

The Bronchial Tree, Lobular Division and Blood Vessels of the Japanese Deer (*Cervus nippon*) Lung

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ABSTRACT. The bronchial tree, lobular division and blood vessels of the lungs were examined in three Japanese deer (*Cervus nippon*). The dorsal, lateral, ventral and medial bronchiole systems arose from the dorsal, lateral, ventral and medial sides of both bronchi, respectively. Furthermore, one bronchiole arose from the right side of the trachea, namely the tracheal bronchus (bronchiole). This bronchiole formed the right cranial lobe. The right middle lobe was formed by the first bronchiole of the lateral bronchiole system. The right accessory lobe was formed by the first bronchiole of the ventral bronchiole system. The remaining bronchioles of the four bronchiole systems constituted the right caudal lobe. In the left lung, the cranial and accessory lobes were absent. The left middle lobe was formed by the first bronchiole of the lateral bronchiole system. This bronchiole was well developed and formed a bilobed middle lobe. The remaining bronchioles constituted the left caudal lobe. The right lung consisted of the cranial, middle, caudal and accessory lobes. The left lung consisted of the middle and caudal lobes. The branches of the pulmonary arteries ran mostly along the dorsal or lateral side of the bronchioles. The pulmonary veins ran the ventral or medial side of the bronchiole, and between the bronchioles.—**KEY WORDS:** blood vessel, bronchial tree, Japanese deer, lobular division, lung.

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Comparative anatomical studies of the lung were initiated by Aeby [1]. He examined the lungs of many mammals including man, and classified the bronchioles into the dorsal and the ventral bronchiole systems. Furthermore, he classified the bronchioles into epiarterial and hyparterial bronchioles according to the course of the pulmonary artery, and considered that the left epiarterial bronchiole, i.e., the left upper lobe bronchiole, is absent in the human lung. Huntington [3] also examined many mammalian lungs and considered that the cranial and middle lobe bronchioles form a common trunk when they arise from the left bronchus. On the other hand, Jackson and Huber [4] divided the human lung into ten pulmonary segments on both sides for convenience of surgery.

In veterinary anatomy, Ellenberger and Baum [2] considered that the left lung of domestic animals except for the horse consists of the apical, cardiac and diaphragmatic lobes. Although this interpretation was widely accepted for many years, Seiferle [7] pointed out that the left cardiac lobe of Ellenberger and Baum [2] is part of the apical lobe. Thus, the way of interpretations of the left lung have differed among authors.

The present author previously examined many mammalian lungs including those of man to establish the fundamental structure of the bronchial ramification of the mammalian lung: the dorsal, ventral, lateral and medial bronchiole systems arise from the dorsal, ventral, lateral and medial sides of both bronchi, respectively. Furthermore, two pairs of bronchioles arise from both sides of the trachea. The cranial lobe bronchioles consist of the first bronchiole of the dorsal bronchiole system (cranial lobe bronchiole I) and the two bronchioles arising from the lateral side of the trachea (cranial lobe bronchioles II

and III). However, the cranial lobe can generally be formed by any one of them. The middle and accessory lobe bronchioles correspond to the first bronchiole of the lateral and ventral bronchiole systems, respectively. The remaining bronchioles of the four bronchiole systems constitute the caudal lobe [5, 6]. In the present study, the bronchial tree, lobular division and blood vessels of the Japanese deer lung were examined on the basis of above-mentioned theory of the present author.

MATERIALS AND METHODS

The lungs of three female Japanese deer (*Cervus nippon*) were used. Two of the deer were found dead at Nikko, Tochigi prefecture, and the remaining one was found dead at Tanzawa, Kanagawa prefecture. These lungs were injected with celluloid solutions of various colors into the bronchial tree and blood vessels through the trachea and heart with a metal syringe. Then they were placed in water until the celluloid solutions coagulated completely. Finally they were treated with hydrochloric acid to remove the soft tissues and washed in running water to obtain the lung models.

RESULTS

Bronchial ramifications and lobular division (Figs. 1–4): The right cranial lobe bronchiole III arose from the right side of the trachea, namely the tracheal bronchus (bronchiole). This bronchiole divided into cranial (a) and caudal (b) branches, the former being more developed than the latter. Shallow fissures were observed on the cranial and caudal margins of the right cranial lobe (Fig. 3). The right cranial lobe was separated from the right



Fig. 1. Celluloid cast model of Japanese deer lung. A: Dorsal aspect B: Ventral aspect. Bar = 3 cm.

Fig. 2. Ventral aspect of the bronchial tree of the Japanese deer lung.

Fig. 3. Lateral aspect of the right lung with the bronchial tree.

Fig. 4. Lateral aspect of the left lung with the bronchial tree.

Fig. 5. Dorsal aspect of the bronchial tree and blood vessels of the lung.

Fig. 6. Ventral aspect of the bronchial tree and blood vessels of the lung.

Abbreviations

Figs. 2-4:

D — dorsal bronchiole system

L — lateral bronchiole system

V — ventral bronchiole system

M — medial bronchiole system

III(D) — cranial lobe bronchiole

L₁ — middle lobe bronchiole

V₁ — accessory lobe bronchiole

The remaining bronchioles of the four bronchiole systems constitute the caudal lobe.

Figs. 5, 6:

1 — right pulmonary artery

2 — right cranial lobe artery

3 — right middle lobe artery

4 — right accessory lobe artery

5 — right cranial lobe vein

6 — right middle lobe vein

7 — right accessory lobe vein

8 — right caudal lobe pulmonary venous trunk

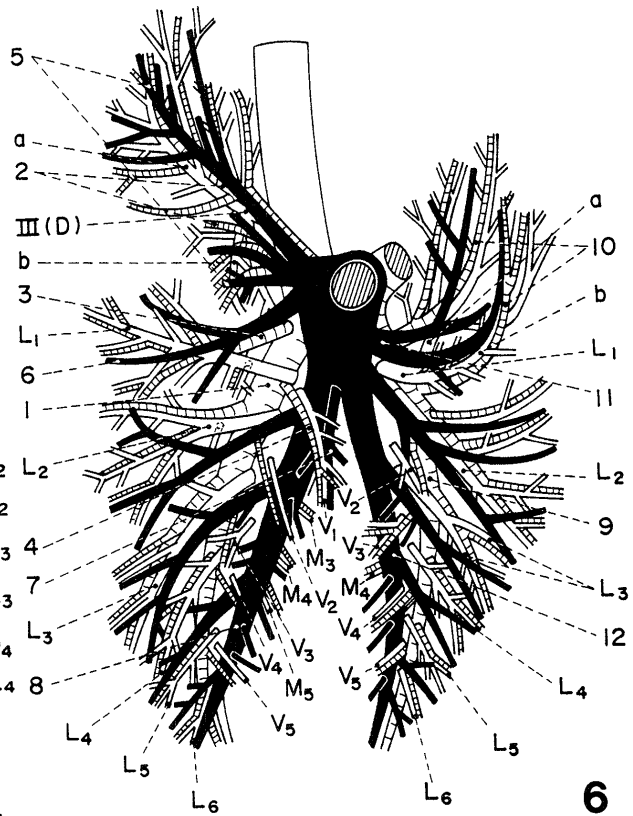
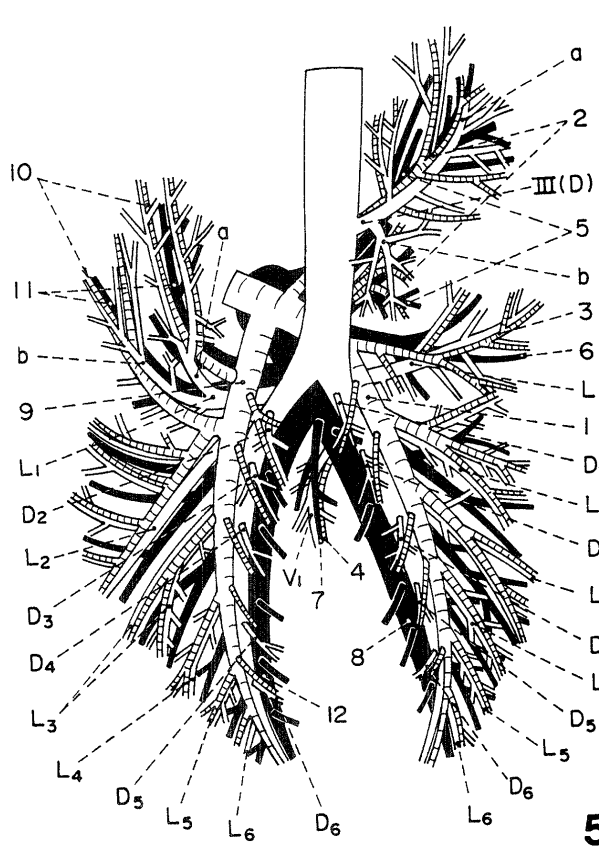
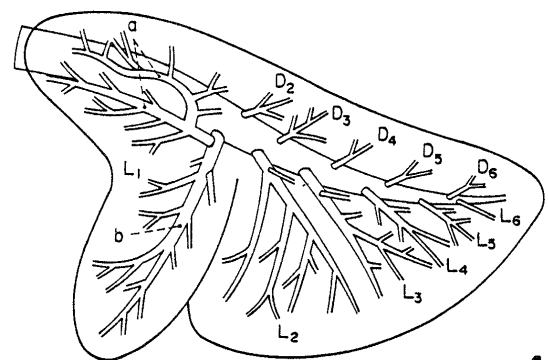
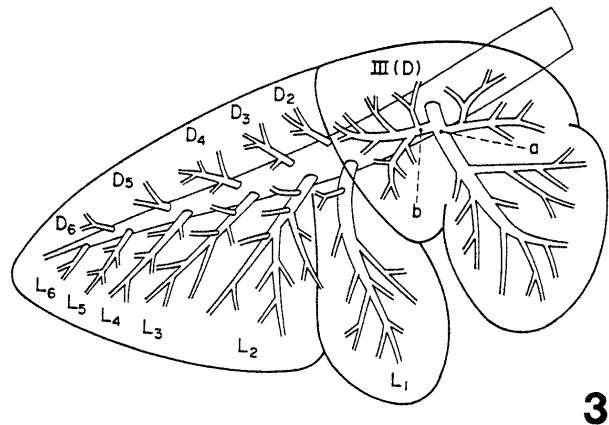
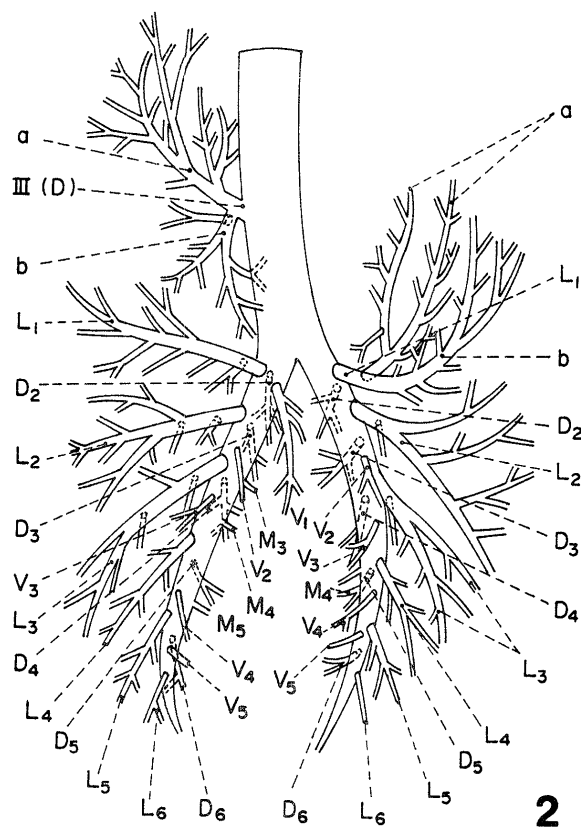
9 — left pulmonary artery

10 — left middle lobe artery

11 — left middle lobe vein

12 — left caudal lobe pulmonary venous trunk

The other arteries and veins are distributed in the caudal lobe.



middle and caudal lobes by a fissure, except in the deep portions. The right middle lobe bronchiole corresponded to the first bronchiole (L_1) of the lateral bronchiole system. This bronchiole arose from the ventrolateral side of the right bronchus and extended in a ventral direction. The dorsal portion of the right middle lobe was united with the right caudal lobe. The right accessory lobe bronchiole corresponded to the first bronchiole (V_1) of the ventral bronchiole system. This bronchiole arose from the ventromedial side of the right bronchus and formed an independent lobe. The remaining bronchioles of the dorsal, lateral and ventral bronchiole systems and all bronchioles of the medial bronchiole system constituted the right caudal lobe. The lateral bronchiole system was well developed and had the second (L_2) to sixth (L_6) bronchioles. The dorsal bronchiole system also had the second (D_2) to sixth (D_6) bronchioles. The ventral bronchiole system had the second (V_2), fourth (V_4) and fifth (V_5) bronchioles. The medial bronchiole system had the third (M_3) to fifth (M_5) bronchioles.

In the left lung, the cranial lobe bronchioles were absent (Figs. 2, 4). The left middle lobe bronchiole corresponded to the first bronchiole (L_1) of the lateral bronchiole system. It arose from the ventrolateral side of the left bronchus and divided immediately into cranial (a) and caudal (b) branches. Each branch formed a lobule (Fig. 4), and together constituted the left middle lobe. The dorsocaudal portion of the left middle lobe was united with the left caudal lobe. The left accessory lobe bronchiole, namely the first bronchiole (V_1) of the ventral bronchiole system, was absent. The remaining bronchioles of the lateral bronchiole system and all bronchioles of the dorsal, ventral and medial bronchiole systems constituted the left caudal lobe. In the left caudal lobe, the lateral bronchiole system was the most developed and had the second (L_2) to sixth (L_6) bronchioles. The dorsal bronchiole system also had the second (D_2) to sixth (D_6) bronchioles. In the ventral bronchiole system, the second (V_2) to fifth (V_5) bronchioles were recognized. The medial bronchiole system had only the fourth bronchiole (M_4).

Relationships between the pulmonary artery and the bronchial tree (Figs. 5, 6): The right pulmonary artery ran obliquely across the ventral side of the trachea at the caudal portion of the origin of the right cranial lobe bronchiole III, and then across the dorsal side of the right middle lobe bronchiole. Thereafter, it ran along the dorsolateral side of the right bronchus between the dorsal (D) and the lateral (L) bronchiole systems.

The right cranial lobe artery arose from the lateral side of the right pulmonary artery with two branches. The first branch was large and ran obliquely across the ventral side of the trachea and along the medial side of the cranial branch (a) in the first, and then along the dorsal or lateral side of the bronchioles. The second branch was small and ran along the medial side of the caudal branch (b). The right middle lobe artery arose from the ventrolateral side of the right pulmonary artery and along the lateral side of the right middle lobe bronchiole. The right accessory lobe

artery arose from the ventromedial side of the right pulmonary artery and ran along the ventral side of the accessory lobe bronchiole (Fig. 6). In the right caudal lobe, the right pulmonary artery gave off arterial branches running along each bronchiole. In the dorsal bronchiole system, arterial branches arose from the dorsomedial side of the right pulmonary artery and ran along the dorsal side of each bronchiole. In the lateral bronchiole system (L), arterial branches arose from the ventrolateral side of the right pulmonary artery and ran along the craniolateral side of each bronchiole. In the ventral bronchiole system (V), arterial branches arose from the ventromedial side of the right pulmonary artery and ran along the ventral side of each bronchiole. However, in the third bronchiole (V_3) of the ventral bronchiole system, an arterial branch ran along the dorsal side of the bronchiole. In the medial bronchiole system (M), arterial branches arose from the medial side of the right pulmonary artery and ran across the dorsal side of the right bronchus and then along the dorsal side of each bronchiole.

In the left lung, the left pulmonary artery ran across the dorsal side of the left middle lobe bronchiole and then along the dorsolateral side of the left bronchus between the dorsal (D) and the lateral (L) bronchiole systems, as in the right lung.

The left middle lobe artery had two branches. The first branch arose from the dorsolateral side of the left pulmonary artery and along the medial side of the cranial branch (a). The second branch arose from the ventrolateral side of the left pulmonary artery and formed a short common trunk with the arterial branch running along the craniolateral side of the second bronchiole (L_2) of the lateral bronchiole system. It continued to run along the caudolateral side of the caudal branch (b) in the first and then gradually came to run along the medial side of the bronchiole. In the left caudal lobe, the distribution patterns of the pulmonary artery and its branches were the same as those in the right caudal lobe.

Relationships between the pulmonary vein and the bronchial tree (Figs. 5, 6): The right cranial lobe vein arose as small veins from both areas of the cranial (a) and caudal (b) branches. In the area of the cranial branch (a), these veins became confluent to form a trunk, which ran along the medial side of the bronchiole. In the area of the caudal branch (b), the small veins became confluent to form three veins, which then formed a short common trunk. These 2 trunks originating from the both areas of the cranial (a) and caudal (b) branches constituted the right cranial lobe vein. The right middle lobe vein ran along the medial side of the right middle lobe bronchiole and formed a trunk of the right middle lobe vein. This and the former two trunks made contact with each other before they entered the left atrium (Fig. 6). The right accessory lobe vein ran along the dorsal side of the right accessory lobe bronchiole and joined at the root of the right caudal lobe pulmonary venous trunk, which ran along the ventromedial side of the right bronchus between the medial (M) and the ventral (V) bronchiole systems. In the right caudal lobe, there

were two kinds of veins in the area of the lateral bronchiole system (L). One arose from the pulmonary segments, and the other ran between them. The former joined the latter and entered the right caudal lobe pulmonary venous trunk. In the dorsal bronchiole system (D), each vein ran between the pulmonary segments and entered the dorsal side of the right caudal lobe pulmonary venous trunk. In the medial bronchiole system (M), pulmonary veins ran between the pulmonary segments and entered the right caudal lobe pulmonary venous trunk. In the ventral bronchiole system (V), the blood drained through the veins which ran between the pulmonary segments or neighbouring small veins, and finally entered the right caudal lobe pulmonary venous trunk directly, or by way of neighbouring large veins.

The left middle lobe vein arose as small veins from the areas of the cranial (a) and caudal (b) branches. They formed large veins running along the medial side of each bronchiole. They became confluent to form a short common trunk, namely the trunk of the left middle lobe vein, and entered the left atrium. In the left caudal lobe, the distribution patterns of the pulmonary veins were the same as those in the right caudal lobe.

DISCUSSION

The anatomical terms used in this report, i.e., the cranial lobe, middle lobe, caudal lobe and accessory lobe, correspond to the upper lobe, middle lobe, lower lobe and medial basal segment (S⁷) in the human lung, respectively. However, in the human left lung, upper lobe and the medial basal segment (S⁷) are absent, and the left upper lobe should be called the left middle lobe from the viewpoint of the comparative anatomy [5, 6]. The term bronchiole corresponds to a lobar bronchus arising from the right and left bronchi, or a segmental bronchus arising from the caudal bronchi.

The left middle lobe bronchiole of the Japanese deer, as designated in this paper, is divided into cranial (a) and caudal (b) branches, each of which forms a lobule corresponding to the left apical and the cardiac lobes of the cow defined by Ellenberger and Baum [2], respectively. They also correspond to the left apical lobe of the cow as defined by Seiferle [7].

However, the right cranial lobe bronchiole of the Japanese deer corresponds to the right cranial lobe bronchiole III in the fundamental structure of the bronchial ramification of the mammalian lung [5, 6]. This bronchiole arises from the right side of the trachea. The right cranial lobe bronchioles I and II are absent in the Japanese deer. However, the right cranial lobe bronchiole II arising from the right side of the trachea is found in the lung of the cow as a variation [6]. The right cranial lobe bronchiole I is found in the lungs of various mammals including dog, cat, horse and man. It arises from the dorsolateral side of the right bronchus as the first bronchiole (D₁) of the dorsal bronchiole system [5, 6]. These three kinds of cranial lobe bronchioles were the

epiarterial bronchioles, because they were situated on the cranial side of the right pulmonary artery. On the other hand, the right middle lobe bronchiole was the first bronchiole (L₁) of the lateral bronchiole system, and arose from the ventrolateral side of the right bronchus. It was one of the hypoarterial bronchioles, because it was situated on the caudal side of the right pulmonary artery. In this way, the right cranial and right middle lobe bronchioles arose at completely different positions, and different relationships to the pulmonary artery and differed in their bronchiole systems.

The left middle lobe bronchiole, as designated in the present study, arose from the ventrolateral side of the left bronchus as the first bronchiole (L₁) of the lateral bronchiole system, and was one of the hypoarterial bronchioles. This bronchiole arose at the same level as the right middle lobe bronchiole. Therefore, the left middle lobe bronchiole, as defined by the author, corresponded to the right middle lobe, but not to any of the right cranial lobe bronchioles. These findings suggest that the left lung consists of the middle and caudal lobes in the Japanese deer.

In the Japanese deer lung, four bronchiole systems were clearly recognized. These bronchiole systems were identified more clearly when the pulmonary artery and the caudal lobe pulmonary venous trunk were taken into consideration. The dorsal (D) and the lateral (L) bronchiole systems were clearly separated by the pulmonary artery. The medial (M) and the ventral (V) bronchiole systems were also clearly separated by the caudal lobe pulmonary venous trunk.

The tracheal bronchus (bronchiole) has been observed not only in the Japanese deer lung, but also in the lungs of the cow, goat and pig. Some authors maintain that these bronchioles represent the cranial transition of the general cranial lobe bronchiole (cranial lobe bronchiole I). However, the present author considers that they are derived from the most cranial bronchiole segment of the trachea.

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