifically, [44] reported a mean weight of 8.93 ± 0.23 kg, while [29] found it to be around 7.5 kg. Additionally, [45] observed a higher relative liver weight of 2.3% for camel liver.

The liver of animals has a different segmentation. Dogs and cats have more subdivisions than herbivores. The hepatic lobes may slide across each other when the spine is maximally flexed or extended. In animals without fissures, virtual lines from landmarks indicate lobes to separate the liver into four major lobes [41].

Ruminants have a single liver mass, however, the right and left major lobes may be seen by separating the umbilical fissure, which includes the round ligament [30], [41]. This finding aligns with the results obtained from our investigation, which indicate that the observed structure is a single mass, with the exception of the caudate lobe, which is divided. But camels deviate from these characteristics of ruminants due to the presence of medial and lateral subdivisions in the right and left lobes, caudate and papillary processes in the caudate lobe, and visceral and parietal lobes in the quadrate lobes. [29], [38], [46]

The gallbladder's shape and size depend on bile content volume and numerous folds (plicae) allow for increased surface area, bile absorption, and distribution. It prevents bile pooling, supports liver function, and accommodates fluctuations in bile production and storage. The dark green appearance of the gallbladder is due to its yellowish-green fluid [47].

The results of earlier researchers [34], [48], [49], [50], [51] indicate that the location and structure of the gallbladder in several animal species, including small ruminants, buffalo, cattle, goats, and Chinchillas, are consistent. However, the lengths vary, measuring 9.5 cm and 11 cm; 18 cm; 10–15 cm; 4.5 cm; and 12.4 mm, respectively.

The left and right hepatic ducts, emerging from the hepatic parenchyma in proximity to the hepatic porta, converge to create the common hepatic duct. This is consistent with findings reported in studies conducted on camels [29], [33], small ruminants [48], buffaloes [49], as well as cattle, humans, and Bengal goats [52]. The common hepatic duct, in contrast, is made up of a number of hepatic ducts, such as the 2-3 in Indian buffalo [53]; dogs have 3-4 hepatic ducts [54], [55]; and chinchillas have complex hepatic ductal networks [50].

Based on the results of our study, it can be seen that the dimensions and configurations of the left and right ducts are influenced by the magnitude of the hepatic tissue from which they originate. There is evidence to suggest that the left canal exhibits a greater length and a higher degree of branching in comparison to the right canal. In a study conducted by [48] it was observed that these ducts in small ruminants exhibited lengths of 2 cm and 4 cm. While in buffaloes, they were 5.5 cm and 2.5 cm [49].

Cattle in this study differ from small ruminants and camels in that they don't have a greater pancreatic duct. Thus, the common hepatic duct opens into the duodenum as the common bile duct. This fact is consistent with what [29], [33], [56] mentioned in camels and [30] in camels, small ruminants, and pigs.
The intramural segment of the common bile duct functions as a sphincter muscle, regulating the flow of bile into the duodenum and preventing the reflux of duodenal contents into the duct. [30], [57].
The distance between the biliary orifice located in the duodenum and the pylorus, 20 ± 2 cm in our result, exhibits variability across different animal species as a result of anatomical variations in the duodenum. This study's measurement (2.75 ± 0.87 cm) in cats, (6.37 ± 0.7 cm) in dogs, (9.76 ± 0.8 cm) in omnivores, (23.72 ± 0.87 cm) in Bengal goats, (25.62 ± 0.77 cm) in sheep, and (55.37 ± 0.68 cm) in cattle [52]. Previous measurements ranged from 20-25 cm for camels and Indian buffaloes [53], [56].

5- CONCLUSION

This study proved that the liver of local cattle possesses overall characteristics similar to those of other cattle, with a difference from other breeds in terms of extension, lobulation, and ligaments of the liver, in addition to the unique ductal system of its kind, which was demonstrated using the resin and x-ray techniques, as the total conformity of the different branches in both techniques was demonstrated. Where the dense and special branching of each part of the liver occurs.

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