The Bronchial Tree, Lobular Division and Blood Vessels of the Masked Palm Civet (Paguma larvata) Lung

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ABSTRACT. The right lung of the masked palm civet (Paguma larvata) consists of the cranial, middle, caudal and accessory lobes. The left lung has no cranial and accessory lobes and has a bilobed middle and caudal lobes. On either side, there are four bronchiole systems, i.e. dorsal, lateral, ventral and medial. The right cranial lobe is formed by the first bronchiole of the dorsal bronchiole system. However, this bronchiole arises from the right lateral side of the trachea, the so-called tracheal bronchus (bronchiole). The right middle lobe is formed by the first bronchiole of the lateral bronchiole system, and the right accessory lobe is formed by the first bronchiole of the ventral bronchiole system. The remaining bronchi (the dorsal, lateral and ventral bronchiole systems and a bronchiole of the medial bronchiole system) constitute the right caudal lobe. In the left lung, the left middle lobe is formed by the first bronchiole of the lateral bronchiole system. This bronchiole divides into two branches, each of which forms a lobe. The remaining bronchi constitute the left caudal lobe as in the right lung. The branches of pulmonary arteries mostly run along the dorsal or lateral side of bronchi (the pulmonary veins run the ventral or medial side of bronchi and between the bronchi).—KEY WORDS: bronchiole system, lobular division, lung, masked palm civet.

Anatomy of the lung involves a complicated problem in interpretation of the left lung, particularly of the left cranial lobe. Regarding the lungs of many mammals including man, Böhn [1] classified the bronchioles into the dorsal and ventral bronchiole systems, and further classified them into the epiarterial and the hypoarterial, according to the location of the pulmonary artery. He suggested a lack of the left epiarterial bronchiole, i.e. the left upper lobe bronchiole in the human lung. Huntington [3], by his examination of many mammalian lungs, considered that the left cranial and middle lobe bronchioles have a common trunk from the left bronchus. Jackson and Huber [4] divided the human lung into ten pulmonary segments on either side for the convenience of surgery. This has been widely accepted in human anatomy because of its practicability.

On the other hand, in veterinary anatomy, Ellenberger and Baum [2] considered that the left lung of the cow, pig and dog consists of the apical, cardiac and diaphragmatic lobes. This lobular division was accepted for many years. However, Seiferle [8] considered that the left cranial lobe described by Ellenberger and Baum [2] should be in fact a part of the apical lobe. Thus the way of interpretation of the left lung differs among authors.

Therefore, the present author has so far studied the lungs of variety of mammalian species including man to establish the fundamental structure of the bronchial ramification. As a result, the following general concept has been obtained: The dorsal, lateral, ventral and medial bronchiole systems arise from the dorsal, lateral, ventral and medial sides of the bronchus on either side, respectively. Furthermore, two pairs of bronchi arise from the lateral sides of the trachea. The cranial lobe bronchi consist of the first bronchiole of the dorsal bronchiole system (cranial lobe bronchiole I) and the two bronchi arising from the lateral side of the trachea (cranial lobe bronchioles II and III). Thus, three kinds of cranial lobe bronchi can be enumerated. The middle lobe bronchiole is the first bronchiole of the ventral bronchiole system. The accessory lobe bronchiole is the first bronchiole of the ventral bronchiole system. The remaining bronchi of the dorsal, lateral and ventral bronchiole systems and all bronchi of the medial bronchiole system constitute the caudal lobe [5, 6].

The present paper describes the lung of the masked palm civet from the view point of comparative anatomy based on the foregoing concept of the present author.

MATERIALS AND METHODS

The lungs of five masked palm civets were used. Celluloid solutions with different colors were injected into the bronchial tree through the trachea and into blood vessels through the heart. After injection, the lungs were placed in water until the injected materials coagulated completely. Then the soft tissues were macerated with hydrochloric acid (HCl) to obtain the lung models by washing in running water (Fig. 1).

RESULTS

Bronchial ramifications (Figs. 2–4): In the lung of the masked palm civet, the dorsal bronchiole system (D), lateral bronchiole system (L), ventral bronchiole system (V) and medial bronchiole system (M) arise from the dorsal, lateral, ventral and medial sides of the bronchus on either side, respectively.

In the right lung, the cranial lobe bronchiole arises from
Fig. 1. Celluloid cast model of a masked palm civet lung. A: Dorsal aspect. B: Ventral aspect.

Fig. 2. Schematic representation of the bronchial tree of the masked palm civet lung. Ventral aspect.
Fig. 3. Right lung. Lateral aspect.
Fig. 4. Left lung. Lateral aspect.
Fig. 5. Bronchial tree and blood vessels of the lung. Dorsal aspect.
Fig. 6. Bronchial tree and blood vessels of the lung. Ventral aspect.

Abbreviations
Figs. 2–4:
D — dorsal bronchiole system
L — lateral bronchiole system
V — ventral bronchiole system
M — medial bronchiole system
D1 — cranial lobe bronchiole
L1 — middle lobe bronchiole
V1 — accessory lobe bronchiole
The remaining bronchioles 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.
the right lateral side of the trachea, and the most caudal position of the trachea. This bronchiolo corresponds to the first bronchiolo (D₁) of the dorsal bronchiolo system, i.e. the right cranial lobe bronchiolo I, even though it arises from the trachea. This bronchiolo divides immediately into two branches, cranial (a) and caudal (b), the former being more developed than the latter. This bronchiolo forms the right cranial lobe. The right cranial lobe bronchiolos II and III are lacking. The right middle lobe bronchiolo is the first bronchiolo (L₃) of the lateral bronchiolo system. This bronchiolo arises from the ventrolateral side of the right bronchus and forms the right middle lobe. The right accessory lobe bronchiolo is the first bronchiolo (V₁) of the ventral bronchiolo system. This bronchiolo arises from the ventromedial side of the right bronchus and forms the right accessory lobe. The remaining bronchiolos of the dorsal, lateral and ventral bronchiolo systems are not found in the medial bronchiolo system. Therefore, both the dorsal and lateral bronchiolo systems have the second to the fifth bronchiolos (D₂–D₅, L₂–L₅, and L₆–L₇, respectively). The ventral bronchiolo system has the second (V₂) and the third (V₃) bronchiolos, and the medial bronchiolo system has the fourth bronchiolo (M₄) only.

In the left lung, the cranial and accessory lobe bronchiolos are lacking (Fig. 1). The left middle lobe bronchiolo, i.e. the first bronchiolo (L₃) of the lateral bronchiolo system, arises from the ventrolateral side of the left bronchus and divides into two branches, cranial (a) and caudal (b). The former branch being more developed than the latter. Each branch forms a lobule. The two lobules thus constitute the left middle lobe by being united at their dorsal portions. The position of origin of the left middle lobe bronchiolo is somewhat more cranial than that of the right middle lobe bronchiolo. The remaining bronchiolos of the lateral bronchiolo system and all bronchiolos of the dorsal, ventral and medial bronchiolo systems constitute the left caudal lobe. The dorsal and lateral bronchiolo systems have the second to the sixth bronchiolos (D₂–D₆, and L₂–L₆, respectively). The ventral bronchiolo system has the third (V₃), the fourth (V₄), and the third bronchiolo, and the medial bronchiolo system has the fifth bronchiolo (M₅) only. Thus, the bronchiolos are arranged stereotaxically.

Distribution of the pulmonary artery (Figs. 5, 6): The right pulmonary artery runs across the ventral side of the right cranial lobe bronchiolo, and then across the dorsal side of the right middle lobe bronchiolo. Therefore, the right cranial lobe bronchiolo is an epiarterial bronchiolo, and the right middle lobe bronchiolo is a hypoarterial bronchiolo. Thereafter, the right pulmonary artery runs along the dorsolateral side of the right bronchus, between the dorsal bronchiolo system (D) and the lateral bronchiolo system (L), and gradually comes to run along the dorsal side of the right bronchus. Thus, the dorsal bronchiolo system (D) and the lateral bronchiolo system (L) can be discriminated clearly.

The right cranial lobe artery arises from the lateral side of the right pulmonary artery, and immediately divides into two branches. These branches run along the lateral side of the cranial (a) and caudal (b) branches of the right cranial lobe bronchiolo, respectively. However, in the first side branch arising from the ventral side of cranial branch (a), a branch of the right cranial lobe artery runs along the medial side of it. The right middle lobe artery arises from the ventrolateral side of the right pulmonary artery and runs along the caudalateral side of the right middle lobe bronchiolo. The right accessory lobe artery arises from the ventromedial side of the right pulmonary artery and runs along the ventrolateral side of the right accessory lobe bronchiolo. In the right caudal lobe, arterial branches run along the lateral side of each bronchiolo in the lateral bronchiolo system. The arterial branches run along the dorsal side of the second bronchiolo (D₂) of the dorsal bronchiolo system, whereas in the other bronchiolo systems of the dorsal bronchiolo system, arterial branches run along the ventral side of the bronchiolo. In the ventral bronchiolo system, arterial branches run along the ventral side of each bronchiolo. In the medial bronchiolo system, an arterial branch arises from the medial side of the right pulmonary artery and runs along the dorsal side of the bronchiolo after running across the dorsal side of the right bronchus.

In the left lung, the left pulmonary artery runs across the dorsal side of the left middle lobe bronchiolo. Therefore, the left middle lobe bronchiolo is a hypoarterial bronchiolo. Then the left pulmonary artery runs along the dorsolateral side of the left bronchus, between the dorsal bronchiolo system (D) and the lateral bronchiolo system (L)

The left middle lobe artery has four branches, three of which arise from the dorsolateral side of the left pulmonary artery and run along the lateral side of the cranial branch (a). The remaining one arises from the ventrolateral side of the left pulmonary artery and runs along the caudalateral side of the caudal branch (b). In the caudal lobe, the distributional patterns of the pulmonary artery are the same as in the right caudal lobe.

Distribution of the pulmonary vein (Figs. 5, 6): The right cranial lobe vein runs along the medial side of the right cranial lobe bronchiolo. This vein makes a contact with the right middle lobe vein, which runs along the cranomedial side of the right middle lobe bronchiolo before entering the left atrium. The right accessory lobe vein runs along the dorsal side of the right accessory lobe bronchiolo and enters the right caudal lobe pulmonary venous trunk. In the right caudal lobe, the right caudal lobe pulmonary venous trunk runs along the ventromedial side of the right bronchus, and between the medial bronchiolo system (M) and the ventral bronchiolo system (V). Therefore, these two bronchiolo systems can be easily distinguished. In the dorsal bronchiolo system, pulmonary veins run along the cranomedial side of each bronchiolo. In the lateral bronchiolo system, pulmonary veins run along the ventral side of the bronchiolo. In the ventral bronchiolo system, pulmonary veins run along the dorsal side of each bronchiolo. In the medial bronchiolo system, a pulmonary
vein runs along the ventral side of the bronchiole. These pulmonary veins enter the right caudal lobe pulmonary venous trunk as a single branch or forming a common trunk.

In the left lung, the left middle lobe vein runs along the medial side of the cranial branch (a), while in the caudal branch (b), it runs along the cranio medial side of the bronchiole. These veins form a short common trunk before entering the left atrium.

In the left caudal lobe, the distributional patterns of the pulmonary veins are the same as in the right caudal lobe.

**DISCUSSION**

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

The right cranial lobe bronchiole of the marked palm civet arises from the right lateral side of the trachea, and the most caudal portion of the trachea. This phenomenon is also observed in the right cranial lobe bronchiole of the lion [7], and there is a tendency to interpret this as the cranial transition of the first bronchiole (D_1) of the dorsal bronchiole system (cranial lobe bronchiole I). However, judging from the positions of origin of the right cranial lobe bronchiole and the other bronchioles, especially the second bronchiole (D_2) of the dorsal bronchiole system, the first bronchiole (L_1) of the lateral bronchiole system and the first bronchiole (V_1) of the ventral bronchiole system, the phenomenon seems to be due to the shallow (caudal) bifurcation of both bronchi. Furthermore, in the domestic cat, the right cranial lobe bronchiole arises from the dorsolateral side of the right bronchus [6]. Therefore, the author considers that the right cranial lobe bronchiole of the masked palm civet is the first bronchiole (D_1) of the dorsal bronchiole system, even though it arises from the trachea, i.e. the tracheal bronchus (bronchiole). However, this bronchiole does not correspond to the right cranial lobe bronchiole, i.e. the tracheal bronchus, in the cow, goat and pig, but to the right cranial lobe bronchiole in the dog. The bronchioles in the cow, goat and pig correspond to the right cranial lobe bronchiole III in the fundamental structure of the mammalian lung and the bronchiole in the dog corresponds to the right cranial lobe bronchiole I [5, 6].

Furthermore, in previous reports, the author already mentioned that the bronchioles arising from the lateral sides of the trachea (cranial lobe bronchioles II and III) probably belong to the dorsal bronchiole system [5, 6]. The right cranial lobe bronchiole of the masked palm civet lung constitutes a good evidence for this mentioning, because it arises from the right lateral side of the trachea, even though it belongs to the dorsal bronchiole system.

The left middle lobe bronchiole, as described by the author, forms two lobules, which correspond to the left apical and cardiac lobes of Ellenberger and Baum [2], respectively. The left middle lobe bronchiole correspond to the first bronchiole (L_1) of the lateral bronchiole system and arise from the ventrolateral side of the left bronchus. This is a hyparterial bronchiole.

On the other hand, the right cranial lobe bronchiole arises from the right lateral side of the trachea and corresponds to the first bronchiole (D_1) of the dorsal bronchiole system. Furthermore, it is an epipartial bronchiole. The right middle lobe bronchioles arises from the ventrolateral side, and is the first bronchiole (L_1) of the lateral bronchiole system. This is also a hyparterial bronchiole. Thus, the cranial lobe bronchiole and the middle lobe bronchiole differ completely in their positions of origin, their bronchiole systems and their relationships to the pulmonary artery. Therefore, the left middle lobe bronchiole, as described by the author, does not correspond to the right cranial lobe bronchiole, but to the right middle lobe bronchiole. Therefore, the author considers that the left lung consists of the middle and caudal lobes. The well developed left middle lobe bronchiole is a compensatory development owing to the absence of the left cranial lobe bronchiole.

Thus, it is concluded that not only external but also internal observation of the bronchial tree and blood vessels in detail is considered to be important for identification of the pulmonary lobes.

**REFERENCES**