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Study of gross anatomy and bronchial ramification of lung in pig by corrosion cast technique

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Abstract
The objective of this study is to describe the airway model with bronchial ramification in porcine lung. The lungs of pig were right and left and not uniform in size which was located in the greater part of thoracic cavity. The right and left lungs were divided into lobes by cardiac notch and interlobar fissures. The apical lobe of right lung was larger than the left, undivided and supplied by separate apical bronchus. The right primary bronchus given off five ventro-lateral (RVL_1 to RVL_5), four ventro-medial (RVM_1 to RVM_4), three dorso-medial (RDM_1 to RDM_3) and two dorsal (RD_1 to RD_2) secondary branches and continued as terminal branch for right lung. The left primary bronchi given off secondary bronchi such as five ventro-lateral (LVL_1 to LVL_5), three dorsal (LD_1 to LD_3), two ventro-medial (VM_1 to VM_2) and continued as terminal branch for distribution to different lobes of left lung.

Keywords: Pig, corrosion cast technique, gross anatomy, bronchial ramification

1. Introduction
The anatomical and physiological similarities between the humans and pig provoked the researchers to investigate the animal models for biomedical research and medicine. The mammalian airway consisted of cartilaginous tube which begins from larynx continued by trachea and bronchi which are then divided into several generations of bronchioles and ultimately terminates in air sacs. In the field of respiratory medicine, the animal respiratory model gains more importance to understand the ventilation mechanisms (Judge *et al.*, 2014) [4]. Animals are commonly used in experimental studies which involve lung physiology and bronchial tree architecture. The objective of this study is to describe the airway model with bronchial ramification in porcine lung. It might be useful to study the comparative anatomy of pig lung models to human model in the area of transitional respiratory medicine.

2. Materials and Methods
1. Specimen collection
Three numbers of fresh intact lungs from pig were collected from slaughter house at Department of Meat Science, Veterinary College and Research Institute, Namakkal. The lungs were dissected to remove the adjacent structures, cleaned and washed in normal saline. The gross anatomy of lungs was studied and fixed in 10% neutral buffered formalin.

2. Specimen processing
After fixation, the lungs were removed from fixative, washed in water and dried for few hours. As mentioned by Nakakuki, 1994a [9] in cow, a white silicone resin was infused through the trachea into all the airways by using silicone gun and the lungs were hanged for three days for curing of silicone resin. The cured lungs were allowed for maceration by adding potassium hydroxide to the water to decompose the soft tissues and washed in running tap water. The obtained silicone model of lung was used to study the bronchial ramification pattern in pig.

3. Results and Discussion
1. Gross anatomy
The lungs of pig were right and left and not uniform in size, the right was little larger than the left which was located in the greater part of thoracic cavity. The lateral surface of the lung was convex and located against the lateral wall of the thorax and had impressions of ribs. The mediastinal surface was irregular and had cardiac impression in front and root of the lung behind. The mediastinal surface also showed impression for esophagus and aorta above and behind the root of the left lung. The dorsal border was long, thick and rounded whereas the ventral border

was thin and short. These findings were in accordance to the Sisson, 1961 [13] in gross morphology of pig lung. The lobulations on the surface of the lungs were distinct. The base of the lung was concave which lies against the thoracic aspect of the diaphragm. The apex of the lung was prismatic and narrow which formed the cranial pole of lobe (Dyce *et al.*, 1996) [3].

The right and left lungs were divided into lobes by cardiac notch and interlobar fissures. The left lung was divided by a cardiac notch and a fissure into three lobes such as apical, cardiac and diaphragmatic lobes. The right lung was divided into three lobes such as apical, cardiac and diaphragmatic by two fissures (Fig.1) and had accessory lobe on its mediastinal aspect (Fig. 2). The apical lobe of right lung was larger than the left and it was undivided. The apical and cardiac lobes appeared equal in size on the left lung. A separate bronchus arose at the level of 3rd rib from right wall of trachea supplied to right apical lobe and subsequently at the level of 5th rib the trachea was bifurcated into two primary bronchi (Nickel *et al.*, 1979) [11].

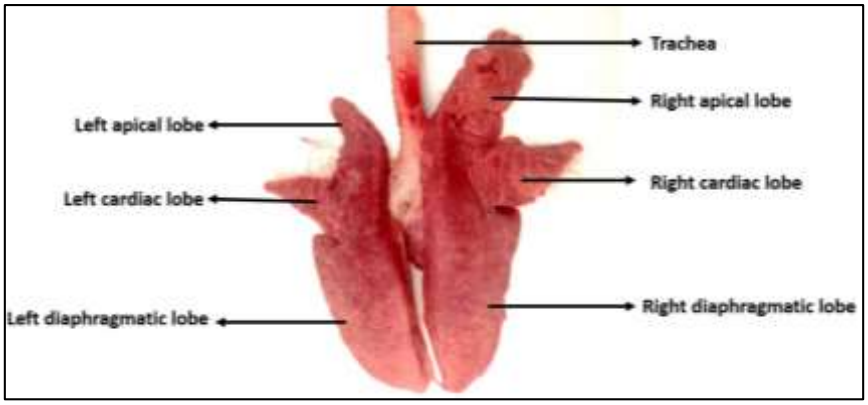

Fig 1: Photograph of pig lung illustrating the different lung lobes (Dorsal view)

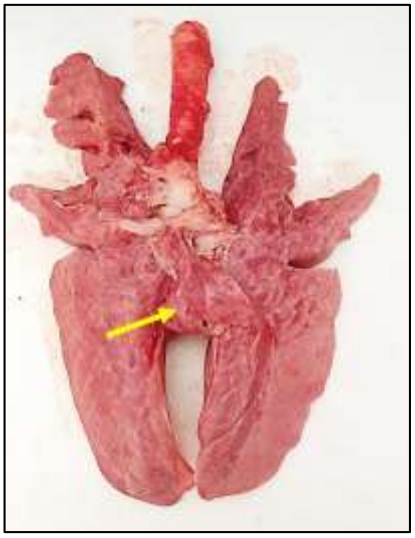

Fig 2: Photograph of pig lung illustrating the accessory lobe on the mediastinal aspect (pointed by arrow) (Ventral view)

2. Bronchial ramification

By using corrosion cast lung model, the bronchial ramification for each lung lobe was recorded and the division pattern was not similar for right and left lungs. Every secondary bronchus arose in an alternate pattern from longitudinal main bronchus without terminal bifurcation which was designated as monopodial pattern as mentioned by Noble *et al.*, 2010 [12] in pig. But Monteiro and Smith, 2014 [6] observed that each bronchial division was ended in terminal bifurcation (dipodial pattern) in Holstein Cow. The diameter and length of bronchial ramifications were reduced gradually as reports made in humans (Maina and Van Gills, 2001; Cohen *et al.*, 1993) [5, 1].

The trachea first given off apical bronchus, then bifurcated into two primary bronchi which was distributed to each lung (Fig. 3). The bronchial division was designated according to its origin in which the secondary bronchi come off from the primary bronchi. They were named as ventro-lateral (VL), ventro-medial (VM), dorso-lateral (DL), dorso-medial (DM) and dorsal (D).

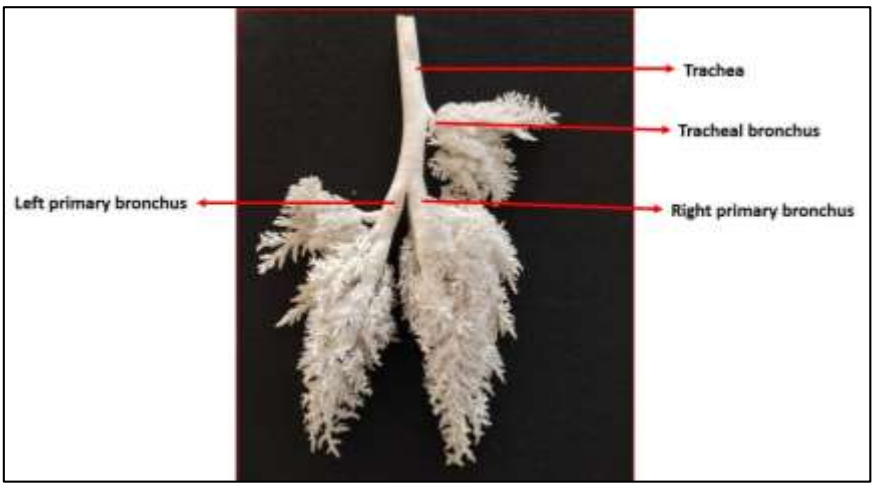

Fig 3: Photograph illustrating the bronchial divisions in corrosion cast lung model of pig (Dorsal view)

3. Right lung

The right lung of pig was ventilated by separate apical bronchus and several secondary bronchi from right primary bronchus (Fig. 3). The right primary bronchus given off five ventro-lateral (RVL_1 to RVL_5), four ventro-medial (RVM_1 to RVM_4), three dorso-medial (RDM_1 to RDM_3) and two dorsal (RD_1 to RD_2) secondary branches and continued as terminal branch to supply the right lung. Several tertiary bronchi arose from secondary bronchi and terminal branch were subdivided into more generations of bronchioles to supply the respective lobes.

3.1. Right apical lobe

A separate apical bronchus which arose directly from the right lateral wall of the trachea few centimeters proximal to the tracheal bifurcation was distributed to the right apical lobe (Fig. 4). It was subdivided into cranial and caudal divisions, both of which were equal in size and length. Several collateral branches arose from both the divisions before termination was also observed as mentioned by Nickel *et al.*, 1979 [11] in pig. In contrast, the tracheal bronchus of Holstein cow was divided into cranial and caudal divisions. The cranial division was longer and larger. The caudal division was shorter which was again subdivided into dorsal and ventral branches. Both cranial and caudal divisions were ended in terminal bifurcations (Nakakuki, 1994a) [9].

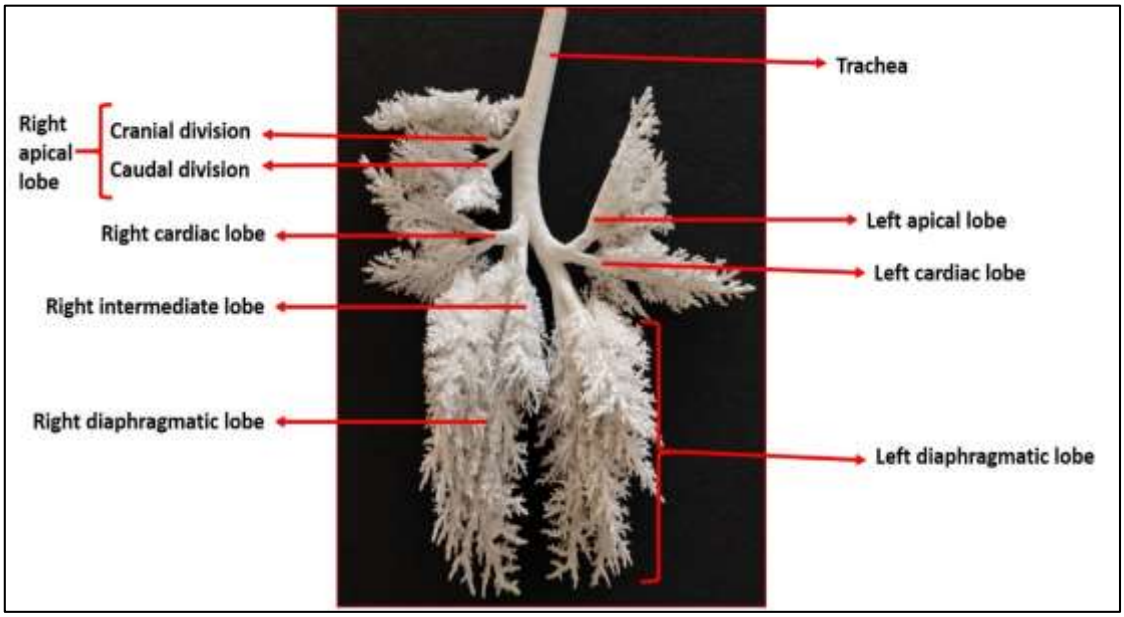

Fig 4: Photograph illustrating the right and left bronchial divisions in corrosion cast lung model of pig (Ventral view)

The equal sized cranial and caudal divisions of apical bronchus was distributed to the undivided right apical lobe in pig which was similar to the reports made by Nakakuki, 1980 [7] in comparative anatomical studies on the mammalian lung. But, the longer cranial division and shorter caudal division were supplied to cranial and caudal part of right apical lobe respectively in Holstein cow lung (Nakakuki, 1994a) [9].

3.2. Right cardiac lobe

The right cardiac lobe of pig was ventilated by first ventro-lateral secondary bronchi (RVL_1) which arose from ventro-lateral aspect of right primary bronchus (Fig. 4). Nakakuki, 1994a [9] also reported that the lateral bronchiole system which arises from the ventro-lateral side of the right bronchus forms the right middle lobe in Holstein cow.

3.3. Right accessory lobe

The ventro-medial secondary bronchi (RVM_1) which arose from ventro-medial aspect of right primary bronchus supplied to accessory lobe of pig (Fig.4). Nakakuki, 1994a [9] and Dondelinger *et al.*, 1998 [2] reported that the right accessory lobe was supplied by the ventral bronchiole system arises from the ventro-medial side of the right bronchus in cow and pig respectively.

3.4. Right diaphragmatic lobe

In pig, the right diaphragmatic lobe was supplied by four ventro-lateral (RVL_2 to RVL_5), three ventro-medial (RVM_2 to RVM_4), two dorsal (RD_1 to RD_2), three dorso-medial (RDM_1 to RDM_3) secondary branches and terminal continuation of primary bronchus (Fig.4). But Nickel *et al.*, 1979 [11], reported that the right caudal lobe was ventilated by four ventral and four dorsal segmental bronchi from right caudal bronchus. Also in contrast, Nakakuki, 1993 [8] mentioned that the bronchioles of lateral, dorsal, ventral and medial bronchiole system constituted the right caudal lobe in deer.

4. Left lung

In pig, the left primary bronchi given off secondary bronchi viz., five ventro-lateral (LVL_1 to LVL_5), three dorsal (LD_1 to LD_3), two ventro-medial (VM_1 to VM_2) and continued as terminal branch for distribution to different lobes of left lung. Several tertiary bronchi arose from secondary bronchi and terminal branch were subdivided into more generations of bronchioles to supply the respective lobes of left lung. (Fig.4). The apical bronchus was absent as mentioned by Nakakuki, 1994b [10] in pig lung.

4.1. Left apical and cardiac lobe

The secondary bronchi which arose from ventro-lateral aspect (LVL_1) of primary bronchi was divided into equal sized cranial and caudal divisions. The cranial division was subdivided into two equal branches which were ramified into several generations of bronchioles to supply the left apical lobe. The

caudal division was not subdivided but ramified into several generations of bronchioles to supply the left cardiac lobe. Judge *et al.*, 2014 [4] also reported that the left cranial lobe bronchus of porcine lung was divided into cranial and caudal segmental bronchi as in humans to supply the cranial and middle lobe. In accordance, Nakakuki, 1994a [9] mentioned that this well-developed nature of left middle lobe bronchiole which supplied to cranial and middle lobe was a compensatory development for the absence of separate left cranial lobe bronchiole in Holstein cow.

4.2. Left diaphragmatic lobe

After giving secondary bronchi to cardio-apical lobe, the left primary bronchus given off four ventro-lateral (LVL_2 to LVL_5), three dorsal (LD_1 to LD_3), two ventro-medial branches (LVM_1 to LVM_2) and continued as terminal branch to ventilate the diaphragmatic lobe (Fig.4). In contrary, Judge *et al.*, 2014 [4] mentioned that the left caudal stem bronchus was divided into four dorsal and four ventral segmental bronchi to ventilate the left caudal lobe in pig.

The accessory lobe bronchi system for left lung was lacking as mentioned by Nakakuki, 1994(a,b)[9,10] in cattle and pig.

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