



GROSS MORPHOLOGY AND BIOMETRIC CHARACTERISTICS OF HEPATIC LOBES IN PIGS OF THE JAMMU REGION OF INDIA

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ABSTRACT

The present study was conducted on the liver (N=10) of adult apparently healthy pigs of Jammu region. The pig liver was a large, somewhat rectangular organ, which exhibited a cherry-brown color. It had convex parietal and concave visceral surfaces, with prominent inter-lobular connective tissue giving a lobulated or honey-comb appearance. The liver was divided by inter-lobular fissures into four principal lobes with accessory caudate and quadrate lobes which were supported by numerous ligaments. Renal fossa was absent. The porta hepatis served as the entry and exit point for the portal vein, hepatic artery, bile duct, and nerves. Quantitative biometry revealed an average weight of 1.89 ± 0.21 kg and volume of 1687.33 ± 144.03 ml. The liver measured 37.98 ± 1.64 cm in length, 21.33 ± 1.85 cm in width, and was thickest at the central region (3.68 ± 0.11 cm). Among lobes, the left lateral lobe was the longest and widest, whereas the caudate lobe was the smallest but exhibited the highest lobular density of 44.83 ± 0.60 lobules/cm². Shape index highlighted morphological heterogeneity, with the caudate lobe being broadest and quadrate lobe most elongated.

Key words: Liver, Pig, Porta hepatis, Renal fossa, Shape index

Introduction

In our country, the total number of livestock is 535.78 million, with pigs accounting for 9.06 million (01.70%) (Livestock Census, 2019). Although India has a large pig population, the production of swine is not fully developed (Chauhan *et al.*, 2016). Pigs have great potential to provide quick economic benefits to farmers because of their efficient feeding, early maturity, and short generation time (Banerjee, 1998). Pigs are also of interest in biomedical research because they are similar to humans in their body structure, function, and disease processes. They are widely used in various scientific fields, such as immunology, organ transplantation, heart disease, and wound healing (Wang *et al.*, 2023).

The liver is both structurally and functionally complex, second only to the brain in complexity (Malarkay *et al.*, 2005). It has many important roles, such as efficient uptake

of amino acids, carbohydrates, bile acids, cholesterol, proteins, lipids, and vitamins (Burt and Day, 2002). It also helps in removing waste, producing clotting factors, fibrinogen, albumin, and other proteins, fighting infections, breaking down toxins, processing drugs, and supporting the body's ability to produce blood cells (Eurell and Frappier, 2006). Understanding the liver's anatomy is crucial for interpreting these processes.

Literature is available on the anatomical studies pertaining to the liver of goat (Bhattacharya *et al.*, 1986), buffalo (Saigal *et al.*, 1992), cow, goat and sheep (Madhan and Raju, 2014), camel (Siddig *et al.*, 2015), water buffalo (Rashad *et al.*, 2017). There is scant anatomical data available on the liver of pigs of Jammu region. In light of the above facts, the current study was proposed to fully understand the anatomical characteristics of the pig liver, gather more knowledge,

and justify the functional importance and essentially of this organ. It will be helpful to scientists engaged in basic, clinical, and paraclinical sciences, as well as meeting the needs of researchers working in the field of pig liver.

Materials and Methods

Collection of samples

Liver along with gall bladder of apparently healthy adult (1-1.5 years) pigs (irrespective of sex) were collected from slaughter houses in and around Jammu City of union territory of Jammu & Kashmir. Age was estimated by examining the dentition. Ten (N=10) samples were collected.

Morphological studies

Immediately after collection, the samples were cleaned with running water and brought to the laboratory for recording the gross morphological and biometrical studies. Morphological studies included recording of shape, colour and lobation of liver.

Gross biometrical studies

Recording the biometry of the pig liver is a valuable practice having wide-range applications in veterinary medicine, animal science, and biomedical research. It provides essential data for monitoring animal health, diagnosing liver-related diseases, improving genetic selection, and evaluating the effects of nutrition and management practices. In research, pigs serve as important models for human liver studies, so making accurate liver measurements becomes crucial for translational science. In present study, biometrical studies included recording of following parameters:

- i. **Total weight (kg) of liver:** Total weight (kg) of liver was recorded with help of Monopan balance.
- ii. **Relative weight (%) of liver:** It was expressed as $(\text{Liver weight}/\text{Body weight}) \times 100$
- iii. **Total volume (ml) of liver:** It was measured by water displacement method (Barnwal and Sinha, 1981).
- iv. **Density of liver (gm/ml):** It was calculated as $\text{Weight of liver (gm)}/\text{Total volume (ml)}$ (Niehues *et al.*, 2010)
- v. **Total length (cm) of liver:** It was measured between the right and left lateral borders of the liver by using scale and non-stretchable thread.
- vi. **Maximum width (cm) of liver:** It was measured between dorsal and ventral border of liver using scale and non-stretchable thread.
- vii. **Thickness (cm):** It was measured between

visceral and parietal surfaces at three sites, i.e. left, middle and right by using vernier calliper.

viii. Length (cm) and width (cm) of individual lobes of liver: It was measured by using scale and non-stretchable thread.

ix. Shape index: $\frac{\text{Length}}{\text{Width}} \times 100$ (Barnwal and Sinha, 1981).

x. Number of lobules per cm² of individual lobes.

Statistical analysis

All the data was subjected to Standard Statistical Analysis (Snedecor and Cochran, 1994).

Results and Discussion

Gross morphology

In present study, the liver was somewhat rectangular in shape (Fig. 1), aligning with previous observations in pig (Singh, 2019; Debroy *et al.*, 2021). However, Biswas *et al.*, (2018) described a relatively large and more irregular shaped in Ghungroo pig. In present study, liver exhibited a cherry-brown coloration as earlier reported by Singh (2019) in pig. Darker hues such as dark red were observed by Vishwanath (1967) in pig, Carvalhode-Souza *et al.*, (2005) in wild boar and Biswas *et al.*, (2018) in Ghungroo pig. Some researchers described variation in color ranging from cherry red to brownish red in Mizoram local pig (Zovawk) (Debroy *et al.*, 2021). In present study, the liver was observed to be thicker at the center and thinner towards the margins which concurs with the findings by Getty (1975) in pig, Biswas *et al.*, (2018) in Ghungroo pig and Ntonas *et al.*, (2020) in swine.

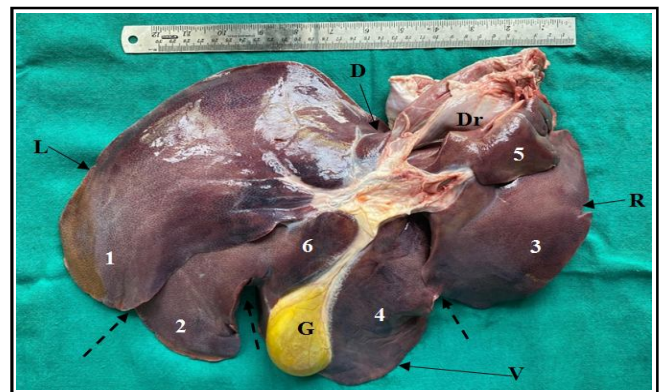


Fig. 1: Photograph of visceral surface of liver of pig showing its rectangular shape and cherry brown colour. Different lobes are left lateral (1), left medial (2), right lateral (3), right medial (4), caudate (5) and quadrate (6). Gall bladder (G) is also evident. Four borders are dorsal (D), ventral (V), right lateral (R) and left lateral (L). Dorsal border is connected to the diaphragm (Dr). Three deep interlobar fissure were prominent (dotted arrow). Middle fissure was the deepest.

Liver of pig presented two distinct surfaces, parietal and visceral. The parietal surface was markedly convex, smooth and closely associated with the right diaphragmatic concavity (Fig. 2), while visceral surface was concave, very irregular and directed caudoventrally which was similar to the findings by Biswas (2017) and Singh (2019) in pig. These surface characteristics were consistent across other mammals such as lion and leopard (Kumari *et al.*, 2010), adult female civet cat (Sarma *et al.*, 2010), dog (Evans and deLahunta, 2013). In the current study, the visceral surface of the liver presented a prominent portal fissure which marked the entry of the portal vein, hepatic artery, nerves and exit of lymph vessels and hepatic duct (Fig. 3 and 4). Similar observation was made by Singh (2019) in pig. In the present investigation, ventral to the portal vein, three or four hepatic lymph nodes of various size were present at the fissure. Renal impression was absent on pig liver which was in agreement with previous reports by Carvalho-de-Souza *et al.*, (2005) in wild boar, Dyce *et al.*, (2010) in pig and Konig and Liebich (2020) in pig. A key distinguishing feature of pig liver was its prominent inter-lobular connective tissue which extended from the capsule into the parenchyma, delineating the hepatic lobules. Macroscopically, this extensive amount of connective tissue gave a distinctive lobulated or honey-comb appearance to the surface of the liver (Fig. 5) as described by Biswas *et al.*, (2018) in Ghungroo pig and Liebich (2019) in pig. Kuehnelt (2023) compared liver surface of pig to honeycomb.

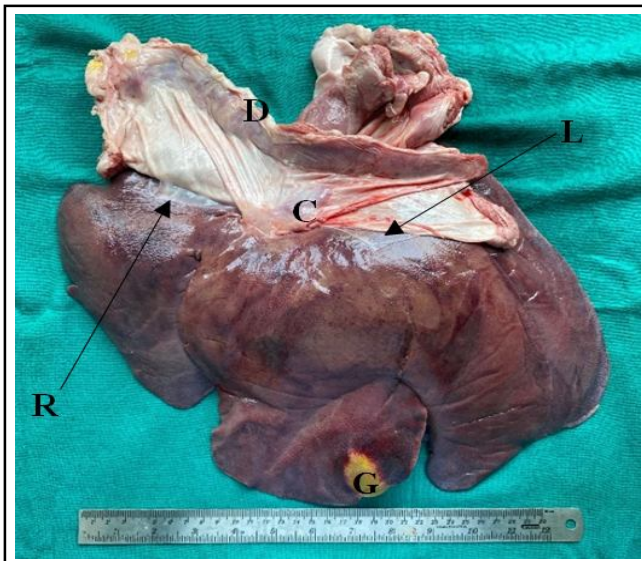


Fig. 2: Photograph showing parietal surface of liver of pig. Towards dorsal border, coronary ligament (C) connects liver to the diaphragm (D). Right (R) and left (L) triangular ligament are seen on either side of coronary ligament. Ventral border presented 'V' shaped notch through which gall bladder (G) is noticeable. This notch was seen in right medial lobe.

In present study, the liver presented four borders as earlier reported by Debroy *et al.*, (2021) in Mizoram local pig (Zovawk). The ventral and lateral borders were sharp while dorsal border was thick and more rounded (Fig. 1). These features resembled with the findings of Raghavan (1964) in ruminants. The dorsal border presented an esophageal notch. The caudal vena cava was deeply embedded in the dorsal border (Fig. 6) as also reported by Singh (2019) in pig. Biswas (2017) in Ghungroo pig also observed the presence of caudal vena cava along the dorsal border of the caudate lobe and was entirely embedded in the substance of the gland. It also received hepatic veins. The embedding of the caudal vena cava along the dorsal border suggested that the venous return from liver was structurally well-protected. The ventral border of the liver presented a deep umbilical fissure. Dorsal border was short and thick whereas ventral border was smooth and curved.

In present study, the pig liver showed distinct lobation with three major fissures dividing it into four principal lobes, namely right lateral, right medial (central), left medial (central), left lateral. It was consistent with the observations made by Getty (1975), Carvalho-de-Souza *et al.*, (2005) in wild boar, Dyce *et al.*, (2010), Ghosh (2015) in pig, Junatas *et al.*, (2017) in Prestice Black-Pied pig and Biswas *et al.*, (2018) in Ghungroo pig. Sivakumar *et al.*, (2023) reported that liver of indigenous pigs of Tamil Nadu consisted of five lobes. Left lateral lobe was the largest lobe (Fig. 1) as noted by Biswas *et*

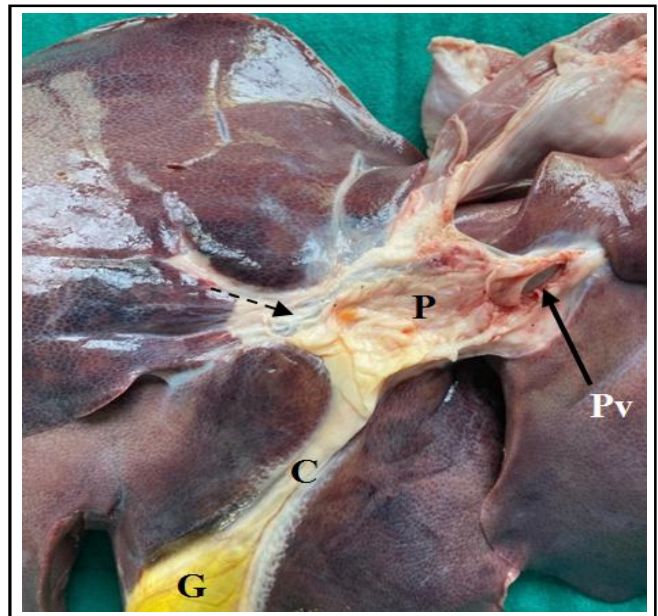


Fig. 3: Photograph showing visceral surface of liver of pig. Distinct *porta hepatis* (P) was present. Portal vein (Pv) was seen entering the liver. Dotted arrow indicated the position of hepatic artery. Cystic duct (C) arises from gall bladder (G).

al., (2018) in Ghungroo pig. In present study, a small caudate lobe was positioned on the dorsal aspect of right lateral lobe whereas quadrate lobe was located on the visceral surface ventral to the portal fissure and between the left medial and right medial lobes (Fig. 1). These observations aligned with earlier findings by Carvalhode-Souza *et al.*, (2005) in wild boar and Biswas *et al.*, (2018) in Ghungroo pig. In present investigation, the caudate lobe was quadrangular shaped and was represented only by a caudate process as papillary process was absent, a feature also reported by Konig and Liebich (2020) in pig. All the other lobes were irregularly oval to leaf shaped. The quadrate lobe did not reach up to ventral border of liver and lied to the left of gall bladder similar to the observation by Singh (2019) in pig.

In present study, liver of pig was large and heavy organ which was held in its position and attached to diaphragm and adjacent structures through specialized peritoneal folds known as ligaments. These ligaments played an important anatomical and functional roles as they are essential for anatomical positioning, support as well as vascular passage. The coronary ligament was a narrow band of connective tissue that attached the dorsal aspect of the parietal surface of the liver to the diaphragm (Fig. 2). Falciform ligament was small and extended to the parietal surface of the liver from the esophageal notch. Sisson (1975) reported that the falciform ligament was either very short or even absent and if present, it was attached to the diaphragm. In present study, the right and left lateral ligaments were on the right and left sides of the coronary ligament (Fig. 2). Biswas (2017) in Ghungroo pig reported that the coronary ligament connected liver

to the diaphragm and extended from left triangular to right triangular ligament along the ventral surface of caudal vena cava. The round ligament was present above the umbilical fissure. The lesser omentum was present near the portal fissure (Fig. 4).

The porta hepatis/hilum of the liver was a transverse fissure located on the visceral surface, positioned between the caudate lobe dorsally and quadrate lobe ventrally (Fig. 3, 4). It served as the gateway for all the major vessels, ducts and nerves entering or leaving the liver as described by Raghavan (1964) in ox and Singh (2019) in pig. The largest vessel was the portal vein. The portal vein along with the hepatic artery entered into the liver through the hilus. The portal vein entered the hilus of the liver between the hepatic artery dorsally and the bile duct ventrally. It immediately divided into right dorsal branch, right ventral branch and then continue to the left as left branch (Fig. 4). Right dorsal branch originated from the portal vein and proceeded through the parenchyma of dorsal part of right lateral lobe in between the latter and caudate lobe. Right ventral branch originated from the ventral aspect of the portal vein and proceeded ventrally within the parenchyma of the right medial lobe. The left branch of the portal vein appeared to be the direct continuation of the portal vein. These findings corroborate with the findings of Osman *et al.*, (2008) in pig.

Biometry

Liver biometry is a key tool for enhancing animal welfare, productivity, and scientific understanding. Quantitative measurements of the pig liver were recorded and summarized in Table 1 and 2.

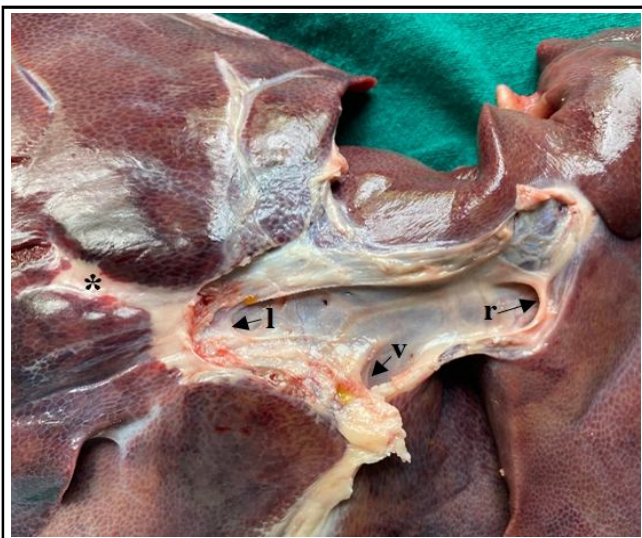


Fig. 4: Photograph showing lesser omentum (*) on the visceral surface of the liver. Portal vein divided into right dorsal (d), right ventral (v) and left branch (l).



Fig. 5: Photograph showing prominent lobulated or honey-comb appearance to the surface of the liver of pig. This feature is due to the presence of abundant amount of connective tissue.

Table 1: Gross biometrical parameters of liver of adult pigs of Jammu region.

Parameter		Mean $\pm$ SE	Range
Adult weight (kg) of animal		94.33 $\pm$ 2.94	85.00–101.00
Weight (kg) of liver		1.89 $\pm$ 0.21	1.629–2.39
Relative weight of liver (%)		1.98 $\pm$ 0.17	1.65–2.49
Volume (ml) of liver		1687.33 $\pm$ 144.03	1200–2100
Density (gm/ml)		1.105 $\pm$ 0.05	0.93–1.141
Length (cm) of liver		37.98 $\pm$ 1.64	30.00–40.30
Maximum width (cm) of liver		21.33 $\pm$ 1.85	16.00–26.80
Shape index of liver		55.93 $\pm$ 3.44	47.22–66.50
Curved length (cm)	APS	38.43 $\pm$ 2.44	27.00–43.20
	AVS	36.20 $\pm$ 1.65	28.50–39.10
Thickness (cm) of liver	Left	2.27 ^a $\pm$ 0.36	1.30–3.00
	Mid	3.68 ^b $\pm$ 0.11	3.41–4.10
	Right	2.20 ^a $\pm$ 0.11	1.85–2.41
APS: Along parietal surface; AVS: Along visceral surface Mean value with different superscript (a, b) within row differ significantly (p<0.05)			

In present study, the average liver weight was 1.89 $\pm$ 0.21 kg which was within the normal range of 1.5 to 2.0 kg as recorded by Getty (1975). Nickel *et al.*, (1979) reported that weight of pig liver varied from 1–2.5 kg. However, it was slightly greater than the data documented in the literature which might be due to breed and regional difference. Niehues *et al.*, (2010) recorded the median liver weight as 1710 g for the crossbred pigs and 534 g for the minipigs. In Large white Yorkshire pig, the average weight of liver was 1.203 kg (Singh, 2015) whereas in Ghungroo pig, the average liver weight was 1.54 $\pm$ 0.21 kg (Biswas *et al.*, 2018). Debroy *et al.*, (2021) recorded average weight of Mizoram local pig (Zovawk) as 1.402 kg. Singh *et al.*, (2025) reported that average weight of liver of adult pig was 0.924 $\pm$ 0.11 kg.

The relative weight of liver in pigs is a useful biological indicator in veterinary science. It can be a valuable

indicator for assessing health status, monitoring growth and development of the organ. Liver enlargement or atrophy may indicate hepatotoxicity or metabolic compromise. In present study, the relative weight of the liver was 1.98 $\pm$ 0.17 % which was within the normal range as reported in the literature. Nickel *et al.*, (1979) reported that pig liver was about 01.70% of the body weight. According to Madhan and Raju (2014), porcine liver weight ranged from 1.5–3% of the animal weight whereas Konig and Liebich (2020) reported that weight of liver in adult pig was 2–3% of body weight.

In present study, the average volume of liver was 1687.33 $\pm$ 144.03 ml which was higher than those previously reported for Large white Yorkshire pig (484.16 ml) by Singh (2015) and Ghungroo pigs (1.425 $\pm$ 0.192 L) by Biswas *et al.*, (2018). In young pig, the volume of liver varied between 652 to 1120 cm³ (Court *et al.*, 2003). The higher values of volume of liver in present study as compared to the previous studies might be due to breed and regional differences.

Liver density (g/ml) calculation in pigs has several important applications. Since pigs are frequently used as models for human liver studies due to anatomical and physiological similarities (Cox and Zhong, 2005), any change in liver density can reflect pathological changes. In present study, the density of liver was 1.105 $\pm$ 0.05 g/ml which was in close approximation with the findings of Niehues *et al.*, (2010) who recorded mean liver density in pig as 1.07 g/ml indicating a normal hepatic architecture. These values were comparable with the findings of Van Thiel *et al.*, (1985) in healthy human liver tissue where density range from 1.02 to 1.09 g/ml.

In present study, the mean length of liver was 37.98 $\pm$ 1.64 cm which was much higher than the values recorded by Debroy *et al.*, (2021) in Mizoram local pig

Table 2: Gross biometrical parameters of different lobes of liver of adult pigs of Jammu region.

Lobes of liver	Length (cm)	Width (cm)	Shape index	Lobules per cm ²
Right lateral	19.20 ^b $\pm$ 1.13 (15.60–21.60)	11.04 ^c $\pm$ 1.26 (7.40–11.40)	57.31 $\pm$ 7.64 (47.44–75.89)	35.17 ^d $\pm$ 0.4 (34.00–36.00)
Right central/medial	19.37 ^b $\pm$ 0.97 (15.70–21.90)	8.50 ^b $\pm$ 0.52 (7.40–10.60)	45.07 $\pm$ 4.96 (33.95–60.51)	33.16 ^c $\pm$ 0.65 (30.00–34.00)
Left lateral	27.02 ^c $\pm$ 1.29 (21.00–29.50)	13.15 ^d $\pm$ 0.54 (10.70–14.80)	48.82 $\pm$ 0.94 (45.89–50.91)	25.33 ^a $\pm$ 0.33 (24–26)
Left central/medial	19.87 ^b $\pm$ 1.16 (16.70–22.90)	10.65 ^c $\pm$ 0.79 (8.50–12.80)	54.85 $\pm$ 5.88 (41.45–72.73)	31.83 ^b $\pm$ 0.47 (31.00–32.00)
Caudate	8.63 ^a $\pm$ 1.10 (5.82–11.80)	5.71 ^a $\pm$ 0.40 (4.71–6.90)	69.39 $\pm$ 5.91 (54.24–80.93)	44.83 ^f $\pm$ 0.60 (43–46)
Quadrate	11.03 ^a $\pm$ 1.03 (7.30–13.70)	4.17 ^a $\pm$ 0.21 (3.60–4.80)	39.41 $\pm$ 3.68 (28.17–45.05)	40.67 ^e $\pm$ 0.62 (39–42)
Mean value with different superscript (a, b, c, d, e, f) within row differ significantly (p<0.05)				

(Zovawk) where average length was 25.65 cm. The maximum width of liver was 21.33 ± 1.85 cm which was in approximation with the findings of Debroy *et al.*, (2021) in Mizoram local pig (Zovawk) where average maximum width was 20.205 cm. The thickness of liver was recorded at three sites, namely right, middle and left. The liver was significantly ($p < 0.05$) thicker in middle (3.68 ± 0.11 cm). In liver of Mizoram local pig (Zovawk), the maximum thickness was 3.06 cm (Debroy *et al.*, 2021).

For individual lobes of the pig liver, length, width, lobules per cm^2 and shape index were recorded. Detailed biometric analysis of individual liver lobes revealed that the left lateral lobe was significantly longest ($p < 0.05$) and caudate lobe was smallest ($p < 0.05$) lobe. Singh *et al.*, (2025) also recorded average length of lobes of pig liver which was 18.4 ± 0.17 cm for right lateral lobe, 14.28 ± 0.26 cm for right medial lobe, 21.3 ± 0.35 for left lateral lobe, 17.84 ± 0.14 cm for left medial lobe, 6.18 ± 0.19 cm for caudate lobe and 6.12 ± 0.10 cm for quadrate lobe, respectively. Our findings corroborate with the results of Singh *et al.*, (2025).

In present study, it was clear that the left lateral lobe was significantly ($p < 0.05$) widest than all the other lobes and quadrate was significantly smallest ($p < 0.05$). However, width of quadrate lobe did not show any significant difference ($p > 0.05$) with the width of the caudate lobe. These findings corroborate with the results of Singh *et al.*, (2025) who also reported that in liver of pig, the left lateral lobe was significantly wider ($p < 0.05$) and quadrate lobe was significantly smallest ($p < 0.05$) than other lobes except caudate lobe. Average width was 8.06 ± 0.21 cm, 8.98 ± 0.18 cm, 13.3 ± 0.22 cm, 7.9 ± 0.15 cm, 3.5 ± 0.15 cm and 3.38 ± 0.09 cm for right lateral lobe, right medial lobe, left lateral lobe, left medial lobe, caudate lobe and quadrate lobe, respectively.

The surface of pig liver showed typical honeycomb shaped lobules. The number of lobules per cm^2 was calculated. From the study it was concluded that the caudate lobe had significantly greater number of lobules per cm^2 ($p < 0.05$) than other lobes and left lateral lobe had significantly ($p < 0.05$) least number of lobules per cm^2 . There was sparse data on number of lobules per cm^2 , due to which, this parameter could not be discussed in details.

Shape index of the pig liver was calculated which provided a quantitative measure of the external morphology or the outline of the liver, particularly its proportion and general shape, whether it is more elongated or broad/rounded. From the study it was clear that the caudate lobe (69.39 ± 5.91) had highest shape index whereas quadrate lobe (39.41 ± 3.68) had least shape

index value. The value indicated an elongated quadrate lobe as compared to other lobes as well as liver as a whole. Sethi *et al.*, (2020) recorded shape index of liver of adult Bakerwali goat and non-descript goats which was 44.84 ± 1.38 % and 46.22 ± 1.13 %, respectively.

Conclusion

From the current study, it was concluded that the indigenous pig liver showed distinct and well-defined lobation. Abundant interlobular connective tissue gave the liver a unique lobulated or honey-comb appearance, serving as a key species-specific identifying feature. Renal impression was absent highlighting the anatomical separation between the pig liver and right kidney, unlike in several other domestic species. The branching pattern of the portal vein (right dorsal, right ventral, and left branches) was clearly organized. Ligamentous support was well-defined. The liver constituted 1.98% of body weight, reflecting its substantial physiological importance in pigs. Left lateral lobe was the longest and widest, caudate lobe was the smallest and quadrate lobe was the narrowest. Left medial lobe had the highest lobule density, potentially indicating higher parenchymal specialization or metabolic activity.

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