Bronchial Tree, Lobular Division and Blood Vessels of the Pig Lung

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ABSTRACT. The pig lung has the dorsal, ventral, medial and lateral bronchiolar systems on either side. In addition, a tracheal bronchiole (bronchus) arises from the right side of the trachea. According to the bronchiolar ramification, the right lung consists of the cranial, middle, caudal and accessory lobes, while the left lung consists of the bilobed middle and caudal lobes. The right and left pulmonary arteries run along the dorsolateral side of the right and left bronchi, respectively. During their course, these pulmonary arteries give off arterial branches running mainly along the dorsal or lateral side of each bronchole. The pulmonary veins run mainly along the medial or ventral side of each bronchiole.---KEY WORDS: bronchial tree, lobular division, pulmonary artery, pulmonary vein, swine.


The left lung is differently interpreted among authors [1, 3, 4], especially with regard to the apical pulmonary lobe. In veterinary anatomy, the lobular division by Ellenberger and Baum [2] was accepted for many years. They distinguished the apical, cardiac, diaphragmatic and intermediate lobes in the right lung, and the apical, cardiac and diaphragmatic lobes in the left lung, except in the horse. However, Seiferle [8] pointed out that the left cardiac lobe of Ellenberger and Baum [2] is a part of the apical lobe. At present in veterinary anatomy, however, the lobes of the right lung are designated the cranial, middle, caudal and accessory lobes, and those of the left lung as the cranial and caudal lobes, except in the horse lung. In this way, the left lung is interpreted differently even in veterinary anatomy. Therefore, the present author examined the lungs of many mammals and proposed the fundamental structure of bronchiolar ramification in the mammalian lung [5, 6]. In the present study, the author examined the pig lung on the basis of this proposal, from the viewpoint of comparative anatomy.

MATERIALS AND METHODS

Thirty-three pig lungs were examined. Twenty-eight specimens were injected with various kinds of colored cellulosid solutions into the bronchial tree and blood vessels through the trachea and heart. Four other specimens were injected into the bronchial tree and pulmonary artery, and the remaining one into only the bronchial tree. After injection, the lungs were immersed in water until the cellulosid had coagulated completely, and then treated with hydrochloric acid to remove the soft tissues. The lung models were obtained after washing in running water (Fig. 1).

RESULTS

Bronchial ramification and lobular division (Figs. 1-4): The pig lung has the dorsal (D), lateral (L), ventral (V) and medial (M) bronchiole systems, and one bronchiole arising from the right side of the trachea. This bronchiole corresponds to the right cranial lobe bronchiole III, the so-called tracheal bronchiole (bronchus). It divides into cranial (a) and caudal (b) branches, the former being better developed than the latter, and forms the right upper lobe. The right upper lobe bronchioles I and II are absent. The right middle lobe bronchiole arises from the ventrolateral side of the right bronchus and extends in a ventrolateral direction. This bronchiole corresponds to the first bronchiole (L₁) of the lateral bronchiole system. Furthermore, a branch arises from the lateral or caudalateral side of this bronchiole, and is comparatively well developed. This bronchiole forms the right middle lobe. The accessory lobe bronchiole arises from the ventromedial side of the right bronchus. This bronchiole is the first bronchiole (V₁) of the ventral bronchiole system and forms the accessory lobe. The remaining bronchioles of the dorsal, lateral and ventral bronchiole systems constitute the right caudal lobe together with bronchioles of the medial bronchiole system. In this lobe, the dorsal bronchiole system has the second (D₂) to sixth (D₆) bronchioles. The lateral bronchiole system also has the second (L₂) to sixth (L₆) bronchioles. Each bronchiole of this system divides into two branches in its distal portion, except for the sixth bronchiole (L₆), the ventral and medial bronchiole systems are poorly developed and often lack some bronchioles. The ventral bronchiole system has the second (V₂) to fifth (V₅) bronchioles, while the medial bronchiole system has only the fourth bronchiole (M₄). Thus, the right lung consists of the cranial, middle, caudal and accessory lobes. These lobes are united at their dorsal portions except for the accessory lobe, and display a deep cardiac notch between the cranial and middle lobes and an incomplete interlobular fissure between the middle and caudal lobes, respectively (Figs. 2, 3).

In the left lung, the cranial lobe bronchioles I to III are absent (Figs. 2, 4). The left middle lobe bronchiole arises from the ventrolateral side of the left bronchus. This bronchiole corresponds to the first bronchiole (L₁) of the lateral bronchiole system, and divides into cranial (a) and
caudal (b) branches. They are well developed and form lobules. These lobules are united at their dorsal portions and constitute the left middle lobe. A deep cardiac notch is present in the craniocaudal portion of this lobe. The remaining bronchioles of the lateral bronchiole system constitute the left caudal lobe together with bronchioles of the dorsal, ventral and medial bronchiole systems. The dorsal bronchiole system has the second (D₂) to seventh (D₇) bronchioles. The lateral bronchiole system has the second (L₂) to sixth (L₆) bronchioles. In general, each bronchiole of this system divides into two branches in the distal portion except for the fifth bronchiole (L₅). The ventral bronchiole system has the second (V₂) to fifth (V₅) bronchioles, and the medial bronchiole system has the fourth (M₄) and fifth (M₅) bronchioles (Fig. 2). Accordingly, the left lung consists of the bilobed middle and the caudal lobes. These lobes are united with each other, and show an incomplete interlobular fissure between them (Fig. 4).

**Distribution of the pulmonary artery (Figs. 5, 6):** The right pulmonary artery runs obliquely across the ventral side of the trachea caudally to the origin of the right cranial lobe bronchiole III, and then across the dorsal side of the right middle lobe bronchiole. Thereafter, it runs between the dorsal (D) and the lateral (L) bronchiole systems along the dorsolateral side of the right bronchus. During its course, it gives off branches running along each bronchiole (Figs. 5, 6).

The right cranial lobe artery arises from the cranioventral side of the right pulmonary artery and divides into two branches. One runs along the dorsomedial side of the cranial branch (a) of the cranial lobe bronchiole, and the other along the ventral side of the caudal branch (b) of the cranial lobe bronchiole. The right middle lobe artery arises from the ventrolateral side of the right pulmonary artery and runs along the caudolateral side of the right middle lobe bronchiole. The right accessory lobe artery arises from the ventromedial side of the right pulmonary artery and runs along the ventral side of the accessory lobe bronchiole (Fig. 6). In the dorsal bronchiole system (D) of the right caudal lobe, branches of the pulmonary artery arise from the dorsal or dorsomedial side of the right pulmonary artery and run along the dorsal or dorsolateral side of each bronchiole. In the lateral bronchiole system (L), branches of the pulmonary artery arise from the ventrolateral side of the right pulmonary artery and run along the cranioventral side of each bronchiole (Figs. 5, 6). In the ventral bronchiole system (V), branches of the pulmonary artery arise from the ventromedial side of the right pulmonary artery and run along the ventral side of each bronchiole (Fig. 6). In the medial bronchiole system (M), a branch of the pulmonary artery arises from the...
Fig. 2. Ventral aspect of the bronchial tree of the pig lung.

Fig. 3. Lateral aspect of the right lung.

Fig. 4. Lateral aspect of the left lung.

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

Fig. 6. Ventral aspect of the bronchial tree and blood vessels.
Abbreviations
Figs. 2–6:
D—dorsal bronchiolar system
L—lateral bronchiolar system
V—ventral bronchiolar system
M—medial bronchiolar system
III—cranial lobe bronchiolar III
L—middle lobe bronchiolar
V—accessory lobe bronchiolar
The remaining bronchioli of the four bronchiolar systems constitute the caudal lobe.
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.
R.P.A.—right pulmonary artery
L.P.A.—left pulmonary artery

medial side of the right pulmonary artery and runs along the dorsal side of the bronchiolus after running across the dorsal side of the right bronchiolus (Fig. 5).

The left pulmonary artery runs across the dorsal side of the left middle lobe bronchiolus. Then it runs between the dorsal (D) and the lateral (L) bronchiolar systems along the dorsolateral side of the left bronchiolus.

The left middle lobe artery arises from the left pulmonary artery with two branches. The first branch arises from the dorsolateral side of the left pulmonary artery and runs along the dorsomedial side of the cranial branch (a) of the left middle lobe bronchiolus. The second branch arises from the ventrolateral side of the left pulmonary artery and runs along the caudolateral side of the caudal branch (b) of the left middle lobe bronchiolus. In the left caudal lobe, the distribution patterns of the pulmonary artery and its branches are the same as those in the right caudal lobe (Figs. 5, 6).

Distribution of the pulmonary vein (Figs. 5, 6): The right cranial lobe vein arises from areas of the cranial (a) and caudal (b) branches of the right cranial lobe bronchiolus. These branches run along the ventromedial side of each branch, respectively, and finally form a short common trunk, i.e. the trunk of the right cranial lobe vein. The right middle lobe vein arises from the area of the right middle lobe and forms a main trunk running along the craniodorsal side of the right middle lobe bronchiolus. In addition, it gives off small veins from its caudal portion to form a vein running obliquely across the lateral side of the right middle lobe bronchiolus and artery (Fig. 5). This vein enters the left atrium together with trunks of the right upper lobe vein and the right middle lobe vein. The distribution patterns of these veins are variable. The right accessory lobe vein arises from the area of the right accessory lobe, runs along the dorsal side of the right accessory lobe bronchiolus and enters the ventromedial side of the root of the right caudal lobe pulmonary venous trunk. In the lateral bronchiolar system (L) of the right caudal lobe, pulmonary veins run along the caudodorsal side of the bronchiolus and enter the right caudal lobe pulmonary venous trunk. In the dorsal bronchiolar system (D), pulmonary veins run along the ventral side of each bronchiolus and enter the dorsal side of the right caudal lobe pulmonary venous trunk. In the ventral bronchiolar system (V), pulmonary veins run along the dorsal side of each bronchiolus and enter the ventral side of the right caudal lobe pulmonary venous trunk. In the caudal bronchiolar system (M), the pulmonary vein runs along the ventral side of the bronchiolus and enters the medial side of the right caudal lobe pulmonary venous trunk (Fig. 5).

The left middle lobe vein arises from areas of the cranial (a) and caudal (b) branches of the left middle lobe bronchiolus. In the area of the cranial branch (a), pulmonary veins run along the ventromedial side of the bronchiolus, whereas they run along the craniodorsal side of the bronchiolus in the area of the caudal branch (b). These veins form the trunk of the left middle lobe vein, which enters the left atrium (Figs. 5, 6). In the left caudal lobe, the distribution patterns of the pulmonary veins are the same as those in the right caudal lobe.

DISCUSSION

The present author has used the term “bronchiolus” in the present and previous reports to discriminate each
bronchus arising from the right and left bronchi from the right and left bronchi themselves. Therefore, the term bronchiole corresponds to a lobar bronchus arising from the right and left bronchus or a segmental bronchus arising from the caudal lobe bronchi in veterinary anatomy.

In most mammalian, both the right and left lungs are divided into several lobes. In some mammals, however, these lobes are united to form a single larger lobe on one or each side. Therefore, the present author considered divided lobes to be sub-lobes, and has used the term lobular division.

The bronchial ramification and the distribution of the pulmonary artery and vein in the pig are similar to those in the Japanese deer [7]. The areas of the cranial (a) and caudal (b) branches of the right cranial lobe bronchiole of the pig correspond to the cranial and caudal parts of the right cranial lobe of the cow, respectively.

In the present study, the right cranial lobe bronchiole of the pig arises from the right side of the trachea. This bronchiole corresponds to the right cranial lobe bronchiole III in the fundamental structure of the bronchial ramification of the mammalian lung [5, 6], and is interpreted as the tracheal bronchiole (bronchus). This bronchiole is further considered to be an epiarterial bronchiole, because it is located on the cranial side of the right pulmonary artery. The right middle lobe bronchiole arises from the ventrolateral side of the right bronchus and corresponds to the first bronchiole (L1) of the lateral bronchiole system. This is one of the hypoarterial bronchioles, because it is located on the caudal side of the right pulmonary artery. Thus, the cranial lobe bronchiole and the middle lobe bronchiole differ with each other in their origins, bronchiole systems and relationship to the pulmonary artery.

The interpretations of the left lung differ among authors, especially with regard to the apical pulmonary lobe. Ellenberger and Baum [2] considered the two cranial lobules to be the apical and cardiac lobes, respectively, whereas Seiferle [8] considered both to be the apical lobe. However, the bronchioles forming these two lobules in the pig have a short common trunk and arise from the ventrolateral side of the left bronchus. Judging from its origin, this common trunk corresponds to the first bronchiole (L1) of the lateral bronchiole system in the fundamental structure of the bronchial ramification of the mammalian lung [5, 6]. This bronchiole is further considered to be one of the hypoarterial bronchioles, because it is located on the caudal side of the left pulmonary artery, and originates at the same level as that of the right middle lobe bronchiole. These features are the same as those of the right middle lobe bronchiole. Furthermore, the left lung lacks not only the tracheal bronchiole (cranial lobe bronchioles II and III) but also the first bronchiole (D1) of the dorsal bronchiole system (cranial lobe bronchiole I). Therefore, the present author considers that the bronchiole arising from the most cranial portion of the left bronchus of the pig is the left middle lobe bronchiole. This bronchiole divides into the cranial (a) and caudal (b) branches to form lobules. These lobules correspond to the cranial and caudal parts of the left cranial lobe of the pig, cow and dog, respectively, in veterinary anatomy. The well development of this bronchiole is probably due to compensation for the absence of the left cranial lobe bronchiole.

The four bronchiole systems can be easily discriminated to take into consideration the right and left pulmonary arteries and the right and left caudal lobe pulmonary venous trunks because the former run between the dorsal (D) and lateral (L) bronchiole systems, and the latter between the ventral (V) and medial (M) bronchiole systems. These findings suggest that not only the external features, but also the bronchial ramification and blood vessels are important for identification of lung lobes.

REFERENCES