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Macroanatomical studies on lung and bronchial pattern in crossbred bovine calf

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Abstract
The lung morphology and bronchial division pattern of cross bred bovine calf was studied by using silicone resin lung model. The lungs were right and left and located in the thoracic cavity. Both lungs were subdivided into cranial, middle and caudal lobes and the right lung had small accessory lobe. The bronchi were divided into tracheal bronchus, right and left primary bronchus. Dissimilar bronchial division pattern was observed in right and left lungs. The general decrease in diameter and length of bronchial ramifications was also observed. Each bronchial division was named according to the order in which the secondary bronchi comes off from the principal bronchi on each side. The right apical lobe was supplied by tracheal bronchus. The remaining lobes of right and left lung were supplied by branches arose from respective principal bronchus.

Keywords: Bovine calf, lung, corrosion cast, bronchial pattern

1. Introduction
The use of animals for scientific purpose is long standing practice in biomedical research and medicine over many decades. The significant anatomical and physiological similarities between the humans and mammalian animals provoked scientists to investigate the animal models for applying discoveries and novel therapies. The animal models have been used to explain variety of scientific queries regarding research in basic science.
Mammalian airways are constructed by tubes formed by cartilaginous trachea and bronchi which are then followed by subdivisions into several generations of bronchioles and terminates in air sacs (Monteiro and Smith, 2014) [6]. The respiratory organs provide exchange of gases between the blood and atmosphere. In the field of respiratory medicine, the animal respiratory model gains more importance to understand the ventilation mechanisms (Judge *et al.*, 2014) [4]. This study was undertaken with the aim of providing anatomical knowledge with regard to bronchial pattern in cross bred bovine calf which will be useful in the field of respiratory medicine.

2. Materials and Methods
Six numbers of intact lungs from the cross bred bovine calf were collected from slaughter house. Immediately after collection, the lungs were cleaned and washed in normal saline and utilized to study the gross morphological features. Subsequently, they were fixed in 10% formalin for 24 hours. After fixation, the lungs were washed in water and allowed to dry for few hours. Afterwards by using silicone gun, a white silicone resin was infused through the trachea until it reaches all the airways and the lungs were hanged for three days for curing of silicone resin. After curing, the lungs were treated with hydrochloric acid to digest the soft tissues (Nakakuki, 1994) [9] and washed in running tap water and silicone rubber cast of airway model was obtained.

3. Results and Discussion
The lungs were right and left which occupied the greater part of thoracic cavity in bovine calf. The two lungs were not uniform in size and the right was relatively larger than the left. Each lung was consisted of two surfaces, two borders, a base and an apex. Costal surface of the lung was convex and located against the lateral wall of the thorax and had costal impressions. The medial surface had cardiac impression in front for adaptation to pericardium and heart. The hilus or root of the lung was noticed behind the cardiac impression. Impression for esophagus and aorta was noticed above and behind the root of the lung in the medial surface of left lung. Dorsal border was observed as long, thick and rounded. Ventral border was thin and short (Sisson, 1961) [12].

As stated by Dyce *et al.*, 1996 [3] in cattle, the surface of the lung was presented with very distinct lobulations. Base of the lung was concave and related to the thoracic aspect of the diaphragm. Apex of the lung was prismatic and narrow. Both right and left lungs were divided into lobes by cardiac notch and interlobar fissures. From cranial to caudal direction, the left lung was divided by a notch and a fissure into three lobes viz., apical (cranial), cardiac (middle) and diaphragmatic (caudal) lobes (Fig. 1). The right lung was divided by two fissures into four lobes viz., apical (cranial), cardiac (middle) and diaphragmatic (caudal) (Fig.1) and intermediate lobes (Fig. 2).

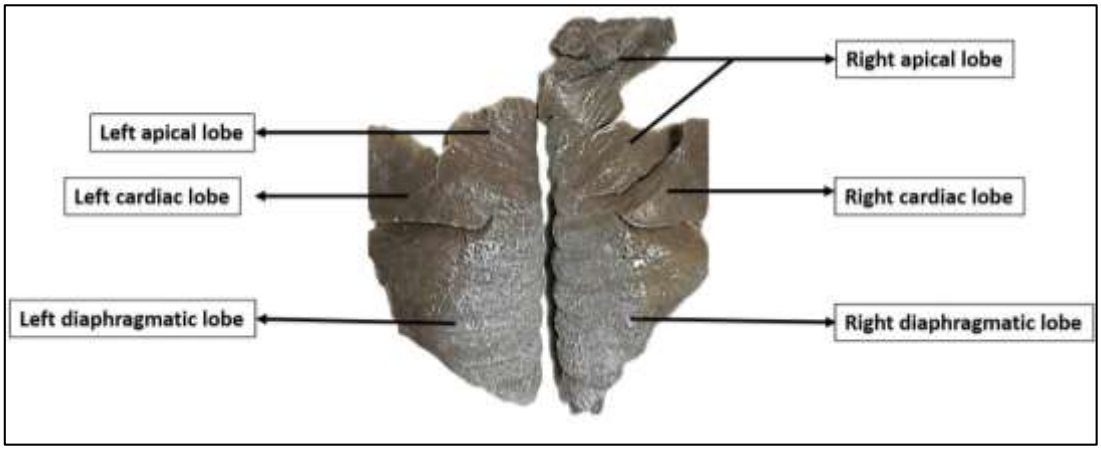

Fig 1: Photograph showing the different lobes of right and left lung in cross bred bovine calf (Dorsal view)

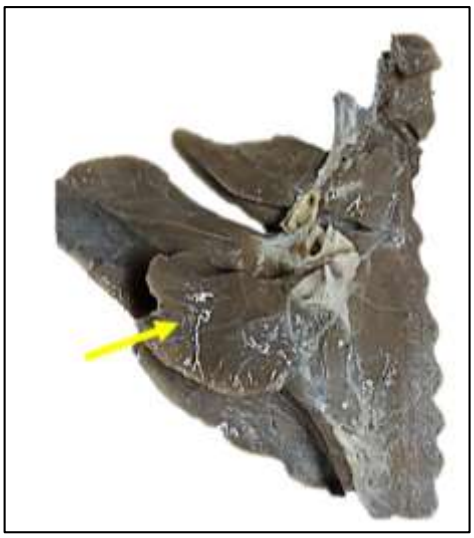

Fig 2: Photograph showing the intermediate lobe (indicated by arrow) of right lung in cross bred bovine calf (Ventral view)

Apical lobe of right lung was larger and divided into two divisions viz., cranial and caudal parts by interlobar fissure. Larger size of cardiac lobe than the apical lobe was observed. A separate bronchus arose from the trachea at the level of 3rd rib entered into the right apical lobe, afterwards the trachea was bifurcated into two principal bronchi at the level of 5th rib in cross bred bovine calf (Nickel *et al.*, 1979) [11].

The detailed bronchial pattern for each lung lobe was studied by using corrosion cast airway model in bovine calf and dissimilar bronchial division pattern was observed in right and left lungs. As mentioned by Monteiro and Smith, (2014) [6], each bronchial division was ended in terminal bifurcation (dipodial pattern). As reported in humans (Maina and Van Gills, 2001; Cohen *et al.*, 1993) [5, 1], the general decrease in diameter and length of bronchial ramifications was also observed in all the airways. The trachea was bifurcated into two principal bronchi to supply the respective lung and in addition, the right lung had separate tracheal bronchus to the right apical lobe (Fig.3).

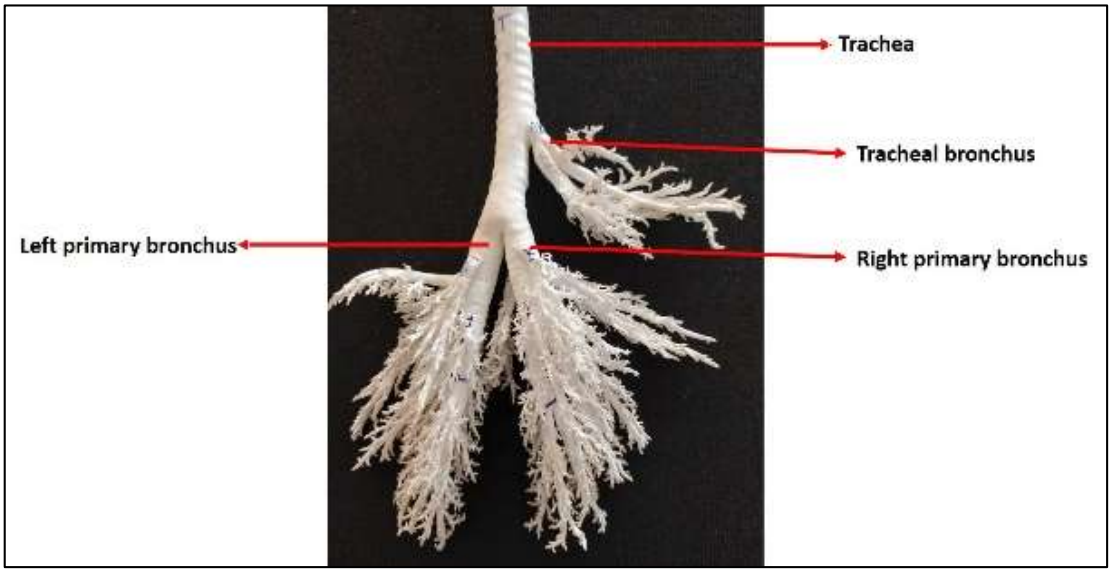

Fig 3: Photograph of corrosion cast showing the primary and tracheal bronchus in cross bred bovine calf (Dorsal view)

The bronchial anatomy lung was classified into ventro-lateral (VL), ventro-medial (VM), dorso-lateral (DL), dorso-medial (DM) and dorsal (D) branching systems. Each was named according to the order in which the secondary bronchi comes off from the principal bronchi on each side.

3.1 Right lung

The right lung was ventilated by separate tracheal bronchus (RTB) and several secondary bronchi from right principal bronchus (Fig. 3).

The right principal bronchus given off three dorso- lateral (RDL_1 to RDL_3), one dorso-medial (RDM_1), three ventro-lateral (RVL_1 to RVL_3) and three ventro-medial (RVM_1 to RVM_3) secondary branches before its terminal bifurcation. Several tertiary bronchi arose from secondary bronchi and terminal bifurcations were subdivided into more generations of bronchioles to supply the respective lobes.

A separate tracheal bronchus (RTB) arose directly from the lateral wall of the trachea on right side few centimeters proximal to the tracheal bifurcation to supply the right apical lobe (Fig.3). The tracheal bronchus was divided into cranial and caudal divisions. The cranial division was longer and larger whereas the caudal division was shorter which was again subdivided into dorsal and ventral branches. Both cranial and caudal divisions were ended in terminal bifurcations. These observations were in accordance with the Nakakuki, 1994a [9] in Holstein cow lung. The longer cranial division and shorter caudal division were supplied to cranial and caudal part of right apical lobe respectively. It was similar to the reports made by Nakakuki, 1980 [7] in comparative anatomical studies on the mammalian lung.

The first ventro-lateral secondary bronchi (RVL_1) which arose from ventro-lateral aspect of right principal bronchus supplied to right cardiac lobe in cattle (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.

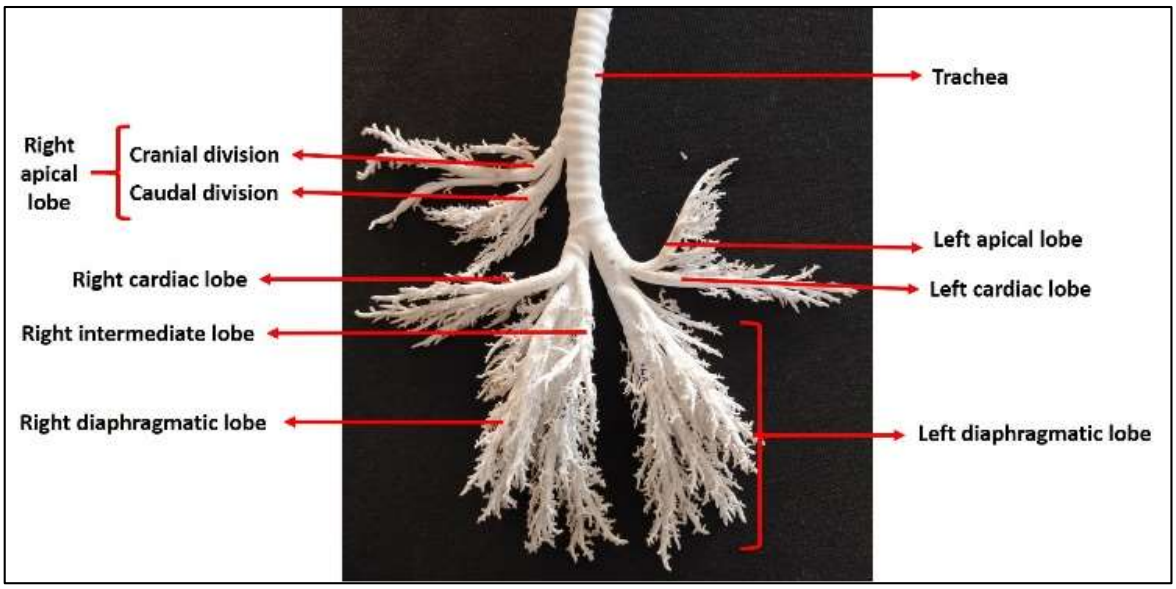

Fig 4: Photograph of corrosion cast showing bronchial branches from right and left principal bronchus in cross bred bovine calf (Ventral view)

The ventro-medial secondary bronchi (RVM_1) which arose from ventro-medial aspect of right principal bronchus supplied to intermediate lobe (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.

After giving branches to cardiac and intermediate lobes, the principal bronchus was continued as stem bronchi which consisted of three dorso- lateral (RDL_1 to RDL_3), one dorso-medial (RDM_1), two ventro-lateral (RVL_2 to RVL_3), two ventro-medial (RVM_2 to RVM_3) secondary branches and terminally bifurcated primary bronchus and were supplied to the diaphragmatic lobe (Fig.4). In contrast, Nakakuki, 1993 [8] also mentioned that the bronchioles of lateral, dorsal, ventral and medial bronchiole system constituted the right caudal lobe in deer.

3.2 Left lung

As mentioned by Nakakuki, 1994b [10] in pig lung, the tracheal bronchus was lacking and the bronchial division pattern of left principal bronchi was dissimilar with right principal bronchi. The left principal bronchi given off three ventro-lateral (LVL_1 to LVL_3), three dorso-lateral (LDL_1 to LDL_3) and one ventro-medial (LVM_1) secondary bronchi before its terminal bifurcation for different lobes of left lung. Several tertiary bronchi arose from secondary bronchi and terminal bifurcations were subdivided into more generations of bronchioles to supply the respective lobes (Fig. 4).

The secondary bronchi which arose from the ventro-lateral aspect (LVL_1) of primary bronchus supplied to apical and cardiac lobe. It was divided into cranial and caudal divisions. The cranial division had several tertiary bronchi which were then ramified into several generations of bronchioles to supply the left apical lobe. The caudal division was longer and resembled the cranial division in branching pattern and supplied to left cardiac lobe (Fig. 4). 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.

After giving secondary bronchi to cardiac and apical lobe, the left principal bronchus was continued by stem bronchus.The two ventro-lateral (LVL_2 to LVL_3), three dorso-lateral (LDL_1 to LDL_3) and one ventro-medial (LVM_1) secondary branches arose from the stem bronchus and terminally bifurcated

principal bronchus were distributed to the diaphragmatic lobe (Fig.4). But Nakakuki, 1994a [9] in Holstein cow observed that the left caudal lobe was supplied by lateral (L_2 to L_5), dorsal (D_2 to D_6), ventral (V_3 to V_5) and medial (M_4 to M_6) bronchiole system.

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