An Anatomical Study on the Bronchovascular Tree of the Japanese Deer
(Cervus nippon T.)

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ABSTRACT.—The bronchi including their distal airways and the pulmonary arteries were studied with special emphasis on their arborization in relation to the bronchopulmonary segments by the use of acrilyc resin and bronchography in the Japanese deer (Cervus nippon T.).

The right lung was divided into four lobes, a cranial, middle, intermediate and caudal. The left lung was divided into two lobes, a cranial and caudal. The pattern of bronchial tree as well as of bronchopulmonary segments was essentially same as that of other ruminants such as cow, goat and sheep.

The pulmonary arteries maintained a close relationship to the bronchi in such a manner that they followed the bronchial arborization.

Acrilyc resin was considered as an injection material suitable for defining both the bronchial tree and the distal airways.

Introduction

The bronchovascular tree has been observed in various animals from an interspecies comparison including man (Araki, 1958; Boyden, 1969, 1971, 1974), dog (Nishi, 1958), rabbit (Kuno, 1959), kangaroo (Kawakami, 1959), raccoon dog (Iino, 1962), cat (Iwasaki, 1962; Andrian, 1964), fox (Kawagoe, 1962), lion (Kurita, 1962), leopard (Miayasawa, 1962), tiger (Saito, 1962), seal (Sakai, 1962; Hojo, 1975), bear (Takano, 1962), elephant (Ichikawa, 1962) and monkey (Boyden, 1976). As for artiodactyla there are some reports concerning sheep (Hare, 1955- Moriya, 1962), pig (Ichikawa, 1962), camel (Kato, 1962) and goat (Nanda, 1967, 1968). In addition Getty (1975) briefly mentioned the lung of cow, sheep and pig in his textbook. No study, however, seems to have been attempted on the bronchovascular tree of the Japanese deer (Cervus nippon T.).

Furthermore almost above mentioned investigators have relied upon the injection of solution of celluloid or butyl butyrate in aceton, or styrol resin in methyl ethyl keton. These methods, however, have revealed a further difficulty in obtaining good contours of the cast especially in distal airways due to shrinkage at a great rate. Acrilyc resin casting have solved this problem and recently scanning electron microscopy also has been applied to corrosion anatomy.

It is the purpose of this paper to observe the bronchial and pulmonary arterial arrangements as related to broncho-pulmonary segments of the Japanese deer in detail by means of the acrilyc resin injection method.
Materials and Methods

Six adult Japanese deer* were used. Methacrylic methyl ester monomer supplemented with 1% benzoyl peroxide (catalyst) and 15% dibuthyl phthalate (plasticizer) was held at 80°C for 1 hour or more to get high viscosity resin preliminarily polymerized. Before injection 1% dimethyl aniline (accelerator), another 1% benzoyl peroxide and a sprinkling of lead particles were added.

A cannula was put into the trachea without taking the lung out of the cadava. Plastic injection was then continued until the pulmonary acini were completely filled with resin, avoiding excessive filing of the respiratory units. In these specimens resin injection into the lung was limited to about 500 ml. Then another cannula was inserted into the jugular vein and about 100 ml of red resin was injected through the vein and heart into the pulmonary artery.

Before taking out of the cadava to corrode the surrounding tissue in a 20% sodium hydroxide solution, the lung was observed from a bronchographic aspect. For macroscopic observation of the bronchovascular tree, prunning was accomplished by gently pulling away the surplus casts of distal airways with iris forceps after observation of distal airways under a scanning electron microscope (for this technique, see Murakami, 1972).

Whenever possible, the nomenclature used in this study followed the guidelines set forth by Nanda (1967), who modified the recomendation of the Thoracic Society (1950) a little.

Results

Lobes

The right lung of Japanese deer was divided into four lobes by interlobar fissures, namely, the cranial or apical (Lobus cranialis), the middle or cardiac (Lobus medius), the caudal or diafragmatic (Lobus caudalis) and the intermediate (Lobus accessorius). The left lung was divided into two lobes, namely, the cranial and caudal lobes. The right and left cranial lobes were subdivided into cranial and caudal parts.

Bronchial tree

The trachea gave off a tracheal or eparterial bronchus at the level of the second intercostal space, i.e., about 9 cm cranial to its bifurcation (Fig. 1, 5). This lobar bronchus was on the right, ventro-lateral side, and ventilated the right cranial lobe. Soon after its eruption from the trachea running in a caudo-lateral course, the lobar bronchus bifurcated into two segmental bronchi: one bronchus called the cranial segmental bronchus (B1+2) passed ventrally giving off a series of cranio-ventral and caudo-ventral subsegmental bronchi, of which the former were so large that it ran to the bulbous part of the cranial lobe, and all of which became smaller toward the apex of the lobe. The other called the caudal segmental bronchus (B3+4) passed caudally and ran parallel to the trachea, giving off caudo-dorsal and caudo-ventral rows of branches. B1+2 and B3+4 segmental bronchi ventilated the cranial and caudal

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parts of bronchopulmonary segments of the right cranial lobe respectively.

The trachea, then, bifurcated into right and left principal bronchi making an angle of about 60° at the level of the sixth intercostal space. Immediately after its bifurcation the trachea gave off a bronchus from its ventral aspect which ventilated the middle lobe and was called the right middle lobar bronchus (B 5+6) (Figs. 2, 6). This bronchus ran in a ventral direction not to divide into two segmental bronchi like that of goat, but to give off several subsegmental bronchi.

At almost the same level as the middle lobar bronchus erupted, the right principal bronchus gave off the intermediate lobar bronchus from its ventro-medial aspect (Fig. 6). It also divided into two segmental bronchi, i.e., B 7 and B 8, which ventilated the dorsal and ventral segments of the right intermediate lobe respectively, the latter directing the apex of the heart was much larger than the dorsal one and represented the continuation of the lobar bronchus.

After giving off the middle and intermediate lobar bronchi, the principal bronchus was continued caudad as the caudal lobar bronchus. The latter bronchus gave off seven segmental bronchi and three supplementary bronchi around its axis at equal intervals (Figs. 1, 2). It gave off from its dorso-lateral aspect three bronchi, namely, B 9, B 11, and B 13 at the level of the sixth intercostal space, the seventh rib, and the eighth rib respectively (Fig. 1). B 9, B 11, and B 13 ran in a dorsal, lateral and caudal direction and ventilated in sequence, cranial, middle, and caudal dorsal bronchopulmonary segments (Fig. 5).

At almost the same level as B 11 erupted, B 12 arose from its medial aspect and passed caudo-ventral ventilating the medial basal bronchopulmonary segment (Fig. 6). From its ventrolateral aspect at the level of the seventh and eighth rib, the lobar bronchus gave off two segmental bronchi called B 10 and B 14 which ran in a ventral, lateral and caudal direction to ventilate ventral and lateral basal bronchopulmonary segments of the caudal lobe respectively. Furthermore from its dorsomedial aspect of the same level of the dorsal segmental bronchi, B 9, B 11, and B 13, three small supplementary bronchi were given off running in a caudo-medial direction (Fig. 5. arrows). These bronchi could not be observed by way of bronchography, since they overlapped in the dorsal segmental bronchi. After forking of these segmental bronchi, the lobar bronchus, then, continued into the dorsal basal, B 15 segmental bronchus to ventilate the rest of the caudal lobe at the level of the eighth intercostal space. There were two or three subsegmentary bronchi arising from the axis of the lobar bronchus which ventilated small areas in a similar manner to above-mentioned segmental bronchi. The branching angle of the lobar and segmental bronchi from the parental bronchus averaged 60°.

The left principal bronchus gave off two lobar bronchi namely the cranial and caudal lobar bronchi. The former lobar bronchus arose at the level of the sixth intercostal space and immediately bifurcated into two segmental bronchi, i.e., B 1 and B 2 (Figs. 1, 3). B 1 passed cranially and ran parallel to the trachea to the apex of the left lung and ventilated cranial bronchopulmonary segment. B 2 passed ventrally and ventilated caudal segment. The left principal bronchus, then, continued by the caudal lobar bronchus which gave off several segmental bronchi as in the right lung: cranial dorsal (B 3), ventral basal (B 4), medial basal (B 5), lateral basal (B 6), middle dorsal
(B 7), caudal dorsal (B 8) and terminating as the dorsal basal segmental bronchus (B 9) and three supplementary bronchi (Fig. 3). The arrangement of the segmental bronchi was same as in the right lung.

The segmental bronchus gave rise to many subsegmental bronchi around its axis at an angle of about 60° (Fig. 7). The bronchi subsequently divided into smaller branches called the bronchioles. The branching type was so far monopodial making an angle of about 80°. From now on the bronchiole repeated to divide dichotomously into 4 to 6 terminal bronchioles, continuing into two or more respiratory bronchioles (Fig. 8). The respiratory bronchiole ended into clusters of alveolar sacs (Fig. 9).

Pulmonary artery

The pulmonary arteries ran, in general, along the bronchial tree. At the distal portion of the airways the bronchioles and pulmonary arteries maintained throughout a further close relationship. The pulmonary arterial trunk bifurcated into right and left pulmonary arteries at the level of the bifurcation of the trachea. Immediately after the bifurcation, the right pulmonary artery gave off two arteries, namely, A 1+2 and A 3+4 segmental arteries. The former ran forward and turned downward near the eruption of the eparterial bronchus and supplied the B 1+2 of the right cranial lobe. The latter, which was shorter than the former, also ran forward on the medial side of B 3+4 and supplied the segments. The stem of the pulmonary artery, then, passed through the cranial side of B 6 and ran caudad on the dorso-lateral aspect of the principal bronchus between the dorsal segmental bronchi (B 9, B 11, B 13) and ventral segmental bronchi (B 10, B 14). On its course the stem artery gave off arteries to bronchopulmonary segments.

The left pulmonary ran caudad after the bifurcation and immediately gave off an artery, namely, A 1 which supplied B 1 of the left cranial lobe. The stem artery, then, passed through the cranial side of B 2 and continued along the principal bronchus and finally terminated in the distal portion of B 9. On its course it gave off an artery which bifurcated into two arteries, namely, A 2 and A 4 (Fig. 4. arrow). They supplied B 2 and B 4 respectively. From now on the mutual relationship between the segmental bronchi and the pulmonary arteries was same as in the right lung.

Discussion

As above mentioned there are many reports concerning the lung of animals. Above all Hare (sheep), Nanda (goat), Adrian (cat), and Getty (horse, cow, sheep, pig and dog) carried out studies with reference to the bronchopulmonary segments. The segments represent not only an anatomical but also a pathological unit (Kramen and Glass, 1932). The lungs of various animals should be further studied with a segmental anatomical aspect.

Discussion of the bronchial-tree and bronchopulmonary segments in animal lungs is sometimes hampered by no common names for designating animal lungs. Almost all investigators including present authors have been in line with the recomendation of the Thoracic Society (1950) that those terms are specific to man. It should be
remembered that the postural and topographic differences exist between man and animals. For this reason nomenclature acceptable internationally for its use in lungs of animals should be framed as soon as possible.

The lungs of the Japanese deer were described as being subdivided into lobes; the right lung into four lobes named cranial, middle, intermediate, and caudal. Each lobe had several segments: in the right lung, the cranial lobe was divided into cranial and caudal segments, the middle lobe into no segment, the intermediate lobe into dorsal and ventral segments, and the caudal lobe into ventral basal, lateral basal, dorsal basal, medial basal, cranial dorsal, middle dorsal, and caudal dorsal segments. In the left lung, the cranial lobe was divided into cranial and caudal segments, and the caudal lobe was subdivided in a similar manner to the right caudal lobe. The gross segmental distribution of the Japanese deer was essentially that of cow, goat and sheep, but with some exceptions.

It is of interest that left B2 and B4 which arose from different lobar bronchi respectively were supplied with blood from a common artery which arose from the stem of the left pulmonary artery. The characteristics of the segmental arteries may affect to physiology or potential pathology in the segments.

There has been a disagreement in the number of segments in the caudal lobe of both sides. Hare (sheep) and Nanda (goat) regarded six segments, but Getty (cow, sheep) recognized one more segment called the middle dorsal segment between the cranial dorsal and caudal dorsal segments. In the Japanese deer, the middle segmental bronchus was recognized without doubt, then Getty's demarcation is true for the Japanese deer.

In the area called the dorsal basal segment, there were two or three bronchi given off around the axis of the lobar bronchus. They can be recognized as segmental bronchi, however the authors consider them as subsegmental bronchi since it is felt that it is better to keep the description as simple as possible. This demarcation is in line with that of Hare in sheep, Nanda in goat and Getty in cow.

An important result in the present study is to get acryl resin casts of the bronchovascular tree. This technique has an advantage in contrast to previous methods, i.e., all injected structures could be studied. In this study the authors obtained a clear and three-dimensional configuration of the most distal airways under a scanning electron microscope. Furthermore, the authors could get resin casting specimens of the bronchovascular tree fixed in situ. The authors could observe the mutual relationship between the bronchial tree and thorax, and accurate arrangement of the bronchi in the cadava. Previous investigators have observed casting specimens of the lung taken out of the cadava and injected. It should be remembered that distortion of the lung does occur after taking the lung out of the cadava or incising the thoracic wall. The more accurate informations of the bronchial tree arrangement we have, the easier it would become to discuss the dynamics of airflow in the lung.

Observation of the distal airways has been attained by light microscopy of sectioned preparations and by reconstruction (Boyden, 1969, 1971, 1974). These methods which can be studied in relation to intact surrounding tissue, however, have been time-consuming process. The present study suggests that scanning electron microscopy of the cast of the bronchial tree may provide a useful method for the elucidation
of the distal airways. Artefact, such as alveolar saccules “blow-out”, because of their characteristic appearance, was easily recognizable when present but was infrequent in occurrence.

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引用文献

—— 1971. The structure of the pulmonary acinus in a child of six years and eight months. Ibid., 132: 275–300.


Explanation of figures

Plate I.

Fig. 1. Lateral radiograph of the Japanese deer lung. (B2, left caudal segmental bronchi)

Plate II.

Fig. 2. Right lateral view of the bronchial tree.

Fig. 3. Left lateral view of the bronchial tree.

Fig. 4. Left lateral view of the bronchial tree and pulmonary arteies. Left B 1 is removed to show the common trunk (arrow) of A 2 and A 4. (cran. v. c., cranial vena cava: caud. v. c., caudal vena cava: r. vent., right ventricle: pul. tru., pulmonary trunk)

Plate III.

Fig. 5. Dorsal view of the bronchial tree.

Fig. 6. Ventral view of the bronchial tree.

Fig. 7. Subsegmentary bronchi (sub) and bronchioles (br). (seg, segmentary bronchus) × 1.

Fig. 8. Distal airways which correspond to the area indicated by a rectangle in figure 7. × 3.

Fig. 9. Scanning electron micrograph of clusters of alveolar sacculles. ×100.
Plate I.
Plate II.
Plate III.