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Radiographic lung patterns of different respiratory conditions in dogs

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Abstract
The present work entitled "Radiographic lung patterns of different respiratory conditions in dogs" was conducted on dogs presented to Veterinary Clinical Complex, Department of Veterinary Surgery and Radiology, College of Veterinary Science, Tirupati. The dogs with respiratory signs clinically observed were subjected for radiographic examination to find out the radiographic lung patterns, also to estimate the haematological and biochemical parameters corresponding to the lung pathology in the clinical conditions. X-ray machine (1000 mA) with computerized radiography system was utilized to perform the radiographic examination. Among the 45 cases under study, alveolar pattern featured by air bronchograms suggesting different stages of pneumonia was noticed in 13 cases. Radiographic interstitial pattern observed in 12 cases which revealed increased radiographic density involving structures of lung parenchyma/interstitium, displacing the normal lung. Vascular pattern was noticed in 8 cases which showed radiographic pattern with increased radiographic density of vessel margin. Bronchial radiographic pattern observed in 7 cases suggested chronic bronchitis and bronchial mineralization featured by tram lines/ donut pattern. Few animals showed mixed radiographic lung patterns involving any combination of interstitial, bronchial, vascular and alveolar patterns. The radiographic lung patterns provided the information about the involvement of lung parenchyma, bronchi or blood vessels in the lungs, which could be correlated with other underlying etiological factor. The results are highly informative before proceeding to administration of anaesthesia, fluids and any surgical interventions.

Keywords: Computerized radiography, lower respiratory tract affections, lung patterns

Introduction
The lower respiratory tract in dogs is susceptible to varieties of infections, inflammatory, degenerative and neoplastic conditions Ettinger (1983) [4]. The lesions might be observed in parenchyma as well as the interstitial tissue. Different infectious agents enter through aerosol or hematogenous route. Pulmonary diseases are the major cause of respiratory signs apart from cardiac and other abnormalities Barrett *et al.*, (2014) [1]. Dogs with pulmonary ailments exhibit cough increased respiratory rate, dyspnoea, exercise intolerance, lethargy, inappetance, weight loss, cyanosis, exercise intolerance, panting, hemoptysis and pyrexia (Lord 1976) [8] and Kirberger and Lobetti (1998) [7]. Radiographic evaluation of pulmonary changes is facilitated by classifying the radiographic appearance of lung in different disease patterns. These patterns were based on any apparent changes in normal radiological anatomy of lungs, aims at disease process and to help further in management of the patient. Pulmonary disease will be either increase or decrease in radiographic opacity of lungs and the alterations are termed as lung patterns. Spasov (*et al.*, 2018) [14] compared the normal and pathological lung patterns in dogs. This study demonstrated differences between common lung patterns with characteristic radiographic signs and descriptive differentiation of pathological conditions. Nykamp (*et al.*, 2002) [11] described the radiographic signs of pulmonary disease instead of pattern in different disease conditions, where in authors stressed on radiographic signs correlated to the knowledge of clinical signs.

Materials and Methods
The present work was carried out to visualize and to record the radiographic appearance of various lung patterns in different lower respiratory affections like respiratory distress, cough, trauma, epistaxis, nasal discharge, weight loss and lethargy indicated for thoracic radiography. Animals were selected based on exclusion and inclusion criteria.

Exclusion criteria
Dogs with upper respiratory affections, cardiac ailments, tracheal affections etc. were excluded from the study.

Inclusion criteria
Dogs with clinical symptoms suggestive of lung involvement only were included in the study.
The research protocol was approved by Institutional Animal Ethics Committee wide reference no. 281/go/ReBi/S/2000/CPCSEA/CVSc/TPTY/020/surgery/2021.

Radiographic procedure
Radiographs were obtained in animals without anaesthesia, however in animals which were ferocious and non-co-operative were sedated using Ketamine hydrochloride @ 8 - 10 mg/kg body weight, intravenous route, inj. Midazolam @ 0.1 - 0.3 mg/kg body weight, intravenous route and Xylazine @ 0.5 - 1 mg/kg body weight, Intramuscular route. All the dogs were subjected to the radiographic procedures in left lateral, right lateral, ventrodorsal views as per Ruehl and Thrall (1981) [13] positioning and these radiographs were evaluated based on the quality, positioning and projections.

Radiographic Features
Any specific pathology noted in total lung field were described in terms of radiological features include different lung patterns such as alveolar, interstitial, vascular and bronchial patterns. Extra thoracic and intrathoracic parts as trachea, mediastinum, pleura, diaphragm, heart and lung`s pathological changes also noted.

Alveolar pattern
Alveolar pattern radiologically characterized as uniform and homogeneous fluid opacity which was varying from faint/fluffy to solid and complete opacification. Lobar sign opacity extends to periphery of lung lobe leaves a dramatic transition between Opacified lobe border and adjacent normal radiolucent lobe. Cardiac silhouette effect such as “border effacement” or loss of border visualization also noticed between the heart and Opacified lung lobe or diaphragm and the lung lobe. Air bronchograms were formed by air-filled bronchus extending through fluid opacity lung lobe. (Lord 1976) [8].

Interstitial pattern
Interstitial pattern characterized by structural and unstructured patterns. Overall increases in haziness, linear opacities smudged vasculature with visible vessels are of unstructured interstitial pattern. Structural interstitial pattern includes primary pulmonary and metastatic neoplasia, fungal granulomas, abscess, haematoma, bullae and cavitated masses or nodules. (Kealy *et al.,* 2010) [6].

Vascular pattern
Vascular pattern was featured by larger quantity of blood in the artery or its adjacent vein. This causes change of the size, form and direction of the vessel which commonly becomes more visible. Pulmonary arteries and/or veins increase in prominence resulting in an increased pulmonary opacity. (Kealy *et al.,* 2010) [6].

Bronchial pattern
Bronchial pattern featured by thickened and increased prominence of the bronchial walls due to smooth muscle hypertrophy, mucous production, cellular infiltrate, and bronchoconstriction. Thickened, end-on bronchi appear as rings or “do-nuts” and thickened bronchi seen longitudinally appear as parallel radiopaque lines, referred as “railroad tracks”. (Kealy *et al.,* 2010) [6].

Mixed pattern
Mixed lung pattern featured by any combination of alveolar, interstitial, vascular and bronchial patterns predominant features of lung patterns during progression of disease process would be evaluated for the review and treatment age, disease complications, disease progression would Effect the lung tissue with mixed radiographic appearance. (Kealy *et al.,* 2010) [6].

Results
Lung patterns
The total cases under study, 45 cases were classified into different lung patterns according to their radiological findings.

Alveolar pattern
Alveolar lung pattern was observed in the present study were noticed in 13 (28.9%) cases. Skiagrams showed substitution of air filled alveoli with fluid/exudate/haemorrhagic material leading to increased opacity. Few Skiagrams showed homogenous radio-opacity of lung areas focal or diffuse. Consolidation of lung lobes and prominent air bronchograms were noticed. Few Skiagrams showed hazy undifferentiated lung lesions with or without lung margins (irregular). Few animals showed lobar signs featured by sharp edge of high density lobe compared to normal lobe. The alveolar pattern was mostly observed in different stages of pneumonia. (Figure 1)

Interstitial pattern
The next most predominant radiographic pathology accounted for interstitial pattern was 12 out of 45 (26.67%) in screened animals with respiratory symptoms showed this pattern. Skiagram showed overlapping appearance of other structures, displacing lung tissue was noticed. Though the Skiagrams showed increased radiographic density, the vasculature/vessels/ bronchi were visible. Few animals showed nodular lesions others showed diffused interstitial pattern. Miliary nodular appearance was also recorded. Lesions could be analyzed as structural and non-structural based on their distribution. Skiagram depicted lesions ranging from small to circumscribed large lesions involving all the lung lobe parenchyma in different neoplastic conditions. (Figure 2)

Vascular pattern
8 out of 45 cases (17.77%) showed vascular lung patterns under the study. Skiagram showed prominent pulmonary or bronchial vasculature with increased diameter or thickness of vessel wall. Direction, course of blood vessel was also altered due to underlying pathology. Increased radiographic density of vessel was noticed in Skiagram. (Figure3)

Bronchial pattern
In the present study, Bronchial pattern was observed were noticed in 7 (15.55%) of cases. The Skiagram showed thick bronchial wall suggesting chronic bronchitis, bronchial mineralization. Characteristic ring like shadows/Tram

lines/Donut pattern was observed in the radiographs. (Figure 4)

Mixed pattern

In the present study, 5(11.11%) cases showed mixed pattern. Animals with chronic disease process due to multifactorial etiological agents, showed mixed pattern. Skiagrams showed alveolar along with interstitial or with bronchial pattern were predominant in mixed pattern. This lung pattern appearance depends upon progression of disease and different tissue involvement (interstitium, alveoli and bronchi etc.) (Figure 5).

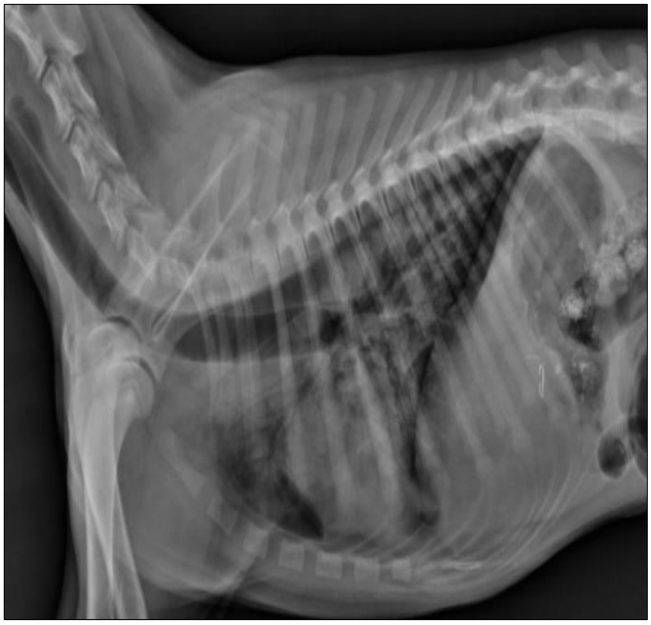

Fig 1: Alveolar Pattern Skiagram of right lateral view of thorax showing enhanced and homogenous Radiopacity on left cranial lung lobe with clear air bronchograms.

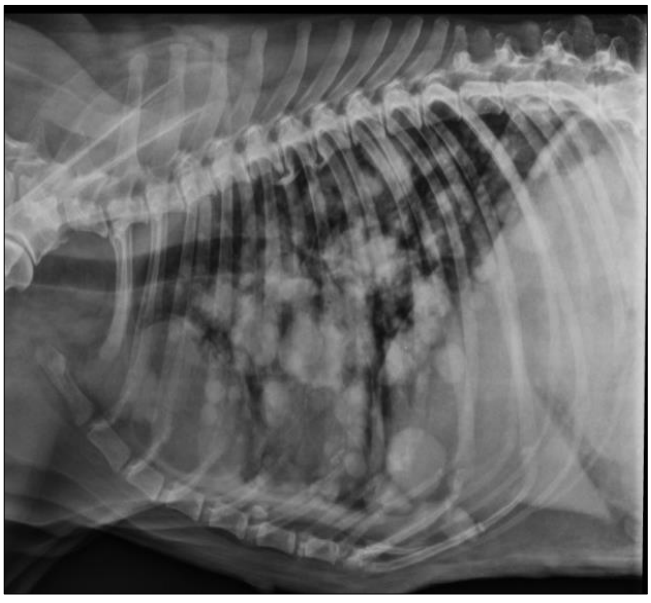

Fig 2: Interstitial Pattern Skiagram of right lateral view of thorax showing multiple nodular interstitial pattern, suggestive of metastasis.

Fig 3: vascular pattern Skiagram of left lateral view of thorax showing prominent increased right cranial pulmonary vessel density, rounding of cardiac silhouette

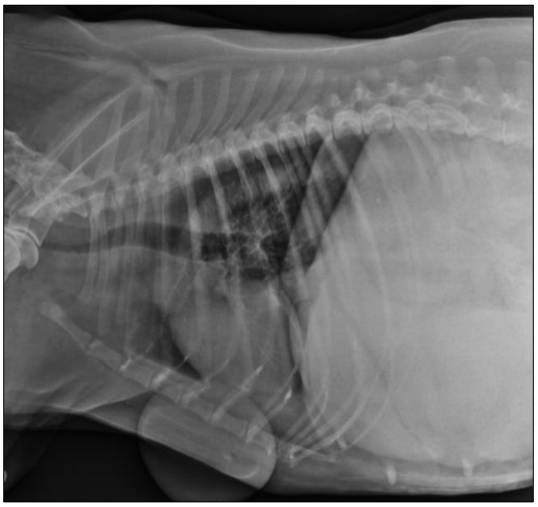

Fig 4: Bronchial Pattern Skiagram of left lateral view of thorax showing mineralized thickening of bronchial walls.

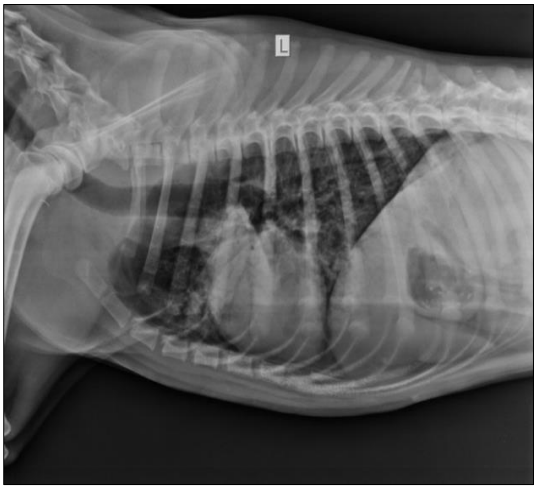

Fig 5: Mixed Pattern Skiagram of **l**eft lateral view of thorax showing lobar sign, air bronchogram of right cranial lung lobe and diffused opacity of parenchyma of caudal lung lobe.

Discussion

Radiographic factors and the positioning views were standard to all the animals under study per Ruehl and Thrall (1981) [13]. Out of 45 animals screened 13 alveolar, 12 interstitial, 8 vascular, 7 bronchial and 5 mixed lung patterns were recorded. Out of 45 cases, 13 cases found to have radiographic alveolar pattern. The Skiagrams of alveolar pattern showed air bronchograms suggestive of fluid filled alveoli, wherein vasculature was not clear. The contrast provided by bronchial airways and alveoli results in blurring of lungs on radiographic examination. This pattern was suggestive of acute pulmonary edema, lobar pneumonia, bronchopneumonia, allergic pneumonia (Lord 1976) [8], Kirberger and Lobetti (1998) [7], Nykamp *et al.*, (2002) [11] and Geyer *et al.*, (2010) [5]. The presence of air bronchograms was noticed and the same were disappearing after paucity of time. Lobar sign was another feature with the appearance of sharp edge formed when high density lobe touched the normal lobe was also noticed. Alveolar densities differed in distribution, shape and size. In the present study pulmonary edema was noticed with alveolar pattern, where in symmetrical distribution was noticed. In the cases of different types of pneumonia, asymmetrical distribution was noticed with transformation of pulmonary parenchyma. These cases were well responded to treatment. Spasov *et al.*, (2018) [14] Observed alveolar pattern with other conditions like non cardiogenic edema, haemorrhage, thromboembolism, atelectasis and allergy. Radiological patterns of extra thoracic diseases in dogs and cats were reported in Pires *et al.* (2015) [12].

In the present study out of 45 cases 12 cases were found to have the interstitial radiographic lung patterns. Interstitial lung diseases normally enhance the densities of interstitial structures like alveolar walls, bronchiolar walls, and interlobular septa either by increasing the fluid content or by depositing cellular/collagenous material (Suter and Lord (1974) [15], Lord (1976) [8] and Myer (1980a) [10]. These interstitial radiographic patterns were divided into unstructured increase of pulmonary density with changes in interstitial structures but not observed individually. The examples for unstructured patterns were interstitial edema, interstitial pneumonia, granulomatous diseases and pulmonary fibrosis. The second type featured by individual changes in the interstitial architecture as nodular or lineal structures. In this study miliary nodules suggestive of fungal disease and metastatic disease were noticed.

In the present study, 8 cases of vascular pattern were noticed. The evaluation of vascular radiographic lung pattern was based on the vascularity of lung field, whether normal, increase or decrease in diameter and involvement of arteries/veins/ both course and direction as described by Myer (1980b) [9], and Spasov *et al.*, (2018) [14], on a lateral radiograph, arteries appear dorsal to vein, in dorsoventral projection, arteries appear lateral to veins. Pulmonary arteries follow bronchi while pulmonary veins sometimes run separately. Bronchial arteries from the aorta supply to bronchi and bronchial vein drain this to the right atrium via azygous vein. The underlying pathology like severe dehydration, right side heart failure, and hypovolemic shock was reported to be the cause. In the cases of present study the patterns showed by the animals might be having dehydration.

In the present study out of 45 cases, the 7 showed bronchial radiographic pattern. The radiographic densities created by bronchial walls appeared as dense, parallel lines/ ring like structures on the radiograph similar to the findings described by Myer (1980b) [9], Dennis (2008a) [2] and Spasov *et al.*, (2018) [14] calcification of bronchial cartilage was normally seen in aged dog suggestive of bronchial and peribronchial disease. Skiagrams showed dilated bronchi suggestive of bronchitis, asthma, kennel cough, mycoplasma/parasitic pneumonia and chronic obstructive disease. Many scientists attributed this pattern to allergy, cardiogenic edema, diffuse tumors and infections. Bronchial wall become more opaque and thickened.

Mixed radiographic lung patterns were 5 among total 45 cases. In general majority of the lung patterns exhibited mixed patterns, due to involvement of different structures of the lung lobe. Mixed patterns many times would not give a conclusive decision, since the different lung structures are involved in conditions like abs cessation, granulomatous pneumonia and metastatic tumours (Kirberger and Lobetti (1998) [7], Dennis (2008b) [3]. Lung pattern distribution (location of lesions) is important rather than knowing pattern alone. It is opined the lung patterns localized in cranial and ventral lungs observed to be associated with infectious cause of pneumonias. The distribution included left cranial lung lobe, ventral aspect of caudal lung lobe, right cranial lung lobe. Caudo-dorsal distribution was associated with edema whereas multifocal distribution related to metastatic lesions.

Conclusion

To conclude any lung pathology starts with bronchial involvement showing bronchial pattern initially proceeds to interstitial or alveolar involvement. Radio graphically if vasculature and bronchitis are noticed, it could be read as alveolar pattern due to bronchopneumonia, edema, lung mass etc. If vessels are noticed, it could be delineated for structured or unstructured interstitial pattern with Cranio-ventral and caudal location of lesions suggestive of pneumonia, pulmonary edema and diffuse neoplasia. Involvement of pulmonary and bronchial vasculature prominently corresponds to vascular lung pattern with increased diameter. Mixed pattern could be observed as a combination of any lung pattern. These provide basis for underlying lung pathology. It is also opined that findings of radiographic lung patterns should be correlated with disease process for delineating the different clinical conditions.

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