Macroscopic Observation and CT Sectional Analysis of the Liver in an Orang-Utan

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オランウータン肝臓の肉眼解剖学的検討と CT 画像解析

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ABSTRACT. The liver was anatomically examined in a dead body of the orang-utan. Since each lobe was not ventrally protruded in the orang-utan, the liver appeared a regular square from the visceral aspect. The area data were obtained in 20 horizontal sections by means of the CT scanning. We pointed out that the volume and the weight were concentrated in the dorso-ventrally middle area, but not in the extremely ventral or dorsal margins in the liver. We suggest that its morphological characteristics may be adaptational to fix the liver in the visceral cavity in a condition of the cranio-caudally-directioned gravitation.

Key words : CT, liver, orang-utan.

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The orang-utan (*Pongo pygmaeus*) has attracted many comparative anatomists since the species shows the early evolutionary step of the bipedalism between the apes and the human. Certainly the locomotor apparatus have been functional-morphologically examined [1-7], however the visceral organs have not been detailed in a view of the transitional status of bipedal locomotion. Although the visceral organs have not been discussed as a key structure of the bipedalism adaptation, we have thought that the shape, the distribution of volume and weight of the liver has been influenced by the cranio-caudally standing visceral cavity. In this study, therefore, we dissected the carcass of the orang-utan from zoo, and described morphological characters of the liver by means of gross anatomy and CT (computed-tomography) scanning.

We used a carcass of the orang-utan, which had been given to the National Science Museum, Tokyo, by Tama Zoological Park (Tokyo, Japan). The individual was female and 19 years old. After the pathological checks, the two parts of the separated liver was donated. We observed the liver grossally

and applied the CT-scanning method (CT-W450-10A: Hitachi Medical Corporation, Japan) for the liver to obtain the area data of the horizontally plane. The liver was sectioned at 8 mm in gap and 2mm in thickness, and the area values were totally obtained from 20 sections.

The visceral surface of the liver is shown in Figure 1. The liver shows a square shape in this aspect. The five lobes were confirmed as follows: the left lobe, the right lateral lobe, the right medial lobe, the caudate lobe and the quadrate lobe.

The left lobe was the largest part in the visceral side, and showed a triangular shape. The right side of the liver consisted of the lateral and medial lobes, and was smaller in the visceral aspect than the left side. The relatively larger lateral lobe appeared a dorso-ventrally elongated square in the visceral aspect. The lateral lobe was considerably thick in the dorsal region at cranio-caudal direction (Fig. 2). The posterior vena cava was present in this thick part (Fig. 2).

The caudate lobe consisted of the long triangular protrusion in the visceral area of the left lobe (Fig. 1). The enlarged quadrate lobe was observed in the ventro-medial area of the

Fig. 1. Visceral aspect of the liver of the orang-utan. Dorsal direction at the top. We can confirm the left (L), caudate (C), right lateral (RL) and right medial (RM) lobes. The quadrate lobe (Q) are enlarged beneath the gall bladder (G). Arrow, the round ligament of the liver.

Fig. 2. Visceral aspect. Dorsal direction at the left. The section surface by the pathological checks is seen. This area is cranio-caudally thick. The vena cava posterior (arrow) runs in the dorso-medial area of the liver. RL, right lateral lobe, RM, right medial lobe, C, caudate lobe.

left lobe (Fig. 1). Although the quadrate lobe did not represent the obviously separated part from the left lobe, it could be distinguished from the ventral part of the left lobe by the ventral area of the falciform ligament and the round ligament of the liver. The gall bladder was confirmed in the caudal area of the quadrate lobe (Fig. 1). The gall bladder was ventrally elongated in the medial side of the round ligament of the liver.

The diaphragmatic surface of the liver is shown in Figures 3 and 4. The surface of the liver was smoothly curved posterior to the diaphragm. In this aspect, the larger left lobe (Fig. 3) and smaller right lateral lobe (Fig. 4) were observed. And the caudate lobe was separated from the left lobe by the ventro-medial area of the falciform ligament. The quadrate lobes could not be seen in diaphragmatic side.

The left and right triangular ligaments were attached to the diaphragmatic surface of the liver. The left triangular ligament was enlarged from the falciform ligament and reached the dorsal margin of the left lobe (Fig. 3). The right triangular ligament was strongly attached to the diaphragmatic surface of the right lateral lobe, and its strong structure of collagen fiber was dorso-laterally enlarged (Fig. 4).

In dorsal aspect of the left lobe, the hepatic vein was encountered (Fig. 5). The dorsal end of the left triangular ligament and the enlarged attachment of the falciform ligament to the diaphragmatic side of the liver were confirmed at this aspect.

An example of the horizontal section by the CT scanning is shown in Figure 6. The area data are shown in Table 1 and Figure 7. The number of sections was ordered from dorsal to ventral planes. The area data of each section pointed out that the volume and weight of the liver were concentrated approximately from the No. 5 to the No. 14 sections (Table 1 and Fig. 7) and that the liver did not distribute the mass to its extremely dorsal and ventral region.

The orang-utan belongs to the apes showing the posture of incomplete bipedalism as an evolutionary stage. The species sometimes fist-walks and knuckle-slides on the ground, whereas uses its long limbs in the arboreal locomotion. The orang-utan, therefore, obliquely stands the thoracic and ventral region of the trunk on the ground. So, we expect that the macroscopic liver structure may be specific and adaptational to this incomplete bipedalism posture.

The present data showed that the shape of the liver looked like a regular square at a diaphragmatic or visceral aspect. In the many tetrapod mammals, for example, the livestock, each lobe is elongated to ventral direction [8, 9]. In the orang-utan, however, the elongation of the lobe was not observed, and the interlobular separation did not seem obvious except for the part near the round ligament of the liver unlike the usual tetrapod mammals. We suggest that these morphological characters may prevent the liver lobe from dropping to the visceral direction by the gravitation, when the orang-utan obliquely stands the trunk.

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Fig. 3. The left (L) and quadrate (Q) lobes. Diaphragmatic aspect. Dorsal direction at the top. The falciform ligament (large arrows) is enlarged in the diaphragmatic surface of the lobes. The round ligament of the liver can be seen in the diaphragmatic aspect (small arrow). The falciform ligament is enlarged to the left triangular ligament in the dorsal margin (arrowhead).

Fig. 4. The right lateral lobe. Diaphragmatic aspect. Dorsal direction at the top. The right triangular ligament (arrows) is enlarged in the lateral area of the diaphragmatic surface of the lobe.

The shape of the liver may be adaptational to the standing posture of the trunk in the orang-utan.

The effects of the bipedalism-related posture have given us the important suggestions from the anatomical data of the human [10, 11] and the other apes [12]. The gorilla possesses the liver morphologically similar to that of the orang-utan, although the left lobe is obviously separated into the two parts in the gorilla [12]. The liver of the human resembles that of the orang-utan in the shape of regular square without ventral projection of lobes [11, 13].

The present data of the human and the apes suggests that the liver may lose the marginal protrusion to restrict the volume and weight to its central region as shown also in this study. We suggest that the liver of general mammals with four limbs is not regulated in shape variation in comparison with the bipedal primates including human [9-12]. We can conclude that the form of the liver without marginal protrusion in the apes is functionally required to the standing trunk that is related to the

bipedal walking.

In addition the strong attachment between the area nuda and the diaphragm is important in the positioning of the liver in the bipedal human, whereas in the general mammals this attachment is not functionally significant [9-11]. In the transitional apes such as orang-utan and gorilla, we point out that the liver attachment by the area nuda has not been developed unlike the human [12]. Instead of the area nuda, the elongated falciform ligament in the orang-utan (Fig. 3) may play a role to fix the liver to the diaphragm resisting the cranio-caudal gravitation. We think that the large volume and heavy weight can be born and supported by the developed falciform ligament, when the orang-utan obliquely stands the ventral region.

要 約

オランウータンの遺体を用いて、肝臓の肉眼解剖学的特徴を検討した。同種の肝臓は左葉、尾状葉、方形葉、外側右葉、内

Fig. 5. The left lobe. Dorsal aspect. Diaphragmatic direction at the top. The left triangular ligament (large arrows) is enlarged in the diaphragmatic surface of the lobe and reaches the dorsal margin. The hepatic veins (small arrows) are encountered in this aspect.

C : caudate lobe.

Fig. 6. An example of CT horizontal sections of the liver. The photograph represents the No. 4 section. The section areas were calculated from a series of sections.

RL : right lateral lobe, L : left lobe, C : caudate lobe. Scale bar = 20 mm.

Fig. 7. The area data of each CT section. Horizontal axis, the section numbers that were ordered from dorsal to ventral planes. Vertical axis, the area (cm²). The three lines with each marker indicate the area of the following lobes.

Square : right lateral and medial lobes. Circle : left, caudate and quadrate lobes. Triangle : total area.

側右葉に分けられ、発達した胆嚢を伴っていた。各葉は、四足獣と異なって、腹側へ突起を伸ばすことはなく、臓側面から見て正方形に近い形態を示した。また、CT スキャンを利用して肝臓の 20 枚の水平断面を得て、その各面積を算出した。その結果、肝臓の体積と重量の大半は背腹方向で見て中央付近に集中し、極端な背側や腹側部に体積や重量をもたないことが明らかとなった。このような特徴は、直立二足歩行前段階として体幹を垂直に立てる姿勢を示す類人猿において、頭尾方向に重力

が生じる条件下で肝臓を負担し固定するために進化した、適応的な機能形態学的機構であることが推察された。

キーワード：オランウータン、肝臓、CT

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Table 1. Area data (cm) of the CT horizontal sections of the liver.

Section No.	1	2	3	4	5	6	7	8	9	10
Left side	4.10	9.92	28.75	40.96	43.99	47.55	52.28	47.92	49.42	47.51
Right side	0.00	0.00	15.79	22.69	29.27	34.15	30.88	28.31	29.90	30.79
Total	4.10	9.92	44.54	63.66	73.26	81.70	83.16	76.23	79.32	78.30

Section No.	11	12	13	14	15	16	17	18	19	20
Left side	48.21	45.67	48.30	47.68	43.13	36.73	29.56	18.70	12.46	5.12
Right side	26.90	30.07	27.49	21.08	14.69	9.81	5.99	4.53	0.00	0.00
Total	75.11	75.74	75.79	68.77	57.81	46.54	35.56	23.22	12.46	5.12

The section numbers are ordered from dorsal to ventral planes.

Left side includes the left, caudate and quadrate lobes, whereas the right side means right lateral and medial lobes.

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