# CLINICAL STUDIES ON THORACIC RADIOGRAPHY IN DOGS WITH SPECIAL REFERENCE TO FABRICATION OF ANIMAL POSITIONERS

**Thesis**

**Submitted to the Guru Angad Dev Veterinary and Animal Sciences University in partial fulfillment of the requirements for the degree of**

**MASTER OF VETERINARY SCIENCE**
**in**
**VETERINARY SURGERY AND RADIOLOGY**
**(Minor Subject: Veterinary Anatomy)**

**By**

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**LUDHIANA – 141 004**

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# CERTIFICATE I

This is to certify that the thesis entitled, **"Clinical studies on thoracic radiography in dogs with special reference to fabrication of animal positioners"** submitted for the degree of **M.V.Sc.,** in the subject of **Veterinary Surgery and Radiology** (Minor subject: **Veterinary Anatomy**) of the Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, is a bonafide research work carried out by **Ravi Singh (L-2018-V-93-M)** under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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## ABSTRACT

The present study aimed to fabricate indigenous radiographic positioners for thoracic radiography, establish criteria for declaring a thoracic radiograph as normal and evaluate thoracic radiographs in relation to various disease conditions in dogs. In the part 1 of study three foam materials were tested for fabricating troughs and wedges on the basis of strength and opacity. Four cloth materials were tested for fabricating sandbags evaluated on the basis of strength and mouldability. Low cost indigenous troughs and wedge fabricated using EPE foam and sandbags fabricated using PVC American Matty filled with coarse gravel were suitable for positioning dogs for thoracic radiography in dogs. In the part 2 of study 507 thoracic radiographs taken from 134 dogs were evaluated. The dogs were grouped under normal (n=38), pulmonary (n=70), cardiopulmonary (n=25) and extra-thoracic (n=1) disorders on the basis of radiographic evaluation. The evaluation of thoracic radiographs was done on the basis of dimensions and features of the various thoracic structures. The radiographic features of normal dogs belonging to different breed types viz. Brachycephalic, Mesocephalic and Dolichocephalic were documented. From the study it was concluded that mesocephalic dogs were most commonly affected with pulmonary and cardiac disorders and Labrador Retriever breed was the most commonly affected breed; among the pulmonary disorders mixed lung pattern was most common followed by interstitial pattern and the caudal lung lobe was most commonly involved; All the dogs with cardiac disorders showed pulmonary involvement out of which mixed lung pattern was most common followed by interstitial pattern and the caudal lung lobe was most commonly affected. Cardiopulmonary disorders were characterised by increased VHS, sternal contact, ICS occupied, percent coverage of cardiac silhouette and enlarged caudal pulmonary vessels. An SOP was proposed for evaluating thoracic radiographs in dogs.

**Keywords:** Fabrication, Dogs, Positioners, Thoracic, Radiograph

**Signature of Major Advisor** **Signature of the student**

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# ABBREVIATIONS

| | | |
|---|---|---|
| % | : | Percent |
| * | : | asterism |
| “ ” | : | quotation marks |
| ± | : | plus-minus |
| ≤ | : | less-than or equal to |
| ≥ | : | greater-than or equal to |
| © | : | copyright |
| CdPA | : | Caudal pulmonary artery |
| CdPV | : | Caudal pulmonary vein |
| cm | : | centimeter |
| COVS | : | College of Veterinary Science |
| CR | : | Computed radiography |
| CrPA | : | Cranial pulmonary artery |
| CrPV | : | Cranial pulmonary vein |
| CVC | : | Caudal Vena Cava |
| DR | : | Direct Radiography |
| DV | : | Dorsoventral |
| e.g | : | For example |
| EPE | : | Expanded polyethylene |
| *et al* | : | *Et alia* (and others) |
| etc. | : | et cetera |
| Fig. | : | Figure |
| GADVASU | : | Guru Angad Dev Veterinary and Animal Sciences University |
| i.e. | : | *Id est* (that’s it) |
| Kg | : | Kilograms |
| kVp | : | Kilo Volt Potential |
| lt | : | left |
| mAs | : | Milli Ampere per second |
| mm | : | millimetre |
| PE | : | Polyethylene |

| | | |
|---|---|---|
| PU | : | Polyurethane |
| PVC | : | Polyvinyl chloride |
| R3 | : | Width of proximal third of third rib |
| R4 | : | Width of proximal third of fourth rib |
| R9 | : | Width of $9^{th}$ rib at intersection of vessel |
| rt | : | right |
| SOL | : | Space occupying lesion |
| SOP | : | Standard operative protocol |
| T1 | : | $1^{st}$ thoracic vertebrae |
| T4 | : | $4^{th}$ thoracic vertebrae |
| T6 | : | $6^{th}$ thoracic vertebrae |
| TD | : | Tracheal diameter |
| TI | : | Thoracic inlet |
| VD | : | Ventro-dorsal |
| VHS | : | Vertebral heart score |
| *viz.* | : | Videlicet (that is to say) |

## CHAPTER I

# INTRODUCTION

Imaging science is a branch of medical science which is gaining position for analysis of numerous diseases not only in human but also in animals. Radiological and other evaluation measures are important to decide the line of treatment, surgical intervention, anaesthetic protocols and assess recovery. Since thoracic cavity harbours major vital centres like heart, lungs and other intra and extra thoracic structures. Evaluation of these organs and complete thoracic cavity becomes obligatory to accurately diagnose any disorder.

Thoracic radiography is a non-invasive, rapid and readily available diagnostic tool frequently used in veterinary practice (Keyserling *et al* 2017). Thoracic radiographs are routinely taken in canines to diagnose conditions affecting the thorax, evaluate its contents mainly cardiac size, shape and contour, vascular and lung patterns, pleural changes, thoracic musculoskeletal conformation and adjoining structures. In such cases, thoracic radiographs are likely to reveal clinically significant and pertinent information about the progression of disease. Thoracic radiographs are also recommended as a screening tool for a variety of disorders in veterinary patients that have no clinical signs associated with the thoracic structures. Specific indications for taking thoracic radiographs in canine patients include geriatric wellness, pre-anaesthesia and general assessment of systemic illness in the patient. The purpose of thoracic radiography in such scenario is to evaluate the patients for any underlying pathology that could alter the diagnostic or therapeutic plan (Keyserling *et al* 2017). Radiographically, the following regions can be searched in order: ribs, vertebrae and sternebrae; soft tissues of the thoracic wall; pleural space; mediastinum; heart; trachea and principal bronchi; pulmonary vessels and finally pulmonary parenchyma (Halvorsen and Swanson 1990). However, it is also important to understand the variation in the dimensions/characteristics of thoracic structures *vis-à-vis* breed / head type and to document radiographic indices of different thoracic structures in dogs belonging to different breed/head type viz brachycephalic, mesocephalic and dolichocephalic. It is also equally important to evaluate thoracic radiographs in various pulmonary, cardiac and extra thoracic affections in dogs and document the changes in the various structures resulting from these disorders.

A good quality radiograph of thorax requires correctly positioned animal and use of correct exposure factors. At least two fine positioned radiographic views (a lateral i.e. right or left projection and either dorsoventral or ventrodorsal projection) are crucial for a complete evaluation. In addition to the above factors evaluation of thoracic radiographs has to take into account the additional problems like likelihood of motion artefacts due to constant respiratory movements, transient atelectasis of dependent lung tissue when animal is put in lateral recumbency and maintaining perfect position of animal for lateral and dorso-ventral (DV) or ventro-dorsal (VD) projections to avoid obliquity of thoracic structures (Sharma 2018). Any obliquity and malpositioning in the thoracic radiograph may lead to misinterpretation (Kirberger and Avner 2006). To avoid these kinds of errors, use of good quality positioners are essential to obtain well oriented thoracic radiographs with minimal obliquity. Radiographic positioners are routinely used in western countries for taking quality radiographs of thorax and contributing a lot in improving clinical diagnostics through aiding positioning and proper projection hence improving visibility and clarity of the thoracic structures. Brown and Brown (2014) have documented the use of positioners like troughs, wedges and sandbags to obtain quality thoracic and abdominal radiographs in canine patients. Positioners made of materials like sponge, acrylic etc are commercially available in international market and the cost may run in several thousand dollars. Ryan (1981) opined that patients which are anaesthetized, or even adequately tranquilized can be held in position by foam blocks and sandbags.

Limited work has been done in India on positioning and interpretation of thoracic radiographs in dogs. Radiographic positioners are not available in Indian market and the positioners which are imported are very costly, so there is need to standardize the radiographic technique/positioning and qualitative and quantitative assessment of different thoracic structures in different breeds of dog in India with some indigenous and economical positioners which can be made easily by the institutions using cheap and easily available raw materials. To correctly interpret a thoracic radiograph, it is important to evaluate each and every structure visible on all the available views and reach at a conclusive diagnosis. In India no standard operative procedure is followed for evaluating thoracic radiographs in dogs and different methods are used to evaluate the radiographs at various institutes/ small animal practices. So, there is need to develop and propose a standard operative procedure which can be adopted pan India for assessment of thoracic radiographs in dogs

Keeping all the points in view, the present study was planned with the following objectives:

1. To develop indigenous radiographic positioners for thoracic radiography in dogs.

2. To establish criteria for declaring a thoracic radiograph as normal.

3. To evaluate thoracic radiographs in relation to various disease conditions in dogs.

# CHAPTER II

## REVIEW OF LITERATURE

Radiographic evaluation of thorax in dogs poses a challenge for the small animal practitioner. Many factors play a role in acquisition of a good quality radiograph which include use of proper exposure factors, good positioning, thorough knowledge of radiographic anatomy, knowledge of the affections of the thoracic cavity etc. The present study was conducted with an aim to fabricate positioners for thoracic radiography in dogs and to evaluate thoracic radiographs in normal and diseased dogs. The relevant literature has been reviewed under the following subheadings: -

**2.1 Positioners and positioning aids for radiography**

**2.2 Affections of the thoracic cavity**

**2.3 Radiographic evaluation of the respiratory system**

**2.4 Radiographic evaluation of the cardio-vascular system**

**2.5 Evaluation of mediastinum, pleural space and extra thoracic structures**

### 2.1 POSITIONERS AND POSITIONING AIDS FOR RADIOGRAPHY-

Lynch (1971) was granted a patent for developing positioners for true lateral body positioning in human radiography. Various positioners like Crest, knee, ankle, abdomen etc were invented for radiography. The positioner blocks of the invention were made of X Ray permeable and semi radiolucent materials preferably of stiff semi yielding materials such as Styrofoam, Styrene or Ethafoam.

Ryan (1981) opined that patients which are anaesthetized, or even adequately tranquillized can be held in position with the help of foam blocks and sandbags.

Kirberger and Avner (2006) evaluated the effect of positioning on the appearance of selected cranial thoracic structures in the dogs and found some interesting information not previously described about cranial thoracic structures position and visibility in the dog. Ventrodorsal radiographs were preferred to dorsoventral radiographs for the evaluation of cranioventral mediastinum and sternal lymph nodes, due to low number of dogs and limited breed diversity in this study.

Mauragis and Berry (2011) proposed use of troughs, wedges, and sandbags for achieving good positioning for thoracic radiographs in dogs. They opined use of foam wedges to maintain laterality of patient and use of ‘V’ troughs to keep the patient spine and sternum aligned for VD /DV projections.

Muhlbauer and Kneller (2013) proposed that non manual restraint devices include sandbags, foam wedges and troughs are recommended whenever possible.

Thrall (2013) recommended that sedation should be avoided unless absolutely necessary as there may be artefactual atelectasis of the dependent lung. In sedated animals, the sandbags and wedges were used to ensure correct positioning in DV view, VD view and lateral view as per requirement of the cases.

Brown and Brown (2014) found that devices like sandbags, foam blocks and wedges, wood blocks and radiolucent trough could be used to assist the positioning during thoracic radiography. They also stated that U and V shaped troughs were essential to maintain patient in dorsal recumbency

**2.2 AFFECTIONS OF THE THORACIC CAVITY-**

Hyun *et al* (2004) through his study on sixty dogs and cats, reported high incidence of diaphragmatic hernia in three and a half years old males and one and a half years old females.

Johnson and Martin (2007) splendidly treated pyothorax in fifteen dogs among which ten dogs were presented with a history of tachypnoea or dyspnoea and five dogs were exhibiting tachypnoea or dyspnoea followed by onset of coughing. Two of these dogs also had painful subcutaneous swelling, one over lateral thorax and another ventral to the sternum.

Radhakrishnan *et al* (2007) examined 65 puppies with community acquired infectious pneumonia exhibiting clinical signs like hypoxemia, coughing, respiratory difficulty and exercise intolerance. History presented was cough in 49 (75%), lethargy in 40 (62%), anorexia in 35(54%), dyspnoea in 31 (48%) puppies. Tachypnoea in 51(78%), increased bronchovesicular lung sound in 48 (74%), increased respiratory efforts in 47 (72%) and fever in 31 (48%) of patients was observed during initial clinical examination.

Ricco and Graham (2007) examined a six years Welsh corgi dog presented for the evaluation of bilateral hind limb paresis, recumbency with no voluntary motor activity and deep pain. The dog had elevated heart rate (180 beats/min), marked cyanosis, hypotension, abdominal breathing pattern and decreased lung sound. Dorso caudal placement of heart sound was noticed on auscultation following anaesthesia. Later on, the case was found to be an undiagnosed diaphragmatic hernia.

Woo *et al* (2007) ascertained tracheal collapse in a dog presented with a history of dyspnoea, persistent cough and cyanosis with goose honking observed after episodes of excitements.

Amrute *et al* (2009) diagnosed bronchopneumonia in a Great Dane which was the presented with a history of laboured breathing, discharge from nostrils, inappetence and pyrexia. Clinically the dog had anaemic oral mucosa, moderate dehydration and bilateral muco-purulent discharge from the nostrils. While performing lung auscultation moist rales on left side of chest area were observed.

Dhumeaux and Haudiquet (2009) examined a six-year old dog presented with the history of acute respiratory distress since 12 hrs, tiredness without any obvious reason and non-productive cough for few days. On clinical observation, severe respiratory distress, cyanotic mucous membrane and tachycardia without arrhythmia was found. Later it came out to be a case of primary pulmonary osteosarcoma.

Geyer *et al* (2010) examined pulmonary lymphoma in 23 animals (16 dogs and 7 cats) with age groups ranging from 4 to 15 years, with a mean of 7.9 years. Out of them, thirteen patients were neutered females and 10 were neutered males. Breeds consisted of Scottish Fold cat (1), Domestic Shorthair cat (3), and Domestic longhair cat (3), Labrador Retriever (3), Golden Retriever (2), Shar Pei (1), Bernese mountain dog (1), Pug (1), English Bulldog (1), Doberman Pinscher (1), Great Dane (1), Australian Shepherd (1), West Highland White Terrier (1), Beagle (1), Kooikerhondje (1), and Scottish Terrier (1).

Meler *et al* (2010) diagnosed eosinophilic broncho pneumopathy on inspecting miniature Pinscher cross bred dog presented with a history of chronic productive cough worsened by excitement with occasional gagging for one year. On clinical examination an increased inspiratory effort and severe coughing episodes easily evoked by tracheal palpation was found. Severe crackle and expiratory wheezes were observed during thoracic auscultation.

Carminato *et al* (2011) diagnosed lipoid pneumonia stimulating lung malignancy in a ten years old male cross bred dog showing signs of fatigue and persistent cough. Crackles were observed in the right ventral thorax on thoracic auscultation suggestive of lower respiratory tract disease.

Klainbart *et al* (2011) examined a 12 years mixed breed dog exhibiting signs of pain, inability to stand, reluctance to move with respiratory sign of dyspnoea, tachypnoea (80 breaths/ min) and sinus tachycardia (160 beats/min). The case was diagnosed as traumatic urothorax.

Den Toom *et al* (2015) evaluated the interstitial pneumonia and pulmonary hypertension associated with suspected ehrlichiosis in a dog. It was found that canine monocytic ehrlichiosis (CME) might be associated with significant pulmonary disease and should be considered as a possible differential diagnosis in dogs presenting with dyspnoea and secondary pulmonary hypertension, especially in dogs that have been in endemic areas. This was important because CME was a treatable disease and its secondary lung and cardiac manifestations might be completely reversible.

## 2.3 RADIOGRAPHIC EVALUATION OF THE RESPIRATORY SYSTEM

Breton *et al* (1986) studied the lateral and ventrodorsal radiographs of a four-year old male Doberman dog which revealed bilateral pleural effusion that was more abundant in right hemithorax with the right middle lung lobe exhibiting air bronchograms and complete consolidation. The case was diagnosed as successive torsion of the left cranial and right lung lobe

Kern *et al* (1994) executed serial radiographic examinations in 24 adult mix-breed dogs to evaluate the incidence of unilateral and bilateral pneumothorax and its resolving capability following the introduction of air into the pleural space. Twenty-two (92%) experimental dogs developed bilateral pneumothorax and two dogs (8%) showed unilateral pneumothorax.

Neath *et al* (2000) examined radiographs of 22 dogs with lung lobe torsion revealing pleural effusion in all 22 cases. All radiographs showed one (n=19) or more (n=3) consolidated lung lobes. 10 dogs with right middle lobe consolidation, 9 with left cranial lobe consolidation, 4 with right cranial lobe consolidation, 1 with right caudal lobe consolidation and 1 with the left caudal lobe consolidation were diagnosed. Tentative diagnosis of lung lobe torsion was made in all dogs, but abnormal bronchial positioning consistent with torsion was seen in only 10 dogs.

Litman (2001) found traumatic diaphragmatic hernia in an otherwise clinically normal 3.5 years old Border collie dog through two sets of thoracic radiographs. In first set, lateral and dorsoventral thoracic radiographs revealed bilateral pneumothorax and marked atelectasis. Large soft tissue opacity and loops of intestines within the lung field were seen in second set of radiographs.

Dahl *et al* (2002) diagnosed bronchogenic cyst in a German shepherd dog on thoracic radiograph as a large rounded area of radiolucency surrounded by a thin radiopaque structure. No abnormal finding for the same case was revealed by bronchoscopy. They found that the lesion increased in volume between consecutive investigations, but otherwise remained alike in appearance.

Baumann *et al* (2004) analysed signs of metastatic disease in dogs diagnosed with mammary gland tumours through a retrospective study on thoracic radiographs. Through the radiography, intrathoracic metastatic disease was found in 13.5 per cent of dogs with malignant mammary gland tumours and 2.5 per cent of dogs with benign mammary gland tumours. It was stated that radiographs were not much sensitive to detect metastasis of mammary gland tumour in dogs at an early stage.

Sigrist *et al* (2004) characterized the clinical findings in dogs and cats that sustained blunt trauma and compared clinical respiratory examination results with post-traumatic thoracic radiography findings. It was found that thoracic trauma was encountered in many blunt trauma patients. The respiration rate of animals with blunt trauma was not useful in predicting thoracic injury, whereas abnormal chest auscultation results were indicative of chest abnormalities. Thorough chest auscultation was, therefore, mandatory in all trauma animals and might help in the assessment of necessity of chest radiographs.

Ober and Barber (2006) diagnosed structured interstitial patterns in dogs by comparing two view thoracic radiograph to three view thoracic radiograph and gave a conclusion that three-view study was better for possible structured interstitial pulmonary disease, including metastatic disease, as two view study would change the diagnosis in 12-15 per cent of patients only.

Echandi *et al* (2007) found a small volume of pleural fluid in thoracic radiographs with alveolar pattern at the level of the right middle lung lobe. At the level of seventh rib and intercostal space two nodular opacities were seen in the subpleural site. Furthermore, thoracic mesothelioma was confirmed as three areas of increased focal extra pleural opacities traversing the left cranial thoracic wall.

Kogan *et al* (2008) analysed radiographic findings in 88 dogs with aspiration pneumonia out of which thoracic radiographs of 65 (74%) dogs depicted a predominantly alveolar infiltrate, and in 23 (26%) dogs an interstitial pattern was found whereas only a single lung lobe was affected in 46 (52%) dogs. It was found that most commonly the right middle lung lobe (21/46 [46%] dogs) had the aspiration pneumonia.

Rani *et al* (2011) examined a six years old male terrier dog with primary lung carcinoma. Right lateral, left lateral and ventrodorsal view thoracic radiographs revealed pneumothorax and cardiac displacement with an opaque wedge-shaped mass in the left caudal lung lobe.

Reetu (2012) performed diagnostic imaging of thoracic cavity in dogs with special reference to respiratory system in various breeds. It was found that respiratory affections were highest in old dogs followed by adults and young ones. It was also concluded that males were more affected as compared to females with respiratory affections. Incidence of respiratory affections among various breeds was statistically highest in mongrel dogs and lowest in pug.

Barret *et al* (2014) conducted radiographic characterization of primary lung tumours in 74 dogs and concluded that a large mass affecting the periphery or the whole of the right middle or left cranial lung lobe with an internal air bronchogram was likely to be a histiocytic sarcoma. A mass in the mid-portion of any lobe was unlikely to be a histiocytic sarcoma. Bronchioalveolar carcinomas were difficult to distinguish from adenocarcinomas based upon radiography alone and tissue sampling was still necessary. The aim of the study was to describe tracheal diameter (TD) and thoracic inlet (TI) ratio (TD: TI), pulmonary patterns present, cardiac silhouette abnormalities and vertebral heart size (VHS) in dogs. Data collected were classified and grouped based on the age of the animal (growing, adult, senior) and the cephalic indices. The TD:TI ratio was normal in all radiographs regardless of cephalic index. Majority of pulmonary patterns observed in dogs with cough were mixed patterns consisting of alveolar and bronchial forms.

Pajas *et al* (2014) conducted a study in which lateral thoracic radiographs of dogs presented with coughing were assessed to determine abnormalities in selected thoracic structures. Thirty radiographic images were used to describe tracheal diameter and thoracic inlet ratio (TD: TI), pulmonary patterns present, cardiac silhouette abnormalities and vertebral heart size (VHS). Data collected were classified and grouped based on the age of the animal (growing, adult, senior) and the cephalic index. The TD:TI ratio was normal in all radiographs regardless of cephalic index. Majority of pulmonary patterns observed in dogs with cough were mixed patterns consisting of alveolar and bronchial forms. Loss of cranial waist and generalized cardiac enlargement were commonly seen in adult and senior dogs. Also, above normal VHS was observed in these animals, suggesting cardiac enlargement. The various radiographic abnormalities found in coughing dogs suggested that a more thorough clinical examination of patients must be done to rule out primary cardiac disease and secondary respiratory problems.

## 2.4 RADIOGRAPHIC EVALUATION OF THE CARDIO-VASCULAR SYSTEM

Buchanan and Bucheler (1995) concluded that the mean vertebral heart score in dogs is 9.7 ± 0.5 (mean ± SD) and 10.2 ± 0.83 vertebrae in lateral and ventrodorsal radiographs, respectively through the studies performed on 100 clinically normal adult dogs.

Lehmkuhl *et al* (1997) suggested caudal vena cava (CVC) size as an indicator of right-sided heart disease by comparing the ratio of the diameter of CVC on left lateral thoracic radiograph to the diameter of descending aorta (Ao), length of the thoracic vertebra above the tracheal bifurcation (VL) and width of right fourth rib (R4) in 35 dogs having right sided heart disease and 35 control dogs with normal heart function. Each CVC ratio (CVC/Ao, CVC/VL, CVC/R4) was statistically greater in dogs with right heart disease. A CVC/Ao < 1.00, CVC/VL < 0.80, or CVC/R4 < 2.25 indicated normal heart i.e. no right sided heart disease whereas a CVC/Ao > 1.50, CVC/VL > 1.30, or CVC/R4 > 3.50 strongly suggested the presence of right-sided heart abnormality.

Lamb *et al* (2000) evaluated the importance of the VHS calculation in the accurate radiographic diagnosis of cardiac diseases by undertaking study on radiographs of 50 dogs with proven cardiac disease, 26 dogs with other thoracic diseases and 50 dogs with no history and signs of cardiovascular or respiratory disease. VHS over 10.7 on the lateral radiograph was found to be moderately precise sign of an ongoing cardiac disease.

Lamb *et al* (2001) evaluated the use of breed specific ranges for the vertebral heart scale as an aid to the radiographic diagnosis of cardiac disease in dogs and assessed the reliability of the vertebral heart scale on accuracy of the radiographic diagnosis of cardiac disease. It was concluded that VHS was not a reliable indicator of cardiac disease.

Rosenstein *et al* (2001) studied radiographs of a dog revealing enlarged cardiac silhouette of irregular shape with incomplete visualization of diaphragm and only six Sternebrae visible. It was diagnosed as a case of diaphragmatic hernia and cholelithiasis.

Fox (2003) suggested that in lateral projection radiograph of a dog, the heart was situated between the 3rd - 8th thoracic vertebrae, occupies about 3 intercostal spaces, and measures about 8.5-10.6 (average, 9.7) vertebral bodies (T4) using the VHS method and hence defined the normal anatomical topography of the heart. Also, it was found that, heart had a roughly elliptical shape with a curved right ventricular and comparatively straight left ventricular border in the ventrodorsal or dorsoventral (DV) projections.

Hansson *et al* (2005) through his findings, found that mean VHS value of 10.8 ± 0.5 vertebrae was normal for cavalier King Charles spaniel dogs, which was slightly above the normal upper limit for VHS in most breeds.

Kibar and Alkan (2005) clinically, radiographically, and ultrasonographically examined 30 geriatric dogs of different breeds, of different age groups and sex such that 15 were females and 15 were males with suspected heart disease. It was found that the diseases resulting into dilation or hypertrophy of the heart usually affected two or more chambers. Left atrial enlargement with a bulge in the two to three o'clock position was found in one case; in two cases rounding of three to five o'clock position was found suggesting left ventricular enlargement; in seven cases right, atrial enlargement was diagnosed because of a bulge at 9 to 11 o'clock position; and a reverse 'D' configuration was found in five cases with right ventricular enlargement.

Diana et al (2009) studied mitral regurgitation in 61 dogs exhibiting cardiogenic pulmonary oedema on thoracic radiographs. The authors found diffuse increase in pulmonary opacity in 11 (18.0%) dogs, perihilar increased pulmonary opacity in 7 (11.5%) dogs and focal increase in pulmonary opacity in 43 (70.5%) dogs. Also, the radiographic evidence of asymmetric pulmonary oedema in a single lung lobe or 2 ipsilateral lobes was seen in 21 dogs and 17 dogs showed involvement of only right caudal lung lobe.

Vosugh and Nazem (2019) executed a study on 20 healthy male and 20 Domestic Shorthair (DSH) cats with right heart failure (RHF). The ratio of caudal vena cava (CVC) size to aorta (Ao), width of fourth rib (R4) and also the thoracic vertebral length (VL) were analysed and significant difference in the CVC/Ao and CVC/R4 between healthy and RHF cats was observed. CVC/VL had higher value in RHF cats as compared to the healthy ones ($P<0.05$) while Ao/VL was lower in right sided heart failure cats than the healthy cats. The study concluded that right heart failure disease in cats might lead to increase in the CVC/Ao, CVC/R4 and CVC/VL.

Boswood (2010) defined that conditions like chronic valvular disease, left sided heart failure, cardiomegaly, left atrial enlargement and increased alveolar density within the lung field in dogs could optimally be monitored using thoracic radiography.

Tappin (2010) stated that large volume pericardial effusions causing a large cardiac silhouette and elevation of the trachea can be evaluated through thoracic radiography.

Oyama (2011) noticed that increased vertebral heart score, increased height of cardiac silhouette or loss of cardiac caudal waist on lateral projection and left auricular enlargement at the two to three O'clock position on dorsoventral or ventrodorsal projection is indicative of left sided heart enlargement. Also enlarged pulmonary veins and perihilar and/or caudodorsal interstitial or alveolar pattern can be found.

Bodh *et al* (2016) conducted a study on Indian dogs to establish reference values of vertebral heart score (VHS) in Indian Spitz, Labrador retriever, and Mongrel dogs; to assess applicability of VHS in these three dog breeds. It was also envisaged to determine if breed, recumbency side, gender, body weight, and thoracic depth (TD) to thoracic width (TW) ratio had an influence on the VHS measurement in these dog breeds. It was found that Breed-specific VHS reference ranges should be used for the objective measurement of heart size in dogs. Furthermore, the radiographic view should also be taken into consideration to avoid any erroneous interpretation of cardiac enlargement in dogs.

## 2.5 EVALUATION OF MEDIASTINUM, PLEURAL SPACE AND EXTRATHORACIC STRUCTURES

Grandage (1974) evaluated various distinguishable radiographic features of the dog diaphragm and concluded that crura was most mobile and the dependent one sagged forward more than the upper one in lateral recumbency. Due to this crura appeared parallel in right lateral recumbency and crossed each other in left lateral recumbency. In frontal DV or VD projection diaphragm was visualized as a solitary dome shaped or triple domed clover leaf structure which included cupula alone and crura both respectively.

Jensen and Arnbjerg (2001) conducted a prospective longitudinal radiographic study on the development of intervertebral disk calcification of thoracic and other vertebrae in the dachshund. They concluded that in dachshunds there was high and low prevalence rates of intervertebral disk calcification in dogs between 6 to 8 months and 8 to 24 months of age, respectively.

Liptak *et al* (2008) studied caudodorsal displacement of cardiac silhouette and lungs with dorsal elevation of the trachea due to cranial mediastinal mass in two dogs through thoracic radiography. A lytic lesion was found in the second rib and also in first and second vertebrae in one dog which was confirmed using CT scan. Thoracic radiographs of four dogs also revealed pleural effusions.

Szezepaniak *et al* (2011) diagnosed retrosternal diaphragmatic hernia in a one-month old female Shih – Tzu puppy through thoracic radiography. Increased lung opacity, narrowed tracheal lumen, enlarged and rounded cardiac silhouette were found during survey radiography with obscured ventral diaphragmatic surface and minute round gas shadow over cardiac silhouette. Presence of numerous small intestine loops in pleural space between cardiac silhouette and thoracic wall were confirmed through contrast radiography.

Smith and O’Brien (2012) conducted study on radiographic characterization of enlarged sternal lymph nodes in 71 dogs and 13 cats and concluded that sternal lymphadenopathy may occur due to affected organs of origin and many diseases. Enlarged lymph nodes were commonly associated with conditions like disseminated and intraabdominal neoplasia, inflammation and haematology. There was no significant advantage for evaluating the lymph nodes based on lateral view and no differences in size or location of lymphnodes were recorded between lateral views within the species.

# CHAPTER III

## MATERIALS AND METHODS

The present work was conducted with the aim to fabricate positioners for thoracic radiography and to evaluate thoracic radiographs in apparently healthy as well as diseased dogs presented to the Department of Veterinary Surgery and Radiology, GADVASU, Ludhiana. The study was divided into 2 parts. Part 1 of the study was conducted on fabrication of different positioning devices like wedges, sand bags from economical and durable materials procured from the local market. Part 2 of the study was conducted on at least 500 thoracic radiographs of dogs presented.

**PART 1**

The study was conducted for fabrication of different positioning devices like troughs wedges and sand bags from economical and durable materials procured from the local market.

For the fabrication of troughs and wedges three different kind of foam materials viz. expanded polyethylene foam (EPE foam), polyethylene (PE) foam and polyurethane (PU) foam (Fig.1) were procured from the local market. Each material was then tested for opacity and strength.

Opacity was tested by taking a single radiograph with exposure factor – 12 mAs and 65 kVp (used for thoracic radiography in medium sized dogs) after placing foam blocks of equal dimensions of all the three materials on a single DR cassette (TRIMAX 3543C). The opacity seen on the radiograph was evaluated and graded by a single observer as mildly visible, moderately visible and prominently visible. The strength of the materials was evaluated by putting animal weight and graded in terms of toughness and cushioning. The material showing least opacity and having good strength was selected for fabricating troughs and wedges of different sizes. A set of four troughs and one wedge was fabricated for dogs of different sizes. Green parachute cloth was pasted over the fabricated troughs and wedges properly with industrial pasting lotion such that there were minimum or no air spaces left between the cloth and the foam.

**Expanded Polyethylene (EPE) Foam**

**Polyethylene Foam**

**Polyurethane (PU)Foam**

**Fig. 1: Equal blocks of different types of foam materials tested for fabrication of troughs and wedge**

For the fabrication of sandbags, four types of cloth material viz Parachute cloth, canvas leather, cotton matty and PVC American Matty were collected from the local market. The cloth was stitched into cylindrical bags (Fig.2) which were then filled with coarse gravel of similar type. The sandbags were tested based on the following parameters:

Strength: The strength was tested by analysing the ability of cloth to bear the weight of gravel without damage. The strength of cloth was graded as

Good: Stable and strong seam after filling of gravel

Fair: Loosening of seam after filling of gravel

Poor: Seam did not hold after filling of gravel

Mouldability of the cloth was subjectively graded as:

Good: Able to take the contour of the part being immobilized.

Fair: Able to mould partially according to part being immobilized;

Poor: Not able to mould and remained stiff.

The thickness of the cloth was graded subjectively as very thin, thin, thick, very thick.

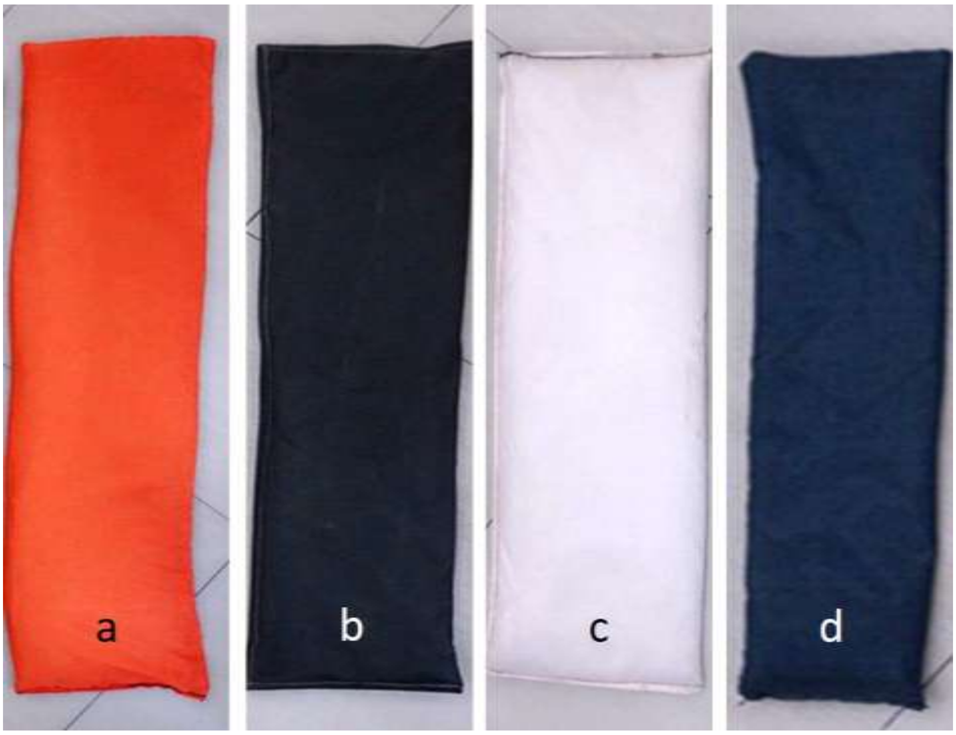



**Fig. 2: Cylindrical sandbags prepared using different types of cloth materials (a) Parachute cloth (b) Canvas leather (c) Cotton Matty (d) PVC American Matty**

The material showing good strength, appropriate thickness and mouldability was selected for making sandbags of different sizes, A set of 6 large and 2 small sandbags was fabricated for dogs of different sizes.

The cost of fabricating one set of positioners which included Four(4) troughs of different sizes, one (1) wedge and eight (8) sandbags of different sizes was worked out. This set was further evaluated in part 2 of study

**PART 2**

The study was conducted on 507 thoracic radiographs obtained from 134 dogs presented at University Veterinary Hospital, GADVASU, Ludhiana.

Positioners fabricated in part 1 of study were evaluated on the clinical cases for their feasibility to use in routine thoracic radiography. The strength of troughs and wedge was tested by placing the animal on the positioners. Animals were positioned in different recumbencies according to the projection such as ventrodorsal and dorsoventral recumbencies using the positioners and wedges. The sandbags were used in lateral recumbency. Any signs of uneasiness, discomfort to the patient was recorded. Also, strength of the positioner was recorded in terms of its ability to withstand the weight of the animal and breakage if any.

Variable exposure factors with different combinations of kVp ranging between 50-80 and mAs ranging between 10-20 were used for taking thoracic radiographs (Fig. 3) depending upon the size of the animal. Mauragis and Berry (2011) proposed a technique to obtain long grey scale images to evaluate the structures of thorax in thoracic radiographs using high kVp and low mAs. The radiographs were taken in the desired recumbency aided by the positioners.


**Fig. 3: Control panel of the X-ray machine (Wipro GE DX-300) showing exposure settings of 50 kVp and 12 mAs**

The ease of use of the positioner by the radiographer/technician and comfort in handling of the positioners were evaluated subjectively on the basis of ease to carry, weight of the positioner and compatibility with the patient.

Radiographic opacity of the fabricated positioners i.e. the opacity of positioners as evident on the radiographs was evaluated by a single observer and compared with that of commercially available acrylic positioners.

The fabricated positioners were used for taking thoracic radiographs in the dogs, wherever required. A total of 507 thoracic radiographs taken from 134 dogs in different projections. For all the animals undergoing thoracic radiography, at least three views viz: right lateral, left lateral and ventrodorsal/dorsoventral were taken in respective recumbencies for screening or assessment of thoracic disorders.

Out of total 134 dogs included in the study, 38 dogs were apparently normal (group-1) and presented for routine screening, vaccinations or elective procedures. The remaining 96 dogs were diseased and were divided into groups according to disorders viz. dogs with pulmonary disorders (n=70, group-2), cardiopulmonary disorders (n=25, group-3) and extra thoracic affections (n=1, group-4). Any dog having cardiac involvement concomitant with pulmonary disorder was included in the cardiopulmonary group similarly, extra thoracic affections concomitant with pulmonary or cardiac affections were included in the above respective groups.

**Observations recorded:** The following observations were recorded for each group

**Signalment:** Age of animals was recorded in years; Gender was recorded as male or female. Breed was recorded on the basis of distinctive appearance and also was classified into brachycephalic, dolichocephalic or mesocephalic on the basis of head shape.

The radiographs were evaluated for the following parameters:

i. Lungs: The lungs were evaluated in all dogs for any lung pattern. The overall lung pattern seen in different lobes of the lungs was decided on the basis of all the available views for a particular dog. The lung pattern was classified as alveolar/ interstitial/bronchial/ vascular/mixed/ normal. Other changes in the lungs (if any) were also recorded.

ii. Heart: The heart was evaluated for shape in terms of normal (oval or elliptical) or apparently enlarged (or globoid). In lateral projection, the size of heart was evaluated by measuring vertebral heart score as per method described by Muhlbauer and Kneller (2013) For calculating VHS, the length of the cardiac silhouette was measured from base of the carina to the apex of the heart (long axis). The short axis of the cardiac silhouette was measured as the broadest part of the heart perpendicular to the long axis. These lengths were then transposed over the thoracic spine beginning at the cranial edge of T4 and the number of vertebral bodies along each measurement was estimated and then added together to calculate the VHS (Fig. 4) The number of intercostal spaces occupied by the cardiac silhouette, sternal contact along with the presence or absence of border effacement were also recorded. On VD/DV view the percentage of cardiac silhouette occupying the thoracic cavity was recorded. The widest part of the cardiac silhouette perpendicular to the long axis(x) and the widest part of the thoracic cavity perpendicular to the long axis (y) were measured. The percentage occupied by the cardiac silhouette was calculated as $x/y \times 100$ (Fig. 5)

iii. Cranial and Caudal Mediastinum: The cranial and caudal mediastinum were evaluated for any space occupying lesion. Visibility of oesophagus in the cranial or caudal mediastinum was evaluated. Trachea was evaluated for its course whether normal, deviated dorsally or ventrally. Diameter of trachea was also recorded. Shape, size and deviation of carina were evaluated. The diameter of the thoracic inlet (TI) was recorded as distance between the cranioventral edge of T1 vertebra and the craniodorsal edge of the manubrium and expressed in mm and the diameter of the trachea (TD) was recorded at the same level and expressed in mm (Fig. 6). The diameter of carina was recorded at the level of base of heart and expressed in mm. The TD:TI ratio was then worked out. The width of proximal $1/3^{rd}$ of the $3^{rd}$ rib was measured on the radiographs and the TD was compared with the width of the proximal $1/3^{rd}$ of $3^{rd}$ rib as described by Muhlbauer and Kneller (2013)

iv. Pleural space: Pleural space was evaluated for presence of fluid/ air/ fissure lines or mass on lateral and VD/DV projections.

v. Vascular structures: The vascular structures viz. aorta, caudal vena cava, pulmonary vessels i.e. pulmonary artery and vein were evaluated for their diameter and visibility. On lateral radiographs diameter of aorta was measured midway between carina and cranial diaphragmatic crus and expressed in mm. The diameter of caudal vena cava was measured midway between caudal border of cardiac silhouette and cranial diaphragmatic crus (Fig. 7). These diameters were compared with the length of T6 vertebra as described by Muhlbauer & Kneller 2013. The diameters of cranial pulmonary artery and vein were measured at the level of fourth rib and compared to proximal $1/3^{rd}$ of $4^{th}$ rib in lateral view and the diameters of caudal pulmonary artery and vein were measured where it intercept the $9^{th}$ rib. Width of $9^{th}$ rib was measured separately from where it intercept the artery and vein and then caudal pulmonary artery/vein diameters were compared with respective $9^{th}$ rib diameter in VD and DV views (Fig. 8).

vi. Extra thoracic structures: The extra thoracic structures viz. diaphragm, ribs, sternebrae, vertebral column and thoracic inlet were evaluated. Diaphragm was evaluated for its continuity, ribs for any deformity or fracture, costochondral reactions or congenital rib disorders, Sternebrae and vertebral column were

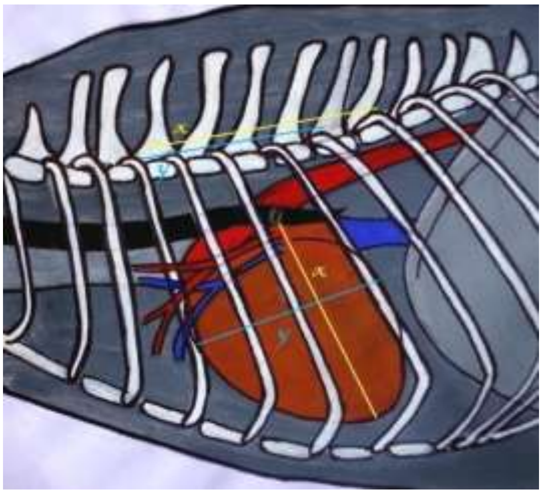


**Fig. 4:** **Schematic diagram of lateral view of thorax showing method for calculating VHS for estimating heart size**

**x= length of the cardiac silhouette measured from base of carina to apex. y= width of cardiac silhouette measured at the broadest part of the heart perpendicular to y. x and y are transported along thoracic spine beginning at the cranial edge of T4 and the number of the vertebral bodies along each measurement is estimated and then added together to calculate VHS.**

**Fig. 5:** **Schematic diagram of DV/VD view of thorax showing measurement of percentage of cardiac silhouette in thoracic cavity**

**x= the widest part of cardiac silhouette (perpendicular to long axis), y= the widest part of thoracic cavity (perpendicular to long axis), Percentage= x/y×100**

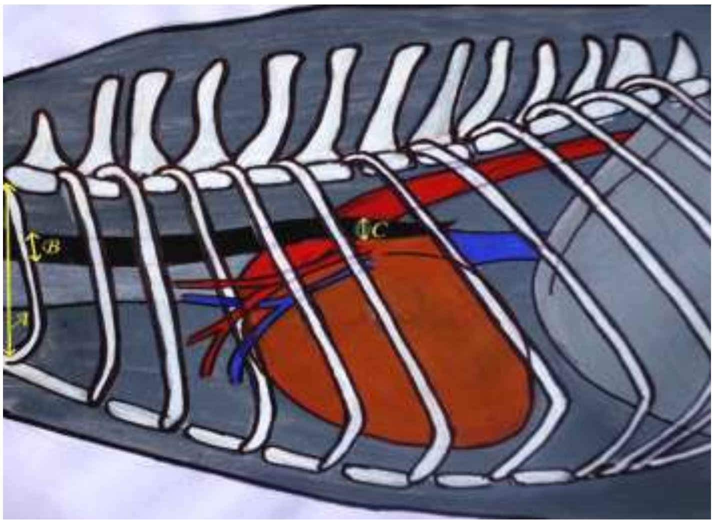




**Fig. 6:** **Schematic diagram of lateral view of thorax showing measurement of structures in cranial mediastinum**

**Thoracic inlet diameter (A) between cranioventral edge of T1 and craniodorsal edge of first Sternebrae, Tracheal diameter (B) at the same level, Tracheal ratio=B/A, Carina diameter(C).**

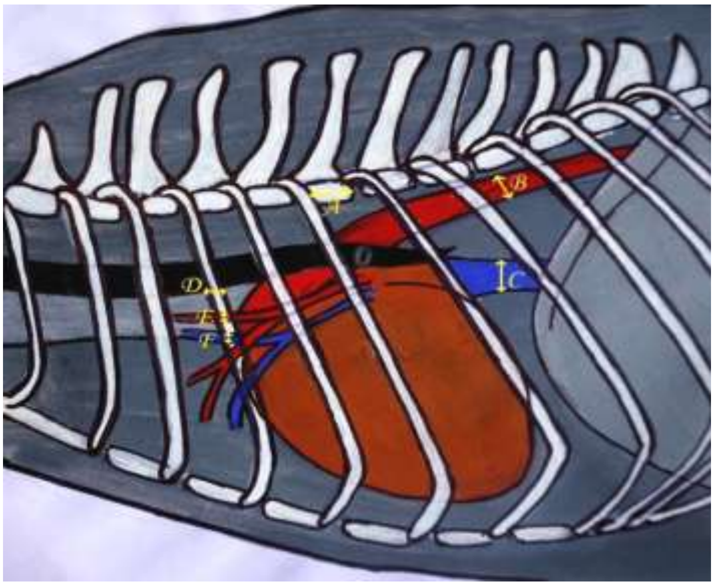




**Fig. 7:** **Schematic diagram of lateral view of thorax showing measurement of vascular structures**

**T6 length(A), Aorta(B) diameter measured midway between carina to cranial crus, Caudal vena cava(C) diameter measured at midway caudal cardiac silhouette to cranial crus, width of the $4^{th}$ rib(D), Width of cranial pulmonary artery(E), Width of cranial pulmonary vein(F)**

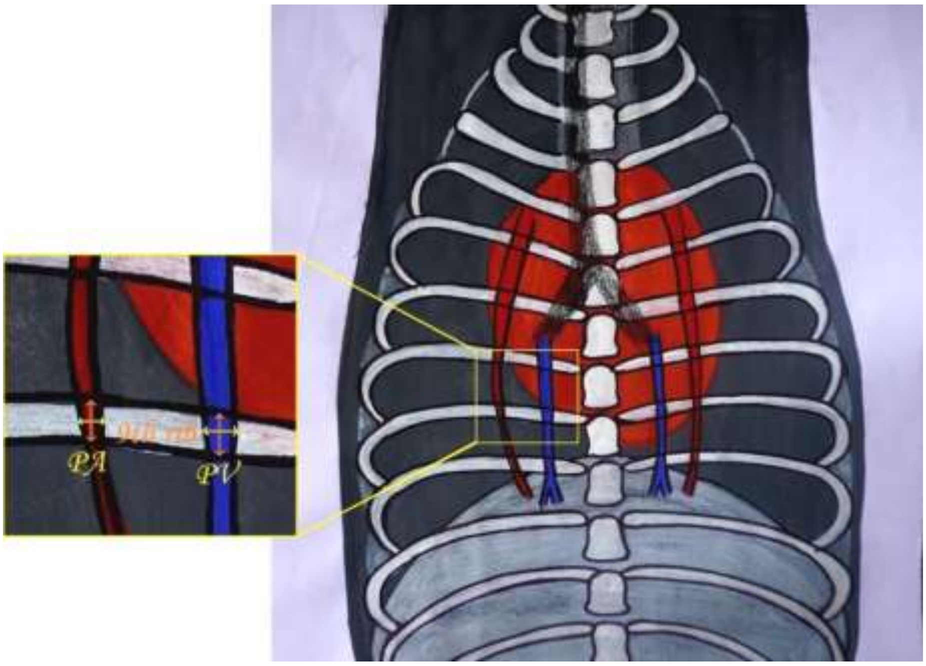



**Fig. 8:** **Schematic diagram of DV/VD view of thorax showing measurement of vascular structures**

**Caudal pulmonary artery (PA) measured where its intersected 9$^{th}$ rib, Caudal pulmonary vein (PV) measured where its intersected 9$^{th}$ rib, 9$^{th}$ rib is measured from place where both caudal vessels intersect**

evaluated for congenital defects, traumatic fractures or bony reactions like spondylosis.

Standard operative procedure (SOP) for reading a thoracic radiograph was developed and proposed.

Criteria for declaring the thoracic radiographs as normal in dogs belonging to apparently normal group was established on the basis of findings.

**Statistical analysis**

The data was analysed by using SPSS 25.0 software. The mean ± SE values for different parameters under study were evaluated. The differences between groups was analysed using one-way anova (Tukey's method). Correlation between various parameters was analysed by using Pearson's correlation coefficient.

# CHAPTER IV

# RESULT AND DISCUSSION

The present work was aimed to fabricate animal positioners for thoracic radiography in dogs and to evaluate thoracic radiographs in apparently normal and diseased dogs. Part 1 of the study was aimed to develop indigenous radiographic positioners for thoracic radiography in dogs. Part 2 of the study was conducted on 507 thoracic radiographs obtained from 134 dogs in order to establish the criteria for declaring a thoracic radiograph as normal and to evaluate thoracic radiographs in relation to various disease conditions.

## PART 1:

The study involved fabrication of different positioning devices like wedge, troughs and sandbags from economical and durable materials procured from the local market. The results of the study are presented below.

### Fabrication of Troughs and Wedges

Three different kinds of foams viz. Expanded polyethylene (EPE) foam, Polyethylene foam and Polyurethane (PU)-foam were procured from the local market for the manufacture of troughs and wedge. These were then tested for Opacity and Strength.

Opacity of material referred to the radiopacity exhibited by the material on the radiographs taken. Radiograph of the three foam blocks was taken on a single cassette with exposure factors set at 12 mAs and 65 kVp (Fig. 9). It was observed that expanded polyethylene (EPE) foam showed mild radiopacity while polyethylene (PE) foam showed moderate radiopacity and polyurethane (PU)-foam was the most radiopaque among the three materials (Table 1). This suggested that the EPE foam could be a suitable material for the fabrication of troughs and wedge.

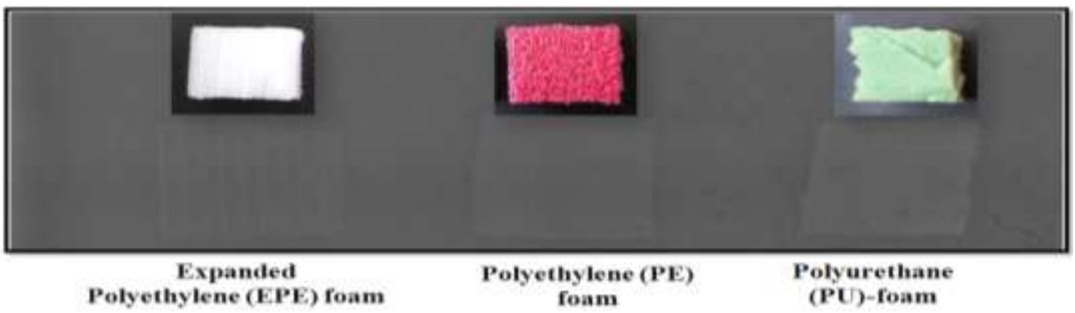



**Fig. 9: Radiopacity of different foam materials used in the study**

Strength was tested by putting animal weight on the foam sheets (Table 1). Expanded polyethylene (EPE) foam was found to be tough and cushiony which was comfortable for the animal. Polyethylene foam was also tough but was less cushiony as compared to the EPE foam. However, PE foam was also comfortable for the animal. Polyurethane (PU)-foam was less tough and compressed completely with the weight of animal, so was not considered suitable. Further the PU foam was difficult to cut and serrated edges were formed after cutting of the foam (Fig. 9). On the other hand, the EPE and PE foam were easy to cut and design as per desired shape using a hacksaw blade.

**Table 1: Observations of testing the foam for opacity and strength for the manufacture of troughs and wedge**

| Materials used | Opacity | Strength |
|---|---|---|
| Expanded polyethylene (EPE) foam | Mild | Tough and cushiony |
| Polyethylene foam | Moderate | Tough but less cushiony |
| Polyurethane (PU)-foam | Prominent | Less tough and more cushiony |

Hence, based on the above parameters EPE foam was selected for the manufacture of wedge and troughs. These were then covered by pasting a thin, waterproof parachute cloth with the help of industrial pasting lotion. After pasting, the cloth was found to have no opacity on the radiograph. A set of four troughs of different sizes and one wedge (Fig. 10) was fabricated according to the estimated size of the animals using the selected materials as per the dimensions given in Fig. 11, Table 2. The measurements of the wedge fabricated was Length (L)-29cm, Breadth (B)-12 cm and Height (H) - 6cm.

**Table 2: Dimensions of fabricated troughs for various sizes of dogs**

| Trough for (dogs) | Width of positioner (W) | Height of positioner (H) | Length of positioner (L) | Thickness at centre (TC) | Wall width (WW) | Inner width (IW) |
|---|---|---|---|---|---|---|
| Large | 45 cm | 19cm | 88cm | 9cm | 6cm | 8cm |
| Medium | 42 cm | 18cm | 65cm | 9cm | 5cm | 6cm |
| Small | 28 cm | 17 cm | 27cm | 8cm | 3cm | 5cm |
| Toy breed | 27 cm | 16 cm | 27cm | 7cm | 2cm | 4.5cm |

**Fabrication of sand bags**

For the fabrication of sand bags, different kind of cloths viz. parachute cloth, canvas leather, cotton matty, PVC American matty were collected from the local market, stitched into cylindrical bags and filled with coarse gravel (Fig. 2). The sandbags so fabricated were tested for strength, thickness and mouldability (Table 3**).**

The parachute cloth had poor strength as seam did not hold after filling of gravel. Thickness of the parachute cloth was graded poor because cloth was very thin and was not considered suitable for making sandbags. The mouldability was however good.

Canvas leather had good strength as it was easily stitched and seam held well after filling of gravel. However, mouldability and thickness was poor because it was extra thick and did not have the ability to contour according to the shape of the part to be immobilized.

Cotton Matty had good strength to be stitched and held the seam after filling of gravel, thickness and mouldability was of fair quality.

PVC American Matty had good strength, was easy to stitch and could hold the seam well after filling of gravel. It had good mouldability and thickness because it was having an appropriate thickness and was able to be take the contour of the part to be immobilized easily.

**Table 3: Parameters observed for evaluating the cloths for fabrication of sandbags.**

| **Materials Used** | **Strength** | **Thickness** | **Mouldability** |
|---|---|---|---|
| Parachute cloth | Poor | Very thin | Good |
| Canvas leather | Good | very thick | poor |
| Cotton Matty | Good | Thick | Fair |
| PVC American Matty | Good | Thin | Good |

The PVC American Matty was selected for fabrication of sandbags because of its good strength, appropriate thickness and good mouldability. Eight sandbags of two different sizes (large and small) were fabricated using this cloth, which were then filled with coarse gravel (Fig. 12).

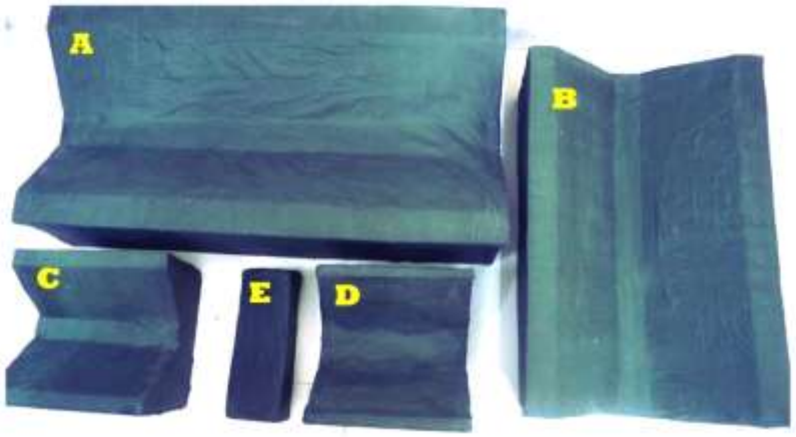
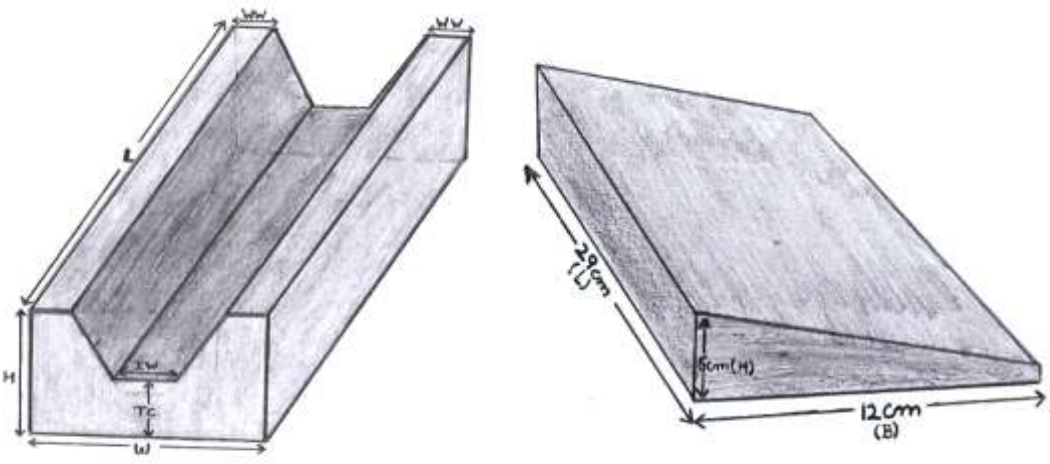



**Fig. 10: Fabricated troughs and wedge of different sizes**

**A-for giant breeds, B-for medium and large breeds, C-for small breeds, D for toy breeds and E-wedge for all sizes of dog**




**(a)** **(b)**

**Fig. 11: Diagrammatic representation of the fabricated trough (a) and wedge (b)**

**{W- width, H-height, L-length, TC-thickness at centre of trough, WW- wall width at centre of trough, IW-inner width at centre of trough, B- breadth}**


**Fig. 12: Fabricated sandbags using PVC American Matty**

**L-for immobilizing large dogs, S-for immobilizing small/toy breed dogs**

**Cost of 4 troughs and 1 wedge**: The cost of one EPE sheet was Rs 1200 per piece. For the manufacture of 4 troughs of variable sizes and 1 wedge, 4 EPE sheets were used. So, the total cost of these sheets was Rs.4800. The parachute Cloth, pasted over the troughs and wedge was priced at Rs.150 per meter and 10 meters of this cloth was used in covering 4 troughs and 1 wedge. So, the total cost of this cloth used was Rs.1500. Industrial pasting lotion employed for the pasting of cloth was priced at Rs 480 per piece (can) and 3 (250 gm) such cans were used making total cost of the pasting lotion to be Rs. 1440.The Labour cost for fabricating the wedge and troughs was Rs 1250.

**Cost of 8 sandbags:** PVC American Matty cloth used for the manufacture of 8 sandbags of variable sizes costed Rs. 220 per meter in the market. 10 meters of this cloth was used in making the sandbags which costed Rs. 2200 in total. For the stitching of the sandbags 2 rolls of sewing thread was employed worth Rs. 250 per piece. The total labour cost for filling of gravel and stitching of set of 8 sandbags was Rs 750/-

The Cost of the set of positioners manufactured including 4 troughs, 1 wedge and 8 sandbags was worked out to be INR12440/- (Table 4). Lynch (1971), Ryan (1981), Kirberger and Avner (2006), Mauragis and Berry (2011), Muhlbauer and Kneller (2013) and Brown and Brown (2014) also reported that devices like sandbags, foam blocks and wedges, wood blocks and radiolucent trough can be used to assist the positioning during thoracic radiography. They also stated that U and V shaped troughs are essential to maintain patient in dorsal recumbency.

**Table 4: Calculation of total cost of fabricating set of the positioners**

| Items | Cost of item (in Rs.) per piece/ per meter | No./ meters of item used | Totals (in Rs.) |
|---|---|---|---|
| EPE foam | 1200 | 4 | 4800 |
| Cloth (troughs & wedges) | 150 | 10 | 1500 |
| Sandbag cloth (PVC American Matty) | 220 | 10 | 2200 |
| Industrial pasting lotion | 480 | 3 | 1440 |
| | 1250 (wedges and trough) | _ | 1250 |
| Labour | 750 (sandbags) | _ | 750 |
| | 250 (sewing thread) | 2 | 500 |
| **Total cost** | **12440/-** | | |

**PART 2:**

The animal positioners fabricated in part 1 of the study were further evaluated in clinical cases requiring thoracic radiography (Part 2of study). It was found that the positioners fabricated were comfortable for the animals and the dogs showed no signs of discomfort when positioned and restrained in the troughs for VD/DV views. The four different sizes of troughs fabricated for dogs of different body size were found suitable and provided the radiographer with flexibility to use appropriate size of positioner. Dogs were sedated wherever required as proposed by Ryan (1981). However, Feeney (2011) and Thrall (2013) recommended that sedation should be avoided unless absolutely necessary as there may be artefactual atelectasis of the dependent lung. In sedated animals, the sandbags and wedges were used to ensure correct positioning in DV view (Fig 13a), VD view (Fig 13b) and lateral view (Fig 13c) as per requirement of the cases. In unsedated animals, manual restraint was adapted and the troughs were used for achieving correct positioning (Fig 14 and 15). It was found that the sandbags, troughs and wedge were suitable for achieving good quality radiographs with minimal to no obliquity, Mauragis and Berry (2011) also proposed use of troughs, wedges, and sandbags for achieving good positioning for thoracic radiographs in dogs. They opined use of foam wedges to maintain laterality


**Fig. 13: Sedated animlas positioned by using fabricated positioners in Dorsoventral (a), Ventrodorsal (b) and Lateral(c) recumbencies**

of patient and use of ‘V’ troughs to keep the patient’s spine and sternum aligned for VD /DV projections. Muhlbauer and Kneller (2013), Brown and Brown (2014) and Sharma (2018) have also recommended use of positioners viz wedges, sandbags and troughs for thoracic radiography in dogs. Positioners were found to be very easy to use and comfortable to handle. The patients did not experience any kind of discomfort or uneasiness during different radiographic projections using the positioners. The positioners had optimal light weight, hence were found to be very easy to carry, place or transport. They were cushiony but hard enough to withstand weight of the animal without compromising the animal’s comfort and ease at handling by the radiographer. Positioners had enough strength to withstand the animal weight without any kind of breakage, both in sedated as well as in non-sedated animals. The sand bags were sufficient to restrain the animals in the desired position. It was found that the opacity of positioners did not interfere with the radiographic quality and evaluation and had negligible opacity (Fig 9). The

Indigenously fabricated wedges and troughs prepared using EPE foam of desired dimensions according to the size of the dog, in the present study, were economical and suitable for obtaining well positioned and good quality radiographs with minimal to no obliquity. The sand bags prepared from American Matty cloth were suitable for restraining sedated patients in the desired position.

**Comparison of radio-opacity of fabricated and Commercially available positioners**

It was found that the opacity of positioners did not interfere with the radiographic quality and evaluation and had negligible opacity which was lesser than the opacity of readymade acrylic positioners available in the market (Fig-14 and 15). Sides of the trough fabricated in the present study showed mild radiographic opacity which might be due to increase in thickness at the sides. However, the opacity of the troughs did not interfere with the area of interest and the radiographs produced were of diagnostic quality.

Further, the part 2 of the study was conducted on 507 thoracic radiographs from 134 apparently healthy as well as diseased dogs

Twenty nine out of 134 dogs in the present study were brachycephalic breeds (Fig-16) which included Pug (14), Pitbull (4), Mastiffs (5) (English Mastiff, French

Mastiff and Bull Mastiff), Cane Corso (2), American Bully (1), Shih Tzu (1), Lhasa Apso (1) and French Bulldog (1) breed. Ninety five out of 134 dogs were mesocephalic including Non-descript (14), Labrador Retriever (47), Golden retriever (6), Beagle (5), Rottweiler (5), Cocker Spaniel (6), Culture Pomeranian (1), Pomeranian (6), Saint Bernard (2), Toy Pomeranian (1) and Gaddi (2). Ten out of 134 dogs were dolichocephalic including German Shephard (6), Greyhound (1), Great Dane (1), Doberman (1) and Dachshund (1) breeds. The study included 47 female and 87 male dogs (Fig-17) with age ranging between 0.16 to 14 years having a mean± SE value of 6.23± 0.30 years. The body weight of the dogs ranged between 1.8 to 65 kg with mean± SE of 24.48 ± 1.08 kg. The above data shows that the dogs of all age groups, weight groups and breed types were included in the present study.

The 134 dogs in the present study included 38 apparently normal dogs (N=38, Group 1) presented for routine screening, vaccination or elective procedures. The remaining 96 dogs were diseased and were divided into groups according to disorders viz. dogs with pulmonary disorders (n=70, group-2), cardiopulmonary disorders (n=25, group-3) and extra thoracic affections (n=1, group-4). Any dog having cardiac involvement concomitant with pulmonary disorder was included in the cardiopulmonary group similarly extra thoracic affections concomitant with pulmonary or cardiac affections were included in the above respective groups (Fig-18).

**Radiographic evaluation of apparently normal dogs (Group 1, n=38)**

Out of a total of 38 normal dogs, 9 were brachycephalic which included 5 Pug, 1 French Mastiff, 1 Cane Corso, 1 French Bulldog and 1 Lhasa Apso breeds. Twenty-six dogs were mesocephalic which included 6 Non-Descript, 13 Labrador Retriever, 1 Indian Spitz, 1 culture Pomeranian, 1 Pomeranian, 2 Saint Bernard and 2 Rottweiler and three were dolichocephalic breeds including 2 German Shepherd and 1 Grey Hound as shown in Fig-19. There were 14 female and 24 male dogs (Fig-20) with age ranging between 0.2 to 14 years having mean ±SE value of 5.45 ± 0.57 years. The mean±SE value of weight was 22.10 ± 1.79 kg.

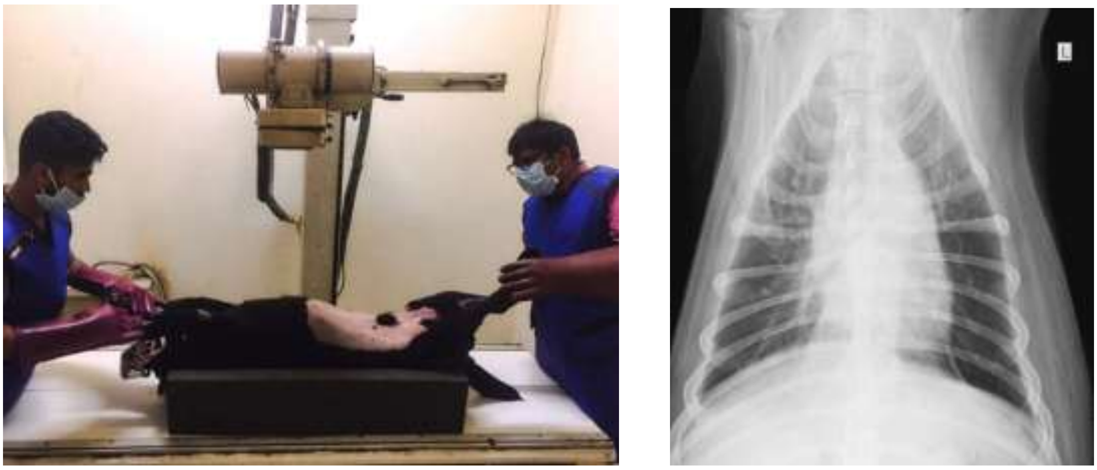



**Fig. 14:** **Use of trough for taking a VD projection in medium sized dog. The radiograph shows good positioning and is of diagnostic quality. The opacity of positioner is barely appreciable on the radiograph**

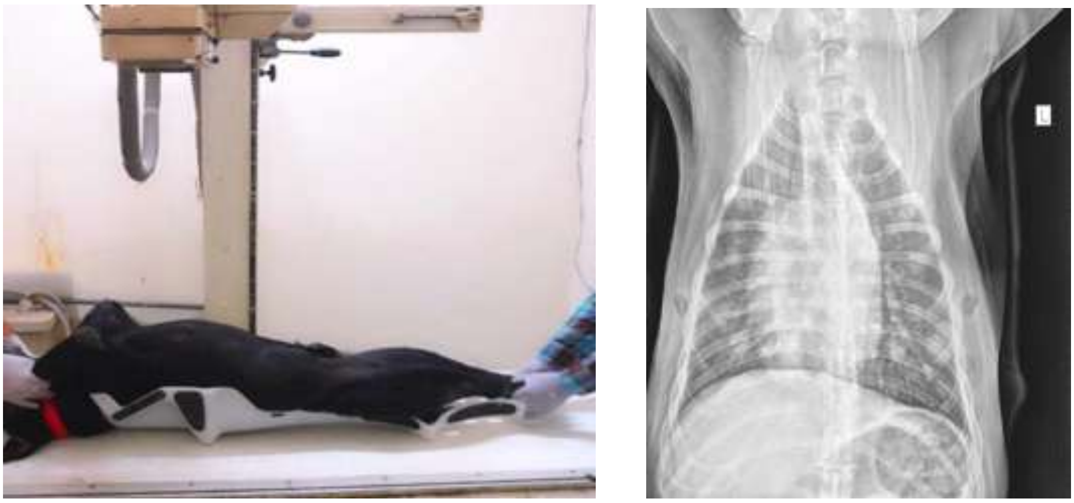



**Fig. 15:** **Use of commercially available acrylic trough for taking a VD projection in medium sized dog. The radiograph shows good positioning and is of diagnostic quality. The opacity of acrylic trough is appreciable on the radiograph**

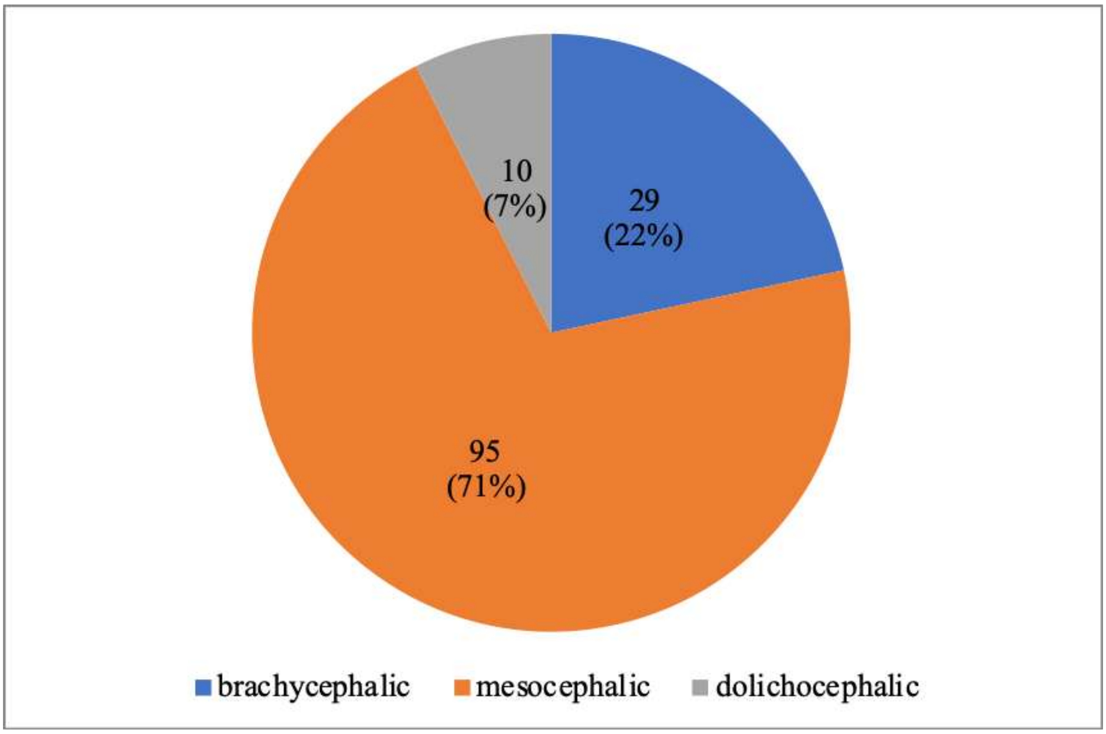



**Fig. 16: Distribution of dogs included in the study (N=134) on the basis of type of head**

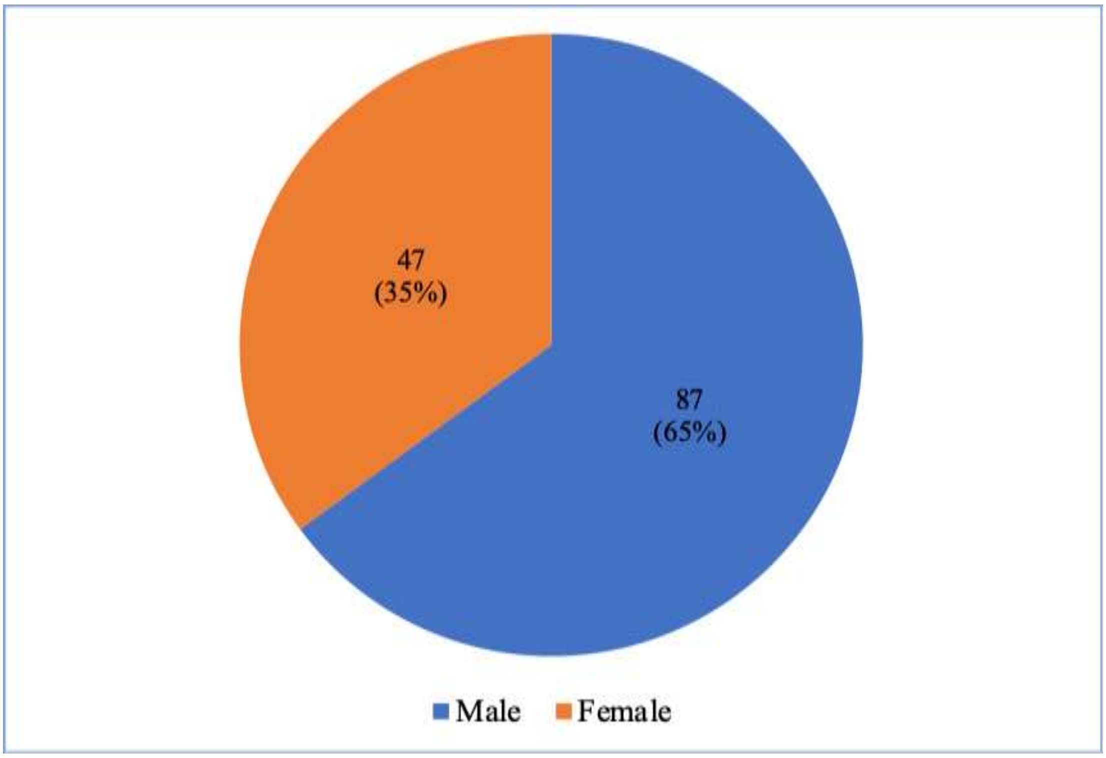



**Fig. 17: Distribution of dogs included in the study (N=134) on the basis of gender**

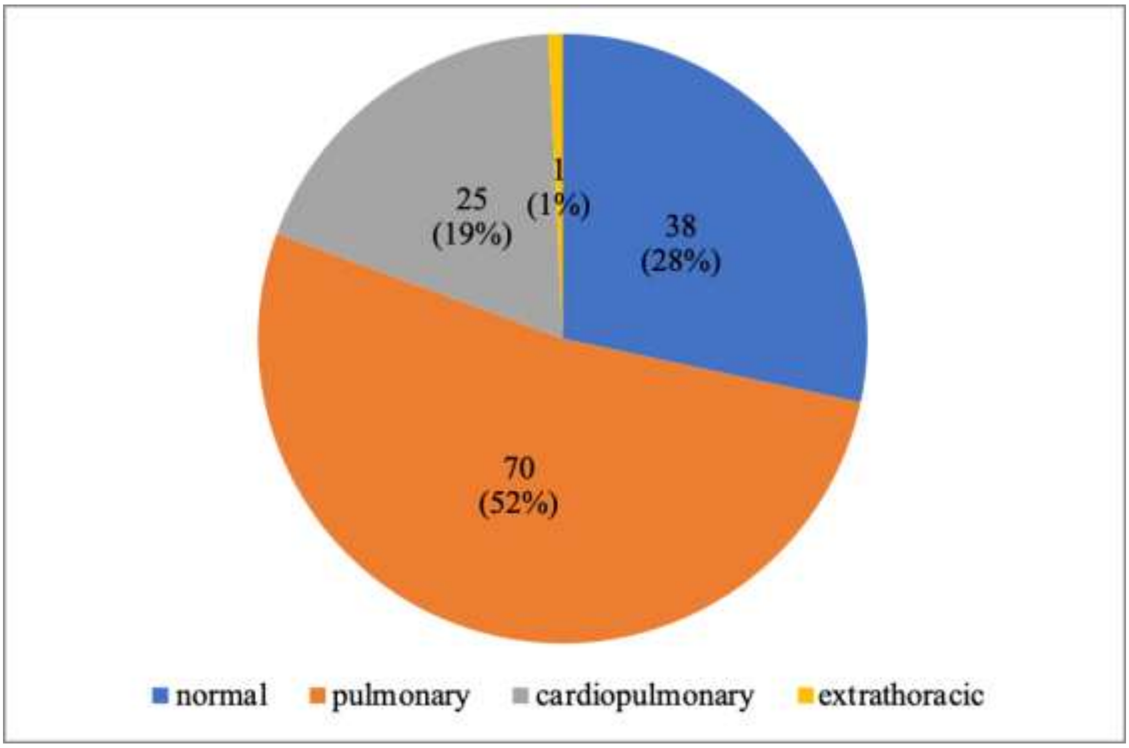



**Fig. 18:** **Distribution of dogs included in the study (N=134) on the basis of normal or type of disorder**

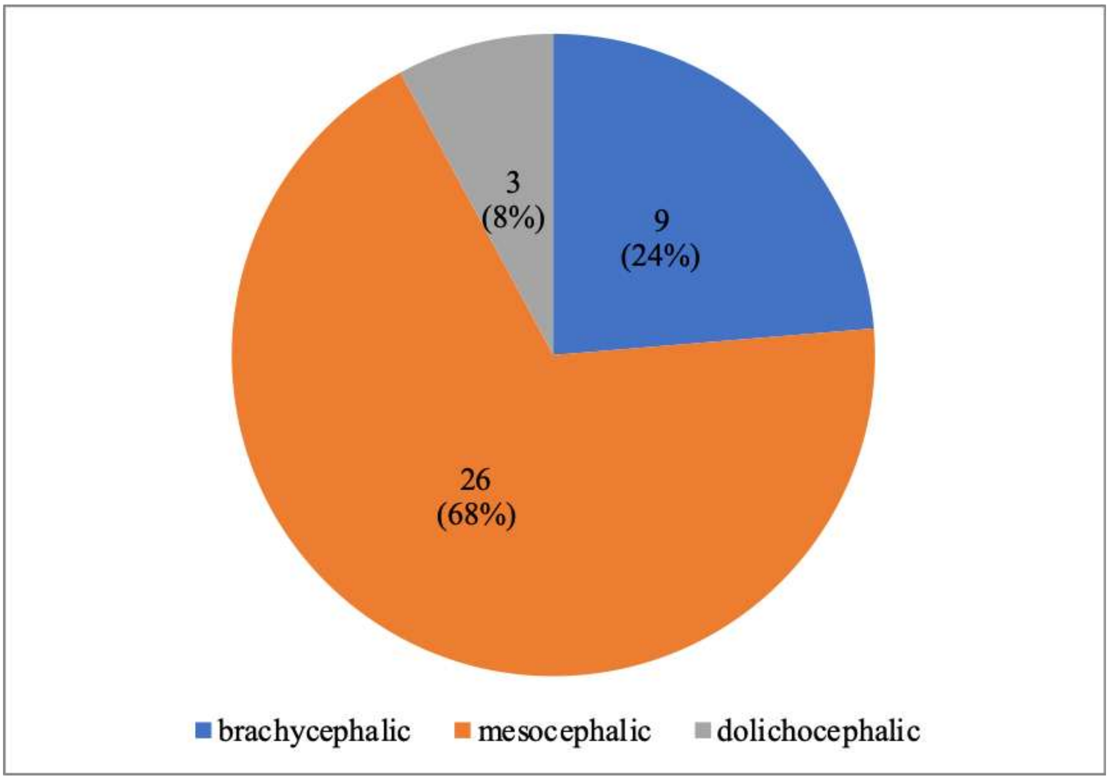



**Fig. 19:** **Distribution of normal dogs (Group 1, n=38) into brachycephalic, mesocephalic and dolichocephalic subgroups**

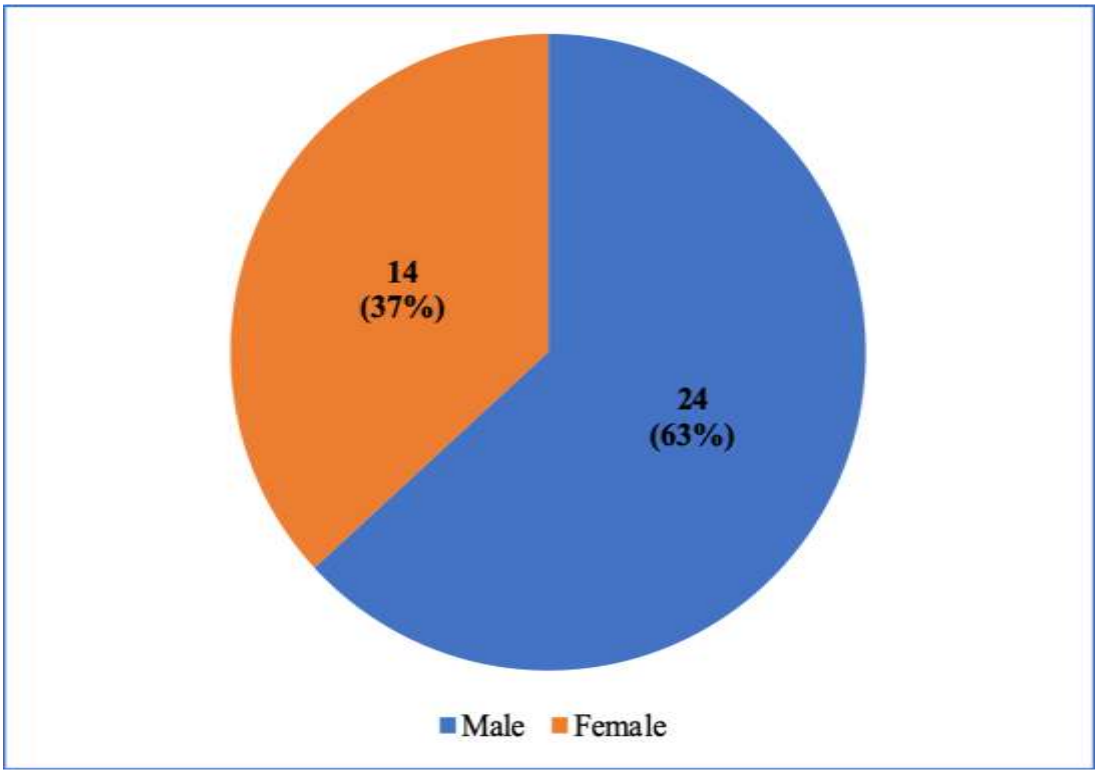



**Fig. 20: Distribution of normal dogs (Group 1, n=38) on the basis of gender**

At least 3 views and wherever possible 4 views were taken to evaluate thoracic radiographs in all apparently normal dogs (n=38). Thrall (2013), Muhlbauer and Kneller (2013), Brown and Brown (2014) and Sharma (2018) also recommended 3-4 views including Left Lateral, Right Lateral, VD and DV projections for proper interpretation of thoracic radiographs in dogs, and subjected to evaluation of various thoracic and extra thoracic structures. The representative image of Right/Left lateral and VD/DV projections in brachycephalic, mesocephalic and dolichocephalic dogs is represented in Fig 21-23.

No lung pattern was appreciable in any animal included in group 1(apparently healthy group). Mild interstitial pattern was visible in a few apparently healthy animals on occasional views. This finding was considered as artefactual as no clinical sign was evident in any animal. All the animals were apparently healthy and were presented for other routine procedures. Thrall (2013) suggested that increased opacity in lungs of normal dogs may be due to expirational radiographs or recumbent atelectasis.

**Evaluation of cardiac silhouette**

**Shape and size**

Shape of heart was normal in all the radiographs and ranged from oval to elliptical on lateral and VD views (Fig 21-23). Muhlbauer and Kneller (2013) also stated that a normal heart in dogs may appear oval, elliptical or “lopsided egg” on lateral and VD projections. The mean ± SE values of dimensions of heart in apparently normal dogs (group 1) are present in Table 5. All the dimensions were measured and expressed in mm.

In brachycephalic breeds, the mean±SE value of VHS was 9.83±0.26 in right lateral and 10.25±0.37 in left lateral radiographs and ranged from 8.25-11. In mesocephalic breeds, the mean ±SE value of VHS was 9.70 ±0.12 in right lateral and 9.50 ±0.13 in left lateral radiographs with a range of 8.25-11. In dolichocephalic breeds, the mean ±SE value of VHS was 10.00 ±0.67 in right lateral and 9.75 ±0.50 in left lateral radiographs and ranged from 8.75-11. The values of VHS in brachycephalic dogs were higher in left lateral recumbency as compared to right lateral recumbency. However, in mesocephalic and dolichocephalic breeds there was slightly lower VHS values were recorded in left lateral recumbency which was similar to findings Greco *et al* (2008) stated that VHS in healthy dogs was significantly higher in right lateral recumbency as compared to the left lateral recumbency. The discrepancy observed in brachycephalic breed in the present study could be due to the barrel and broad shape of the chest. In contrast Gugjoo *et al* (2013) reported no significant difference in VHS, when animals were radiographed in right or left lateral recumbency. The mean values of VHS in either recumbency among various breed types i.e. brachycephalic, mesocephalic and dolichocephalic in the present study were within the normal reference range of 8.5 – 10.5 as proposed by Buchanan and Bucheler (1995), similar VHS had been reported by Sharma (2018) and Bodh *et al* (2016).

The Percentage of cardiac silhouette occupying the thoracic cavity was assessed in VD/DV views. In brachycephalic breeds, the mean ±SE value of percentage of cardiac silhouette in thoracic cavity was 58.22 ±1.99 in right lateral and 60.87 ±2.27 in left lateral radiographs with a range of 49.1-60.92. In mesocephalic breeds, the mean ±SE value was 57.57 ±1.37 in right lateral and 58.45 ±1.42 in left

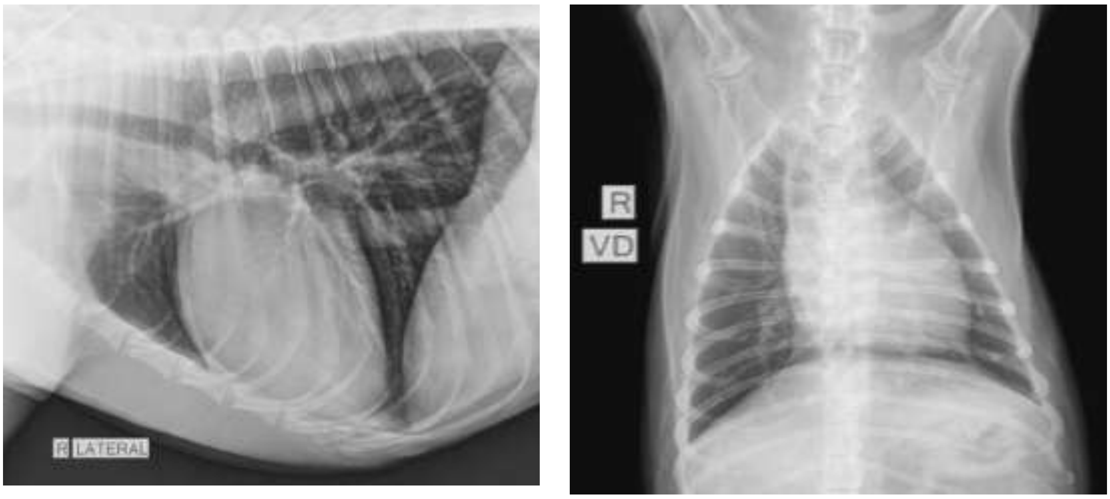



**Fig. 21:** **Right lateral and ventrodorsal radiograph of apparently normal brachycephalic dog**

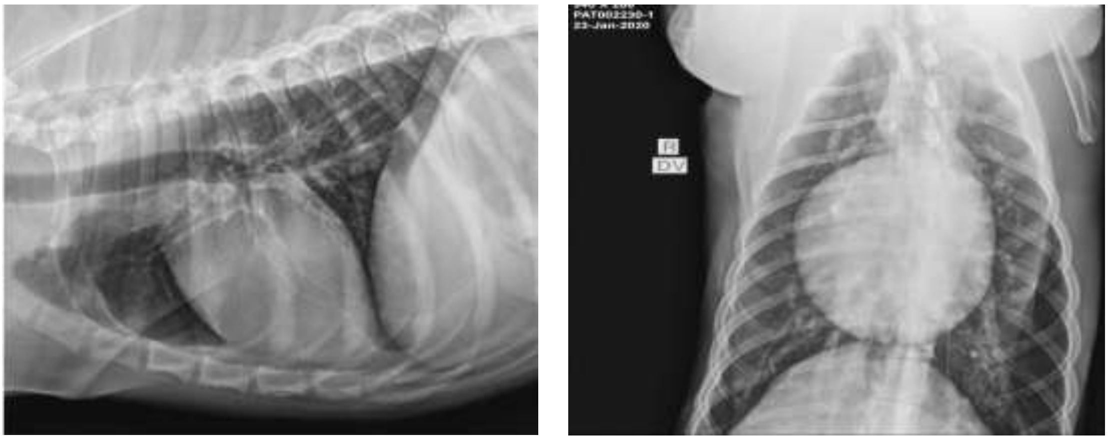



**Fig. 22:** **Right lateral and dorsoventral radiographs of apparently normal mesocephalic dog**

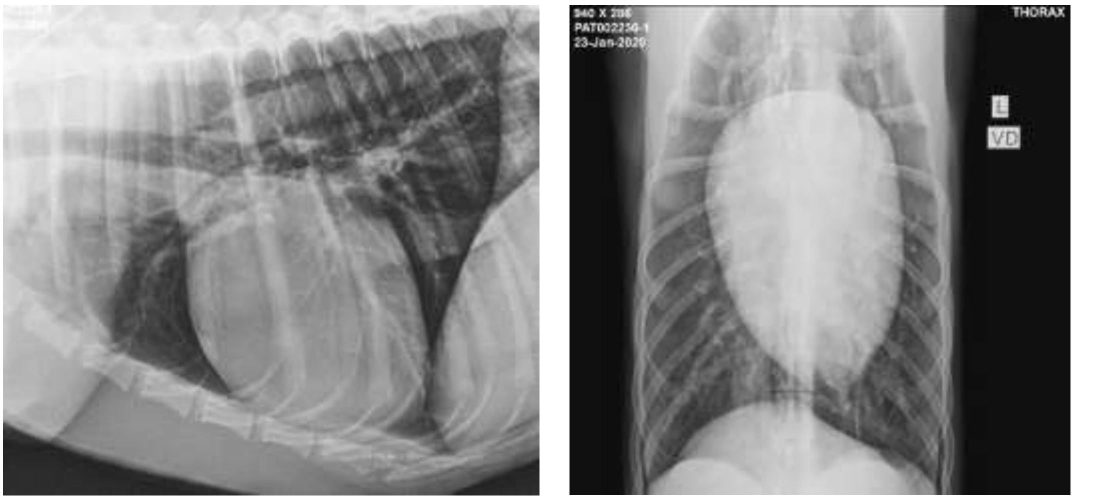



**Fig. 23:** **Right lateral and ventrodorsal radiograph of apparently normal dolichocephalic dog**

lateral radiographs with a range of 51.2- 65.26. In dolichocephalic breeds, the mean ±SE value was 60.68 ±3.67 in right lateral and 59.02 ±2.83 in left lateral radiographs which ranged from 55.29- 65.34 (Table 5). Irrespective of the breed type the percentage space occupied by the cardiac silhouette in the thoracic cavity on VD/DV views was within the normal range of 60-65% as proposed by Poteet (2001).

No border effacement of cardiac silhouette was apparently visible in any lateral radiograph which confirmed no involvement of lungs or pleural space. Thrall (2013) opined that border effacement could result from pathologies like lung lobe pneumonia and pleural effusions.

In brachycephalic breeds, the mean ±SE value of Inter Costal Space occupied was 2.72 ±0.09 in right lateral and 3.20 ±0.25 in left lateral radiographs which ranged from 2.5-3.5. In mesocephalic breeds, the mean ±SE value of ICS was 2.68 ±0.06 in right lateral and 2.79 ±0.06 in left lateral radiographs ranged from 2.3-3.5. In dolichocephalic breeds, the mean ±SE value was 2.83 ±0.17 in right lateral and 2.83 ±0.16 in left lateral radiographs with a range of 2.5-3. These values were similar to Muhlbauer & Kneller (2013) stated that normal width of cardiac silhouette may range from 2.5 ICS in narrow deep chested breeds that have an upright heart to 3.5 ICS in wide shallow chested or barrel-chested dogs with greater sternal contact. Lamb *et al* (2001), Root and Bahr (2002) and Fox (2003) also reported similar ICS coverage by the cardiac silhouette in normal dogs.

In brachycephalic breeds, the mean ±SE value of sternal contact of the cardiac silhouette was 2.72 ± 0.12 in right lateral and 2.70 ±0.20 in left lateral radiographs with a range of 2-3. In mesocephalic breeds, the mean ±SE value was 2.60 ±0.08 in right lateral and 2.52 ± 0.10 in left lateral radiographs ranged from 2-3.5. In dolichocephalic breeds, the mean ±SE value was 2.83 ±0.17 in right lateral and 2.83 ±0.17 in left lateral radiographs with a range of 2.5-3. No marked difference was observed between the right and left lateral views as regards the sternal contact of cardiac silhouette. Earlier workers had reported sternal contact of cardiac silhouette ranged between 2 to 3 depending on the breed type.

There was no significant difference among brachycephalic, mesocephalic and dolichocephalic with respect to VHS, Percentage of cardiac silhouette in thoracic cavity, ICS occupied and Sternal contact in both right and left lateral radiographs.

**Table 5: Radiographic dimensions of heart in apparently normal dogs belonging to different breeds**

| Breed type | VHS | | Percentage of cardiac silhouette in thoracic cavity | | ICS occupied | | Sternal contact | |
|---|---|---|---|---|---|---|---|---|
| | R | L | VD | DV | R | L | R | L |
| Brachycephalic (N=9) | 9.83±0.26 (8.25-11) | 10.25±0.37 (9.5-11) | 58.22±1.99 (49.88-60.12) | 60.87±2.27 (49.1-60.92) | 2.72±0.09 (2.5-3) | 3.20±0.25 (2.5-3.5) | 2.72±0.12 (2-3) | 2.70±0.20 (2-3) |
| Mesocephalic (N=26) | 9.70±0.12 (8.55-11) | 9.50±0.13 (8.25-10.75) | 57.57±1.37 (53.67-64.08) | 58.45±1.42 (51.2-65.26) | 2.68±0.06 (2.3-3.5) | 2.79±0.06 (2.5-3.5) | 2.60±0.08 (2-3.5) | 2.52±0.10 (2-3.5) |
| Dolichocephalic (N=3) | 10.00±0.67 (8.75-11) | 9.75±0.50 (8.75-10.25) | 60.68±3.67 (64.58-65.34) | 59.02±2.83 (55.29-64.58) | 2.83±0.17 (2.5-3) | 2.83±0.16 (2.5-3) | 2.83±0.17 (2.5-3) | 2.83±0.17 (2.5-3) |

### Correlation between various parameters of heart

Pearson's correlation revealed significant ($p \leq 0.01$) positive correlation between VHS and ICS occupied by the heart (Table 6) VHS had a significant ($p \leq 0.05$) positive correlation with sternal contact. This suggested that with an increase in the ICS/sternal contact VHS is expected to be higher or vice versa in normal dogs.

**Table 6: Correlation between various parameters of heart in apparently healthy dogs (n= 38)**

| | | VHS | % of cardiac silhouette | ICS |
|---|---|---|---|---|
| % of cardiac silhouette | r | 0.184 | | |
| | p | 0.27 | | |
| Inter costal space | r | .426** | 0.147 | |
| | p | 0.008 | 0.377 | |
| Sternal contact | r | .372* | 0.1 | 0.278 |
| | p | 0.022 | 0.549 | 0.091 |

*values differ significantly ($p \leq 0.05$)

**values differ significantly ($p \leq 0.01$)

### Evaluation of mediastinum

All the dimensions of mediastinum were measured and expressed in mm. No space occupying lesion was apparently visible in the cranial or caudal mediastinum in any dog. The cranial and caudal mediastinum were normal as reported by earlier workers (Thrall, 2013; Muhlbauer and Kneller, 2013)

Oesophagus was apparently not visible in any radiograph irrespective of the view.

In brachycephalic breeds, the mean ±SE value of carina diameter was 10.44±1.83 in right lateral and 10.63±1.59 in left lateral radiographs which ranged from 6.07-24.68. In mesocephalic breeds, the mean ±SE value was 17.81 ±0.93 in right lateral and 16.73 ±0.96 in left lateral radiographs which ranged from 7.61-28.27. In dolichocephalic breeds, the mean ±SE value was 23.73±2.91 in right lateral and 23.79 ±1.52 in left lateral radiographs which ranged from 19.39-29.28 (Table 7). The mean value of carina diameter on right and left lateral views was significantly ($p \leq 0.05$) lower in brachycephalic breeds as compared to mesocephalic and dolichocephalic breeds. However, in left lateral view the dolichocephalic breeds showed significantly ($p \leq 0.05$) higher values as compared to brachycephalic and mesocephalic breeds. Overall, the carina diameter was lower in brachycephalic breeds as compared to other groups. The reason for small carina diameter in brachycephalic group may be due to majority of size of dogs in this group and narrow airway in brachycephalic breed (Kealy and McAllister 2000, Farrow 2003, Muhlbauer and Kneller 2013, Thrall 2013, Brown and Brown 2014, Sharma 2018).

Trachea in all dogs irrespective of breed, deviated ventrally towards base of heart and was considered normal as described by Muhlbauer and Kneller (2013)

In brachycephalic breeds, the mean ±SE value of trachea diameter (TD) was 8.60 ±1.48 in right lateral and 9.14 ±1.94 in left lateral radiographs with a range of 4.89-18.75. In mesocephalic breeds, the mean ±SE value of TD was 15.64 ±0.86 in right lateral and 14.86 ±0.90 in left lateral radiographs ranged from 5.91-25.84. In dolichocephalic breeds, the mean ±SE value was 20.61±2.51 in right lateral and 20.14±2.70 in left lateral radiographs with a range of 15.36-24.72. (Table 7). The mean value of tracheal diameter in brachycephalic group was significantly lower from that of mesocephalic and dolichocephalic group. This could be attributed to the reasons discussed above for carina.

In brachycephalic breeds, the mean ±SE value of thoracic inlet (TI) diameter was 50.01 ±4.73 in right lateral and 52.29±6.39 in left lateral radiographs with a range of 39.45-83.16. In mesocephalic breeds, the mean ±SE value was 69.72 ±2.58 in right lateral and 68.73 ±2.87 in left lateral radiographs with a range of 35.59-89.32. In dolichocephalic breeds, the mean ±SE value of TI was 90.92±5.65 in right lateral and 86.14±7.04 in left lateral radiographs ranged from 77.71-102.19. The TI diameter was significantly ($p \leq 0.05$) different in all the groups.

**Tracheal diameter: thoracic inlet diameter ratio (TD: TI)**

In brachycephalic breeds, the mean ±SE value of TD: TI was 0.17 ±0.02 in right lateral and 0.17 ±0.02 in left lateral radiographs with a range of 0.10-0.26. In mesocephalic breeds, the mean ±SE value was 0.22 ±0.01 in right lateral and 0.21 ±0.01 in left lateral radiographs ranged from 0.16-0.32. In dolichocephalic breeds, the mean ±SE value of TD: TI was 0.23 ±0.04 in right lateral and 0.24 ±0.05in left lateral radiographs with a range of 0.15-0.32 (Table 7). Muhlbauer and Kneller (2013) stated that the tracheal ratio in non-brachycephalic dog breeds: TR ≥ 0.20 & in brachycephalic breeds: TR ≥ 0.16. Thrall (2017) stated that non-bulldog brachycephalic breeds, both with and without respiratory signs, have a smaller average tracheal-diameter-to-thoracic-inlet ratio (16% ± 3%) than non-brachycephalic dogs (20% ±3%). Bulldogs have an even smaller ratio (13% ±4%). The smallest ratio in asymptomatic bulldogs was 9%.

In brachycephalic breeds, the mean ±SE value of proximal 1/3rd of 3rd rib diameter (R3) was 3.99 ±0.44 in right lateral and 4.78 ±1.01in left lateral radiographs ranged from 2.83- 8.31. In mesocephalic breeds, the mean ±SE value of $3^{rd}$ rib was 6.45 ±0.27 in right lateral and 6.61 ±0.37 in left lateral radiographs with a range of 2.17- 9.18. In dolichocephalic breeds, the mean ±SE value was 8.66 ±0.47 in right lateral and 8.06 ±0.40 in left lateral radiographs with a range of 7.63- 9.52.

**Trachea diameter: proximal 1/3rd of 3rd rib diameter**

In brachycephalic breeds, the mean ±SE value of trachea diameter: proximal 1/3rd of 3rd rib diameter was 2.18 ±0.23 in right lateral and 1.93 ±0.14 in left lateral radiographs with a range of 1.41-3.24. In mesocephalic breeds, the mean ±SE value was 2.45 ±0.12 in right lateral and 2.30±0.10 in left lateral radiographs ranged from 1.51-3.56. In dolichocephalic breeds, the mean ±SE value was 2.42 ±0.38 in right lateral and 2.54 ±0.44 in left lateral radiographs ranged from 1.65-3.24. Muhlbauer and Kneller (2013) stated that normal tracheal width should be approximately 3 times width of proximal 1/3 of 3rd rib but in our study the tracheal width was found to be in range 2.05- 2.50 times width of proximal 1/3 of 3rd rib. Brown and Brown (2014) stated that at the third rib, trachea generally considered to be about three times the diameter of that rib; alternatively, the height of the trachea should be half that of the thoracic inlet.

In brachycephalic, mesocephalic and dolichocephalic group there was no significant difference between the mean values of TD: TI ratio on right lateral radiographs. Mean value of TD: TI on left lateral radiographs was significantly ($p \leq 0.05$) lower in brachycephalic breeds as compared in mesocephalic and dolichocephalic group. However, there was no statistically significant ($p \leq 0.05$) difference between mean values of TD: TI in mesocephalic and dolichocephalic group.

In the present study TD: TI ratio was highest in Doberman and German Shepherds 0.20±0.32 and lowest 0.15±0.02 in Pugs. However, no statistically significant difference could be identified among the two breeds. The results in the present study are in line with those reported by Muhlbauer and Kneller (2013) who reported TD: TI ratio as 0.20 in non-brachycephalic breeds and 0.16 in brachycephalic breeds. The TD: $3^{rd}$ rib ratio in the present study was as low as 1.41 in brachycephalic breed to as high as 3.56 in mesocephalic breed. The mean values irrespective of the groups however, remain around 2.50. This was in contrast to Muhlbauer and Kneller (2013) who reported that TD: $3^{rd}$ rib ratio should be approximately 3.0 in normal dogs. In both right and left lateral radiographs, the mean values of tracheal diameter: proximal 1/3rd of 3rd rib diameter had no significant difference among the 3 groups.

**Correlation between Radiographic dimensions of mediastinal structures (Table-8)**

Carina diameter had a significant ($p \leq 0.05$) positive correlation with TD, TI, TD: TI, width of proximal $1/3^{rd}$ of $3^{rd}$ rib and TD: $3^{rd}$ rib. The tracheal diameter had a significant ($p \leq 0.05$) positive correlation with TI, TD: TI, width of proximal $1/3^{rd}$ of $3^{rd}$ rib and TD:$3^{rd}$ rib. Thoracic inlet diameter had a significant ($p \leq 0.05$) positive correlation with TD: TI and $3^{rd}$ rib. TD: TI had a significant ($p \leq 0.05$) positive correlation with proximal $1/3^{rd}$ of $3^{rd}$ rib and TD:$3^{rd}$ ratio.

**Table 7: Radiographic dimensions of mediastinal structures in apparently healthy dogs belonging to different breeds**

| Breed type | Carina diameter (in mm) | | Trachea diameter TD (in mm) | | Thoracic inlet diameter TI (in mm) | | TD: TI | | Proximal 1/3rd of 3rd rib diameter (in mm) | | Tracheal diameter: proximal 1/3rd of 3rd rib diameter | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **R** | **L** | **R** | **L** | **R** | **L** | **R** | **L** | **R** | **L** | **R** | **L** |
| Brachy cephalic | 10.44±1.83$^{a}$ (6.83-24.68) | 10.63±1.59$^{a}$ (6.07-15.85) | 8.60±1.48$^{a}$ (4.89-18.75) | 9.14±1.94$^{a}$ (5.02-16.06) | 50.01±4.73$^{a}$ (39.45-83.16) | 52.29±6.39$^{a}$ (40.44-77.08) | 0.17±0.02 (0.10-0.26) | 0.17±0.02$^{a}$ (0.11-0.21) | 3.99±0.44$^{a}$ (3.16-6.99) | 4.78±1.01$^{a}$ (2.83-8.31) | 2.18±0.23 (1.41-3.24) | 1.93±0.14 (1.46-2.30) |
| Meso cephalic | 17.81±0.93$^{bc}$ (8.25-27.79) | 16.73±0.96$^{ab}$ (7.61-28.27) | 15.64±0.86$^{bc}$ (6.19-22.79) | 14.86±0.90$^{ab}$ (5.91-25.84) | 69.72±2.58$^{b}$ (35.59-89.32) | 68.73±2.87$^{ab}$ (37.43-87.85) | 0.22±0.01 (0.16-0.32) | 0.21±0.01$^{ab}$ (0.16-0.32) | 6.45±0.27$^{b}$ (3.04-9.18) | 6.61±0.37$^{ab}$ (2.17-8.86) | 2.45±0.12 (1.63-3.38) | 2.30±0.10 (1.51-3.56) |
| Dolicho cephalic | 23.73±2.91$^{c}$ (19.39-29.28) | 23.79±1.52$^{c}$ (22.2-26.84) | 20.61±2.51$^{c}$ (15.75-24.15) | 20.14±2.70$^{b}$ (15.36-24.72) | 90.92±5.65$^{c}$ (84.41-102.19) | 86.14±7.04$^{b}$ (77.71-100.2) | 0.23±0.04 (0.15-0.28) | 0.24±0.05$^{b}$ (0.15-0.32) | 8.66±0.47$^{c}$ (7.9-9.52) | 8.06±0.40$^{b}$ (7.63-8.86) | 2.42±0.38 (1.65-2.82) | 2.54±0.44 (1.73-3.24) |

Figures in parentheses indicate range

Values with different superscripts$^{(a,b,c)}$ indicate significant difference between the breed types.

**Table 8: Correlation between radiographic dimensions of mediastinal structures in apparently healthy dogs (Group 1)**

| | | Carina diameter | Trachea diameter TD | Thoracic inlet diameter TI | TD: TI | Proximal 1/3rd of 3rd rib diameter |
|---|---|---|---|---|---|---|
| **Trachea diameter TD** | r | .889** | | | | |
| | P | 0 | | | | |
| | N | 38 | | | | |
| **Thoracic inlet diameter TI** | r | .811** | .823** | | | |
| | P | 0 | 0 | | | |
| | N | 37 | 37 | | | |
| **TD: TI** | r | .688** | .853** | .430** | | |
| | P | 0 | 0 | 0.008 | | |
| | N | 37 | 37 | 37 | | |
| **Proximal 1/3rd of 3rd rib diameter** | r | .772** | .765** | .868** | .475** | |
| | P | 0 | 0 | 0 | 0.003 | |
| | N | 37 | 37 | 36 | 36 | |
| **Tracheal diameter: proximal 1/3rd of 3rd rib diameter** | r | .452** | .647** | 0.291 | .783** | 0.033 |
| | P | 0.005 | 0 | 0.085 | 0 | 0.845 |
| | N | 37 | 37 | 36 | 36 | 37 |

*values differ significantly (p≤0.05)

**values differ significantly (p≤0.01)

**Evaluation the pleural space**

The pleural space was normal in all the dogs belonging to the apparently normal group. No fluid, air, fissure lines or mass was apparently visible in any case (Fig. 24)

**Evaluation of Vascular structures**

All the dimensions of vascular structures were measured and expressed in mm (Table 9). In brachycephalic breeds, the mean ±SE value of aorta diameter was 12.95 ±2.52 in right lateral and 13.38 ±3.80 in left lateral radiographs ranged from 9.58-17.94. In mesocephalic breeds, the mean ±SE value was 17.19 ±0.72 in right lateral and 17.99 ±0.69 in left lateral radiographs and ranged from 14.32-24.02. In dolichocephalic breeds, the mean ±SE value was 21.83 ±2.39 in right lateral and 19.66 ±0.59in left lateral radiographs with a range of 17.96-26.18.

In brachycephalic breeds, the mean ±SE value of caudal vena cava diameter was 9.14 ±0.80 in right lateral and 11.87 ±2.72 in left lateral radiographs with a range of (6.51-19.87). In mesocephalic breeds, the mean ±SE value was12.69 ±0.59 in right lateral and 13.14 ±0.57 in left lateral radiographs ranged from 5.21-17.73. In dolichocephalic breeds, the mean ±SE value was19.41 ±2.62 in right lateral and 20.25 ±2.71in left lateral radiographs with a range of 16.80-25.67.

In brachycephalic breeds, the mean ±SE value of length of T6 was 12.52 ±1.08 in right lateral and 13.04 ±1.69 in left lateral radiographs with a range of 10.17-20.46. In mesocephalic breeds, the mean ±SE value was 17.98 ±0.60 in right lateral and 17.66 ±0.75 in left lateral radiographs and ranged from 9.22-23.79. In dolichocephalic breeds, the mean ±SE value was 22.11 ±0.84 in right lateral and 22.35 ±0.95 in left lateral radiographs with a range of 20.75-24.04. The significantly ($p \leq 0.05$) greater Ao, CVC and T6 dimensions seen in the dolichocephalic breeds might be due to the breed differences and large size of the animals. Similarly, significantly ($p \leq 0.05$) lower dimensions in brachycephalic breeds may be attributed to majority of small sized dogs included in this group.

In brachycephalic breeds, the mean ±SE value of Aorta: Length of T6 was 0.95 ±0.05in right lateral and 0.88 ±0.00 in left lateral radiograph ranged from 0.88-

1.05. In mesocephalic breeds, the mean ±SE value was 0.89 ±0.02 in right lateral and 1.00 ±0.05 in left lateral radiograph with a range of 0.75-1.46. In dolichocephalic breeds, the mean ±SE value was 0.98±0.07 in right lateral and 0.88 ±0.03 in left lateral radiograph with a range of 0.83-1.10 (Table 9). The vascular structures viz. Aorta, CVC, Cranial and Caudal pulmonary vessels could not be visualized in some of the radiographs. Means were calculated from the measurements available from the radiographs where the vascular structures were clearly visualized and measured. Lehmkuhl *et al* (1997) opined that measurements of CVC and Ao is difficult to impossible in some patients due to various factors like radiographic quality, pulmonary vasculature markings etc.

In brachycephalic breeds, the mean ±SE value of Caudal vena cava: Length of T6 was 0.73 ±0.03 in right lateral and 0.84 ±0.06 in left lateral radiographs ranged from 0.57-1.01. In mesocephalic breeds, the mean ±SE value was 0.71 ±0.03 in right lateral and 0.79 ±0.03 in left lateral radiographs with a range of 0.28-1.03. In dolichocephalic breeds, the mean ±SE value was 0.86 ±0.07 in right lateral and 0.90 ±0.09 in left lateral radiographs ranged from 0.79-1.07. In the present study irrespective of group the width of CVC was less than the length of T6 with a ratio of less than 1. This finding was similar to Lehmkuhl *et al* (1997), Muhlbauer and Kneller (2013), Thrall (2013) and Sharma (2018) reported that normal width of CVC was less than the T6 length. The width of CVC was less than 1.5 times the width of Ao in the present study which corroborated with findings of Lehmkuhl *et al* (1997), Muhlbauer and Kneller (2013), Thrall (2013) and Sharma (2018). The ratios of Ao:T6, CVC: T6 had no significant difference between the three groups**.**


**Fig. 24:** **Radiograph showing normal pleural space in a mesocephalic dog belonging to group 1**

**Table 9: Radiographic dimensions of caudal vena cava, aorta and T6 in apparently healthy dogs belonging to different breeds**

| Breed type | Aorta diameter (in mm) | | Caudal vena cava diameter (in mm) | | Length of T6 (in mm) | | Aorta diameter: Length of T6 | | Caudal vena cava diameter: Length of T6 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | R | L | R | L | R | L | R | L | R | L |
| **Brachy-cephalic** | 12.95 ±2.52[a] (9.72-17.94) | 13.38 ±3.80[a] (9.58-17.18) | 9.14 ±0.80[a] (6.51-14.29) | 11.87 ±2.72[a] (8.2-19.87) | 12.52 ±1.08[a] (10.17-20.46) | 13.04 ±1.69[a] (10.62-19.63) | 0.95 ±0.05 (0.88-1.05) | 0.88 ±0.00 (0.88) | 0.73 ±0.03 (0.57-0.86) | 0.84 ±0.06 (0.73-1.01) |
| **Meso-cephalic** | 17.19 ±0.72[ab] (14.32-21.95) | 17.99 ±0.69[ab] (14.33-24.02) | 12.69 ±0.59 [ab] (5.21-16.53) | 13.14 ±0.57[ab] (7.65-17.73) | 17.98 ±0.60[bc] (10.27-23.24) | 17.66 ±0.75[ab] (9.22-23.79) | 0.89 ±0.02 (0.77-1.04) | 1.00 ±0.05 (0.75-1.46) | 0.71 ±0.03 (0.28-0.90) | 0.79 ±0.03 (0.38-1.03) |
| **Dolicho-cephalic** | 21.83 ±2.39[b] (17.96-26.18) | 19.66 ±0.59[b] (18.5-20.47) | 19.41 ±2.62[c] (16.8-22.03) | 20.25 ±2.71[c] (17.46-25.67) | 22.11 ±0.84[c] (21.14-23.79) | 22.35 ±0.95[b] (20.75-24.04) | 0.98±0.07 (0.85-1.10) | 0.88 ±0.03 (0.83-0.92) | 0.86 ±0.07 (0.79-0.93) | 0.90 ±0.09 (0.79-1.07) |

Figures in parentheses indicate range

Values with different superscripts[(a,b,c)] indicate significant difference between the breed types.

**Correlation between Radiographic dimensions of caudal vena cava, aorta and T6 (Table-10)**

Aorta diameter had a significant ($p \leq 0.05$) positive correlation with CVC diameter and T6. Similarly, CVC diameter had significant ($p \leq 0.05$) positive correlation with length of T6 and CVC: T6 ratio.

**Table 10: Correlation between radiographic dimensions of caudal vena cava, aorta and T6 in apparently healthy dogs (Group 1)**

| | | Aorta diameter | Caudal vena cava diameter | Length of T6 | Aorta: Length of T6 diameter |
|---|---|---|---|---|---|
| **Caudal vena cava diameter** | r | .846** | | | |
| | P | 0 | | | |
| | N | 14 | | | |
| **Length of T6** | r | .882** | .730** | | |
| | P | 0 | 0 | | |
| | N | 17 | 32 | | |
| **Aorta: Length of T6 diameter** | r | 0.404 | 0.287 | -0.07 | |
| | P | 0.108 | 0.32 | 0.791 | |
| | N | 17 | 14 | 17 | |
| **Caudal vena cava: Length of T6 diameter** | r | 0.216 | .557** | -0.149 | 0.499 |
| | P | 0.459 | 0.001 | 0.415 | 0.069 |
| | N | 14 | 32 | 32 | 14 |

*values differ significantly ($p \leq 0.05$)

**values differ significantly ($p \leq 0.01$)

**Evaluation of cranial pulmonary vasculature**

All the dimensions of cranial pulmonary vasculature were measured and expressed in mm (Table 11). In brachycephalic breeds, the mean ±SE value of cranial pulmonary artery diameter (CrPA) was 2.72 ±0.42 in right lateral and 3.05 ±0.62 in left lateral radiographs with a range of 1.51-5.61. In mesocephalic breeds, the mean ±SE value of CrPA was 3.99 ±0.24 in right lateral and 4.42 ±0.23 in left lateral radiographs with a range of 1.52-7.24. In dolichocephalic breeds, the mean ±SE value for CrPA was 5.77 ±0.82 in right lateral and 6.75 ±1.75 in left lateral radiographs ranged from 4.4-7.24.

The mean ±SE value of cranial pulmonary vein diameter in brachycephalic breeds, (CrPV) was 2.60 ±0.31in right lateral and 3.16 ±0.52 in left lateral radiographs ranged from 1.78-5.22. In mesocephalic breeds, the mean ±SE value of CrPV diameter was 3.94 ±0.21 in right lateral and 4.71 ±0.26 in left lateral radiographs with a range of 2.01- 7.92. In dolichocephalic breeds, the mean ±SE value of CrPV was 5.70 ±0.61 in right lateral and 6.28 ±0.76 in left lateral radiographs with a range of 4.69- 7.80. The significantly ($p \leq 0.05$) greater CrPA and CrPV dimensions seen in the Dolichocephalic breeds may be due to the breed differences and large size of the animal. Similarly, significantly ($p \leq 0.05$) lower dimensions in brachycephalic breeds may be attributed to majority of small sized dogs included in this group.

In brachycephalic breeds, the mean ±SE value of proximal 1/3rd of 4th rib diameter (R4) was 4.39 ±0.70 in right lateral and 4.75 ±1.10 in left lateral radiographs with a range of 3.14- 9.91. In mesocephalic breeds, the mean ±SE value was 7.49 ±0.37 in right lateral and 7.09 ±0.40 in left lateral radiographs and ranged from 2.68-11.73. In dolichocephalic breeds, the mean ±SE value was 9.63 ±0.41 in right lateral and 9.45 ±0.88 in left lateral radiographs with a range of 7.88- 10.93.

The mean ±SE value of ratio of CrPA: proximal 1/3rd of 4th rib diameter in brachycephalic breeds, was 0.62±0.04 in right lateral and 0.65 ±0.05 in left lateral radiograph ranged from 0.44- 0.77. In mesocephalic breeds, the mean ±SE value was 0.54 ±0.03 in right lateral and 0.61 ±0.04 in left lateral radiograph with arrange of 0.36- 0.76. In dolichocephalic breeds, the mean ±SE value was 0.60 ±0.10 in right lateral and 0.69 ±0.11in left lateral radiograph with a range of 0.42- 0.76.

The ratio of CrPA: proximal 1/3rd of 4th rib diameter and CrPV: proximal 1/3rd of 4th rib diameter had no significant difference between 3 groups.

In brachycephalic breeds, the mean ±SE value of CrPV: proximal 1/3rd of 4th rib diameter was 0.61 ±0.03 in right lateral and 0.70 ±0.05 in left lateral radiographs ranged from 0.49- 0.70. In mesocephalic breeds, the mean ±SE value was 0.54±0.02 in right lateral and 0.65 ±0.04 in left lateral radiographs with a range of 0.31-0.75.

## Table 11: Radiographic dimensions of cranial pulmonary vessels and 4[rd] rib in apparently healthy dogs belonging to different breeds

| Breed type | Cranial pulmonary artery diameter (in mm) | | Cranial pulmonary vein diameter (in mm) | | Proximal1/3rd of 4th rib diameter (in mm) | | Cranial Pulmonary artery: Proximal 1/3rd of 4th rib | | Cranial Pulmonary vein: proximal 1/3rd of 4th rib | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **R** | **L** | **R** | **L** | **R** | **L** | **R** | **L** | **R** | **L** |
| Brachy-cephalic | 2.72±0.42[a] (1.51-5.61) | 3.05±0.62[a] (2.13-5.45) | 2.60±0.31[a] (1.78-4.88) | 3.16±0.52[a] (2.4-5.22) | 4.39±0.70[a] (3.14-9.91) | 4.75±1.10[a] (3.47-9.17) | 0.62±0.04 (0.44-0.77) | 0.65±0.05 (0.58-0.70) | 0.61±0.03 (0.49-0.70) | 0.70±0.05 (0.57-0.69) |
| Meso-cephalic | 3.99±0.24[ab] (1.52-6.96) | 4.42±0.23[ab] (2.97-7.24) | 3.94±0.21[ab] (2.01-6.75) | 4.71±0.26[ab] (3.35-7.92) | 7.49±0.37[bc] (2.88-11.73) | 7.09±0.40[ab] (2.68-9.85) | 0.54±0.03 (0.36-0.76) | 0.61±0.04 (0.40-0.75) | 0.54±0.02 (0.31-0.75) | 0.65±0.04 (0.40-0.75) |
| Dolicho-cephalic | 5.77±0.82[c] (4.4-7.24) | 6.75±1.75[c] (4.18-7.24) | 5.70±0.61[c] (4.69-6.81) | 6.28±0.76[b] (5.4-7.8) | 9.63±0.41[c] (8.96-10.38) | 9.45±0.88[b] (7.88-10.93) | 0.60±0.10 (0.42-0.76) | 0.69±0.11 (0.53-0.76) | 0.59±0.06 (0.52-0.71) | 0.66±0.04 (0.59-0.71) |

Figures in parentheses indicate range

Values with different superscripts[(a,b,c)] indicate significant difference between the breed types.

In dolichocephalic breeds, the mean ±SE value was 0.59 ±0.06 in right lateral and 0.66 ±0.04 in left lateral radiographs with a range of 0.52- 0.71 (Table 11). The ratios of CrPA and CrPV with the proximal 3$^{rd}$ of 4$^{th}$ rib were within the reference range as reported by Muhlbauer and Kneller (2013). Other workers have also reported that the cranial pulmonary vessels should not be greater in width as compared to the width of proximal 1/3$^{rd}$ of the 4$^{th}$ rib (Thrall 2013, Oui *et al* 2015 and Sharma 2018).

**Correlation between Radiographic dimensions of cranial pulmonary vessels and 4$^{rd}$ rib (Table 12)**

CrPA had a significant ($p \leq 0.05$) positive correlation with CrPV and with proximal 1/3$^{rd}$ of 4$^{th}$ rib diameter. Similarly, CrPV: proximal 1/3 of 4$^{th}$ rib ratio had a significant ($p \leq 0.05$) positive correlation with proximal 1/3$^{rd}$ of 4$^{th}$ rib diameter and ratio of CrPA: proximal 1/3$^{rd}$ of 4$^{th}$ rib. CrPV had a significant ($p \leq 0.05$) positive correlation with proximal 1/3$^{rd}$ of 4$^{th}$ rib diameter.

**Evaluation of caudal pulmonary vasculature**

All the dimensions were measured and expressed in mm (Table 13). In brachycephalic breeds, the mean ± SE value of caudal pulmonary artery diameter (CdPA) was 3.63 ±0.64 in ventrodorsal and 4.66 ±0.84 in dorsoventral radiographs ranged from 1.99-7.91. In mesocephalic breeds, the mean ±SE value of CdPA was 5.49±0.31 in ventrodorsal and 5.77±0.62 in dorsoventral radiographs with a range of 2.27-9.5. In dolichocephalic breeds, the mean ±SE value was 4.79 ±0.55 in ventrodorsal and 6.50 ±1.36 in dorsoventral radiographs ranged from 3.69- 8.69).

The mean ±SE value of caudal pulmonary vein diameter (CdPV) in brachycephalic breeds was 3.77 ±0.59 in ventrodorsal and 4.96 ±1.01in dorsoventral radiographs ranged from 2.58- 8.41. In mesocephalic breeds, the mean ±SE value of CdPV was 6.02 ±0.38 in ventrodorsal and 5.74 ±0.41 in dorsoventral radiographs with a range of 2.41-9.6. In dolichocephalic breeds, the mean ±SE value of CdPV was 6.71± 0.95 in ventrodorsal and 7.19 ±1.27 in dorsoventral radiographs ranged from 4.86-9.23.

The mean ±SE value of 9th rib diameter at intersection with artery in brachycephalic breeds, was 3.83 ±0.4 in ventrodorsal and 4.44 ±0.63 in dorsoventral radiographs with a range of 2.65-7.50. In mesocephalic breeds, the mean ±SE value was 5.87 ±0.24 in ventrodorsal and 6.01 ±0.34 in dorsoventral radiograph ranged from 2.94- 8.09. In dolichocephalic breeds, the mean ±SE value was 6.89 ±0.69in ventrodorsal and 7.76 ±0.77 in dorsoventral radiographs ranged from 5.91- 8.82.

**Table 12: Correlation between radiographic dimensions of cranial pulmonary vessels and 4rd rib in apparently healthy dogs (Group 1)**

| | | Cranial pulmonary artery diameter | Cranial pulmonary vein diameter | Proximal1/3rd of 4th rib diameter | Cranial Pulmonary artery: proximal 1/3rd of 4th rib diameter |
|---|---|---|---|---|---|
| **Cranial pulmonary vein diameter** | r | .861** | | | |
| | P | 0 | | | |
| | N | 38 | | | |
| **Proximal 1/3rd of 4th rib diameter** | r | .756** | .797** | | |
| | P | 0 | 0 | | |
| | N | 38 | 38 | | |
| **Cranial Pulmonary artery: proximal 1/3rd of 4th rib diameter** | r | .383* | 0.118 | -0.285 | |
| | P | 0.018 | 0.48 | 0.083 | |
| | N | 38 | 38 | 38 | |
| **Cranial Pulmonary vein: proximal 1/3rd of 4th rib diameter** | r | 0.036 | 0.152 | -.460** | .684** |
| | P | 0.83 | 0.362 | 0.004 | 0 |
| | N | 38 | 38 | 38 | 38 |

*values differ significantly (p≤0.05)

**values differ significantly (p≤0.01)

In brachycephalic breeds, the mean ±SE value of 9th rib diameter at intersection with vein was 4.17 ± 0.49 in ventrodorsal and 4.53 ±0.64 in dorsoventral radiographs with a range of 3.14- 7.60. The mean ±SE value in mesocephalic breeds, was 5.80 ±0.29 in ventrodorsal and 6.21 ±0.40 in dorsoventral radiographs ranged from 3.14-9.45. In dolichocephalic breeds, the mean ±SE value was 6.76±0.67 in ventrodorsal and 8.22 ±0.57 in dorsoventral radiographs with a range of 5.47-9.26.

**Caudal pulmonary artery diameter:9th rib**

In brachycephalic breeds, the mean ±SE value of CdPA: 9th rib ratio was 0.92 ±0.06 in ventrodorsal and 1.02±0.10 in dorsoventral radiographs ranged from 0.75-1.25. In mesocephalic breeds, the mean ±SE value was 0.95 ±0.05 in ventrodorsal and 0.96 ±0.07 in dorsoventral radiographs with a range of 0.64- 1.72. The mean ±SE value in dolichocephalic breeds, was 0.70 ±0.09 in ventrodorsal and 0.82±0.12 in dorsoventral radiographs with a range of 0.57-1.06.

**Caudal pulmonary vein diameter: 9th rib**

In brachycephalic breeds, the mean ±SE value of CdPV:9th rib ratio was 0.89 ±0.08 in ventrodorsal and 1.07±0.12 in dorsoventral radiographs ranged from (0.56-1.38). In mesocephalic breeds, the mean ±SE value was 1.06 ±0.06 in ventrodorsal and 0.93±0.04 in dorsoventral radiographs with arrange of (0.65-1.81). In dolichocephalic breeds, the mean ±SE value was 0.99 ±0.06 in ventrodorsal and 0.87 ±0.10 in dorsoventral radiographs with a range of (0.67-1.11). The width of CdPA and CdPV should not exceed the width of 9$^{th}$ rib at the point where the vessels intercept with the 9$^{th}$ rib (Muhlbauer and Kneller 2013, Thrall 2013). Oui *et al* (2015) recommended using the accompanying pulmonary artery and 1.22 x the diameter of the 9$^{th}$ rib as a radiographic creation for assessing the size of the right caudal pulmonary vein.

The reasons for significantly ($p \leq 0.05$) higher dimensions of caudal pulmonary vasculature on DV view in dolichocephalic breeds and lower dimensions in brachycephalic breeds have been discussed earlier for cranial pulmonary vessels, Ao, CVC. However, this trend was not seen in DV view and no significant difference in the diameter of caudal pulmonary vessels was seen among the 3 breed types. However, in both ventrodorsal and dorsoventral radiographs, the mean values of CdPA: 9$^{th}$ rib and CdPV: 9$^{th}$ rib had no significant difference among brachycephalic, mesocephalic, dolichocephalic groups

## Table 13: Radiographic dimensions of caudal pulmonary vessels and 9$^{th}$ rib in apparently healthy dogs belonging to different breeds

| Breed type | Caudal pulmonary artery diameter (in mm) | | Caudal pulmonary vein diameter (in mm) | | 9th rib diameter (in mm) artery | | 9th rib diameter (in mm) vein | | Caudal pulmonary artery diameter: 9th rib | | Caudal pulmonary vein diameter: 9th rib | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | VD | DV | VD | DV | VD | DV | VD | DV | VD | DV | VD | DV |
| Brachy-cephalic | 3.63±0.64 (1.99-7.91) | 4.66±0.84 (2.59-7.48) | 3.77±0.59$^{a}$ (2.58-8.41) | 4.96±1.01 (2.88-8.41) | 3.83±0.49$^{a}$ (2.65-7.05) | 4.44±0.63$^{a}$ (3.39-7.5) | 4.17±0.49$^{a}$ (3.14-6.77) | 4.53±0.64$^{a}$ (3.39-7.6) | 0.92±0.06 (0.75-1.19) | 1.02±0.10 (0.76-1.25) | 0.89±0.08 (0.56-1.13) | 1.07±0.12 (0.70-1.38) |
| Meso-cephalic | 5.49±0.31 (2.27-8.8) | 5.77±0.62 (3.49-9.5) | 6.02±0.38$^{ab}$ (2.41-9.6) | 5.74±0.41 (3.75-8.62) | 5.87±0.24$^{bc}$ (2.94-8.09) | 6.01±0.34$^{ab}$ (3.49-8.07) | 5.80±0.29$^{ab}$ (3.14-9.45) | 6.21±0.40$^{ab}$ (4.3-9) | 0.95±0.05 (0.64-1.61) | 0.96±0.07 (0.64-1.72) | 1.06±0.06 (0.71-1.81) | 0.93±0.04 (0.65-1.18) |
| Dolicho-cephalic | 4.79±0.55 (3.69-5.46) | 6.50±1.36 (4-8.69) | 6.71±0.95$^{b}$ (5.28-8.5) | 7.19±1.27 (4.86-9.23) | 6.89±0.69$^{c}$ (5.91-8.23) | 7.76±0.77$^{b}$ (6.25-8.82) | 6.76±0.67$^{b}$ (5.47-7.69) | 8.22±0.57$^{b}$ (7.3-9.26) | 0.70±0.09 (0.57-0.88) | 0.82±0.12 (0.64-1.06) | 0.99±0.06 (0.89-1.11) | 0.87±0.10 (0.67-1.00) |

Figures in parentheses indicate range

Values with different superscripts$^{(a,b,c)}$ indicate significant difference between the breed types.

**Correlation between Radiographic dimensions of caudal pulmonary vessels and $9^{th}$ rib (Table 14)**

CdPA diameter had a significant ($p \le 0.05$) positive correlation with CdPV, $9^{th}$ rib artery intersection, $9^{th}$ rib vein intersection, CdPA: $9^{th}$ rib and CdPV: $9^{th}$ rib. The ninth rib diameter at artery intersection and CdPA: $9^{th}$ rib had a significant ($p \le 0.05$) positive correlation with $9^{th}$ rib diameter at vein intersection and CdPV respectively.

**Evaluation of various extra thoracic structures (Fig. 25)**

Diaphragm, Ribs, Sternebrae, Vertebral column were apparently normal in all radiographs of dogs belonging to group 1 i.e. normal animals

From the various measurements recorded in apparently normal dogs it was concluded that absence of any lung pattern and associated values ranging from; Vertebral Heart Score: 8.25-11, % Coverage of Heart: 49.1-60.92, Intercostal Space: 2.5-3.5 , Sternal Contact: 2-3,TD/TI: 0.10-0.26 , Tracheal Diameter/3rd Rib Ratio: 1.41-3.24, Aorta/T6: 0.88-1.05, Caudal Vena Cava/T6: 0.57-1.01, CRPV /4th Rib Ratio: 0.44-0.0.77, CDPV/9th Rib: 0.56-1.20 were suggestive of normal thorax in brachycephalic dogs. absence of lung pattern and associated values ranging from; Vertebral Heart Score: 8.25-11, % Coverage of Heart: 51.2-65.26, Intercostal Space: 2.3-3.5, Sternal Contact: 2-3.5, Td/Ti: 0.16-0.32, Tracheal Diameter/3rd Rib Ratio: 1.51-3.56, Aorta/T6: 0.75-1.46, Caudal Vena Cava /T6: 0.28- 1.03, CRPA /4th Rib Ratio: 0.31-0.76, CDPV/9th Rib: 0.64-1.18 were suggestive of normal thorax in mesocephalic dogs. Similarly, absence of lung pattern and associated values ranging from; Vertebral Heart Score: 8.75-11, % Coverage of Heart: 55.12-64.58, Intercostal Space: 2.5-3, Sternal Contact: 2.5-3, Td/Ti: 0.15-0.32, Td/3rd Rib Ratio: 1.65-3.24, Ao/T6 Ratio 0.83-1.10, Cvc/T6 Ratio: 0.79-1.07, CRPV /4th Rib Ratio: 0.42-0.76, CDPV/9th Rib: 0.57-1.11 were suggestive of normal thorax in dolichocephalic dogs.

**Table 14: Correlation between radiographic dimensions of caudal pulmonary vessels and 9$^{th}$ rib in apparently healthy dogs (Group 1)**

| | | Caudal pulmonary artery diameter | Caudal pulmonary vein diameter | 9th rib diameter at artery | 9th rib diameter at vein | Caudal pulmonary artery diameter:9th rib |
|---|---|---|---|---|---|---|
| Caudal pulmonary vein diameter | r | .817** | | | | |
| | p | 0 | | | | |
| | N | 33 | | | | |
| 9th rib diameter at artery | r | .697** | .645** | | | |
| | p | 0 | 0 | | | |
| | N | 33 | 33 | | | |
| 9th rib diameter at vein | r | .671** | .716** | .868** | | |
| | p | 0 | 0 | 0 | | |
| | N | 32 | 32 | 33 | | |
| Caudal pulmonary artery diameter:9th rib | r | .611** | .450** | -0.17 | -0.083 | |
| | p | 0 | 0.009 | 0.336 | 0.647 | |
| | N | 33 | 33 | 34 | 33 | |
| Caudal pulmonary vein diameter:9th rib | r | .466** | .675** | -0.053 | -0.077 | .773** |
| | p | 0.007 | 0 | 0.769 | 0.672 | 0 |
| | N | 32 | 32 | 33 | 33 | 33 |

*values differ significantly (p≤0.05)

**values differ significantly (p≤0.01)


**Fig. 25:** **Right lateral radiograph showing normal extra thoracic structures in an apparently normal dog (Group 1)**

**PULMONARY DISORDERS**

A total of 96 dogs out of 134 included in the present study were diseased. On the basis of clinical signs and radiographic evaluation 70 dogs were grouped under pulmonary disorders (group-2). Out of the 70 dogs with pulmonary disorder (Fig. 26) 15 were brachycephalic which included American Bully (1), Mastiff (4), Cane Corso (1), Pitbull (4), Pug (4) and Shih Tzu (1) breeds. Forty-nine were mesocephalic breeds which included Beagle (4), Cocker Spaniel (3), Gaddi (2), Golden Retriever (4), Labrador Retriever (21), Non-Descript (7), Pomeranian (4), Rottweiler (3) and Toy Pomeranian (1). Six dolichocephalic breeds were reported with pulmonary disorders which included German Shepherd (3), Doberman (1), Great Dane (1) and Dachshund (1). Pulmonary disorders were recorded in 26 female and 44 male dogs in the present study (Fig. 27). The age of the animals in the present study ranged between 0.2 to 14 years with a mean of $6.20 \pm 0.41$ and the mean weight of the animals was $26.16 \pm 1.63$ kg.

In the present study the mesocephalic breeds represented 70% of the dogs with pulmonary disorder and out of mesocephalic breed, Labrador Retriever was the most commonly affected breed. The reason for greater representation of male mesocephalic breeds in the present study may be the popularity of male mesocephalic breeds especially Labrador Retriever in this region. A similar presentation pattern was seen among apparently normal dogs (group-1) in the present study.

A set of 3-4 views were taken for all the dogs belonging to this group which included Left lateral, Right lateral and VD/DV projections.

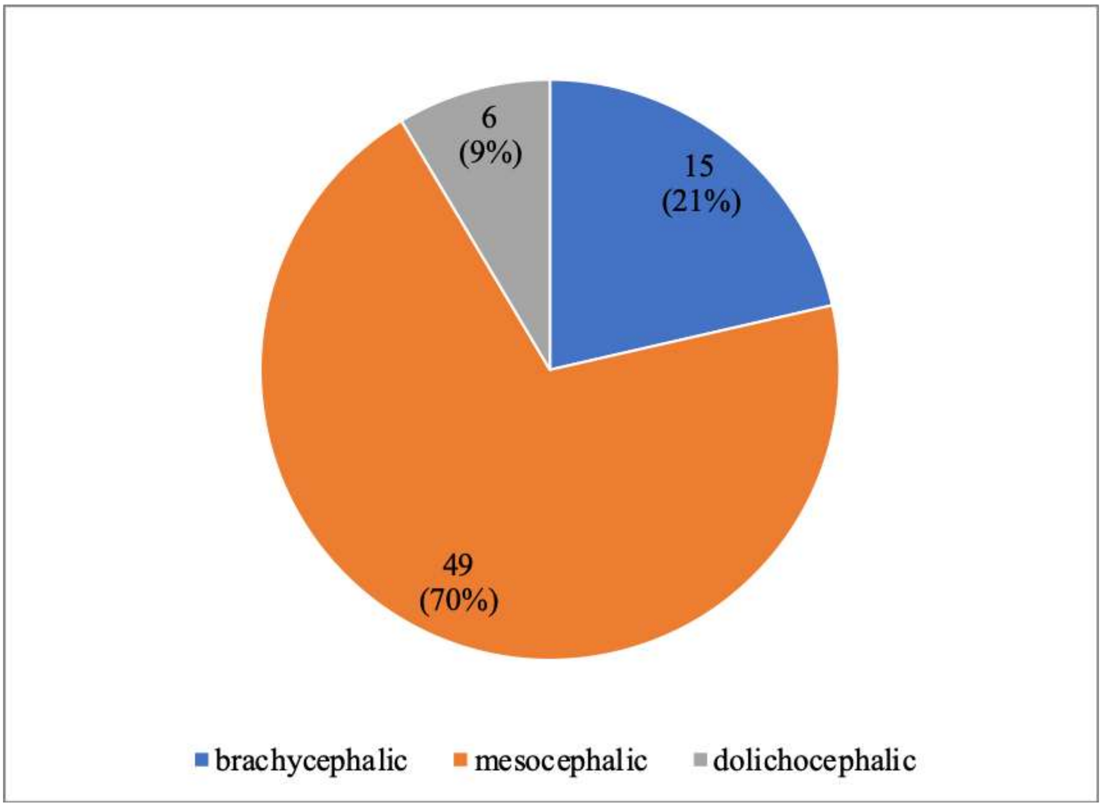



**Fig. 26: Distribution of dogs with pulmonary disorders (N=70) on the basis of breed type (brachycephalic, mesocephalic and dolichocephalic)**

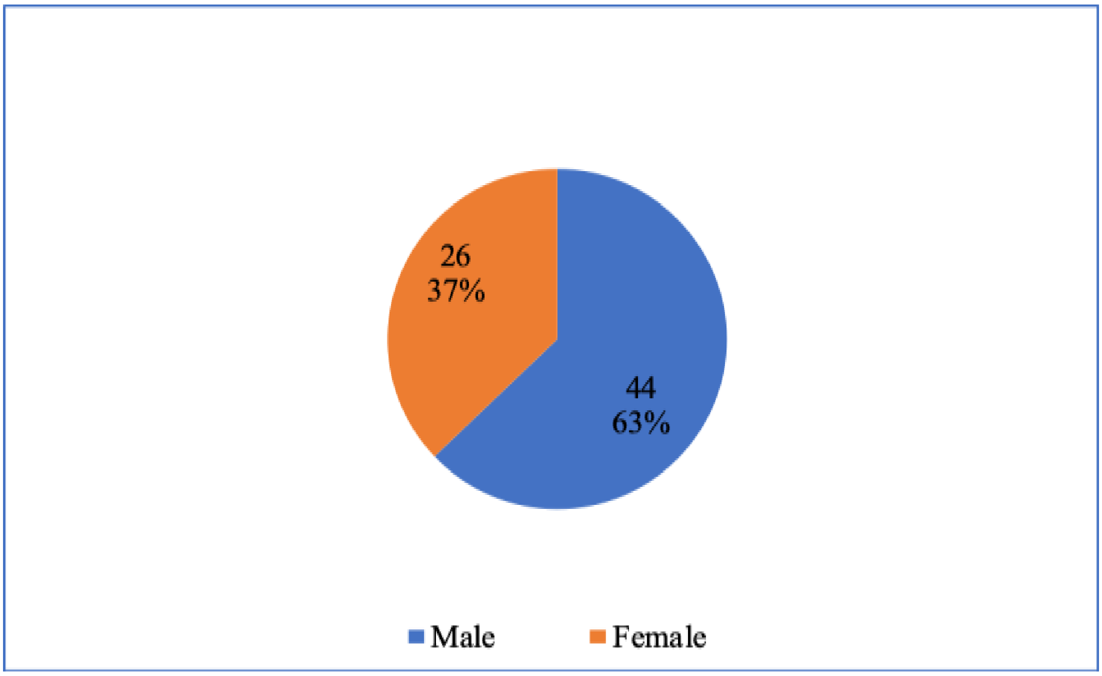



**Fig. 27: Distribution of dogs with pulmonary disorders (N=70) on basis of gender**

**Evaluation of Lungs**

The lungs in all the 70 dogs were evaluated for various lung patterns viz alveolar (n=12), interstitial(n=21), bronchial, vascular or mixed(n=37) Other lesions were also noticed if any. Twelve of the 70 dogs showed alveolar pattern (Fig. 28) in the lungs which was characterized by the presence of air bronchograms (Kealy and McAllister 2000, Farrow 2003, Muhlbauer and Kneller 2013, Thrall 2013, Sharma 2018). Border effacement of the cardiac silhouette was another important feature in all the dogs with alveolar pattern as described by earlier workers (Kealy and McAllister 2000, Muhlbauer and Kneller 2013, Thrall 2013)

The alveolar pattern, in the present study was seen involving multiple lung lobes in majority of the cases (Fig-29). Out of the 12 dogs, 11 had alveolar pattern in the middle lung lobe while 10 in cranial and 8 each in caudal and accessory lung lobes. The higher involvement of middle lung lobe might be due to it being the dependent lung lobe. The alveolar pattern was involved with pleural effusions (Fig. 33 & 35) in 5 dogs. Differentials for alveolar pattern may include pneumonia, non-cardiogenic pulmonary oedema, haemorrhage, thromboembolism, atelectasis, allergy and primary lung tumour (Muhlbauer and Kneller 2013, Thrall 2013)

In the present study we took at least 3 views for the better evaluation of lung patterns. Ober and Barber (2006) also opined that a three-view study is better for evaluation of interstitial pattern. Twenty one out of 70 dogs showed interstitial pattern (Fig. 28) in the lungs which was characterized by presence of multiple large nodules (Fig. 36), numerous small nodules widespread throughout lungs i.e. snowstorm pattern (Fig. 46) (Muhlbauer and Kneller 2013) and loss of clarity in the outline of vessels, general loss of contrast in the lung field (Fig. 37) (Kealy and McAllister 2000). In the present study interstitial pattern was seen involving multiple lung lobes in majority of cases (Fig. 30). Out of the 21 dogs with interstitial pattern, 21 had involvement of caudal lung lobes, 13 had interstitial pattern in cranial lung lobe and 7 and 6 had interstitial pattern in accessory and middle lobe respectively. Differentials for interstitial pattern may include multiple solid nodules, solitary solid mass, multiple cavitary nodules, and solitary cavitary mass (Muhlbauer and Kneller 2013; Thrall 2013).

Thirty seven out of 70 dogs showed mixed pattern which included combinations of one or more patterns viz. interstitial, alveolar and bronchial. (Fig. 28). Pajas et al (2014) also reported majority of pulmonary patterns in dogs having cough to be mixed patterns consisting of alveolar and bronchial forms. Kealy and McAllister (2000) concluded that in many conditions, the lung pattern will be a mixed one because of the close relationship between the various structures within the lungs. They opined that interstitial infiltration may precede alveolar infiltration and therefore at the time of radiography, some areas may show predominantly interstitial changes, and other areas may show predominantly alveolar changes in the lungs. The bronchial pattern admixed with other patterns was characterized by presence of donuts, due to bronchial wall thickness increased by fluid infiltration (Thrall 2013) and peri bronchial infiltrations (Kealy and Mc Allister 2000). In majority of cases of the present study mixed pattern was seen involving multiple lung lobes (Fig. 31). Out of total 37 dogs, 36 had mixed pattern in caudal lung lobe, 22 had mixed pattern in cranial lung lobes and 19 and 16 dogs had mixed pattern in accessory and middle lung lobes, respectively. The mixed pattern involving various lung lobes were appreciable both in lateral views (Figure 32 and 34) and DV views (Figure 39,41,43).

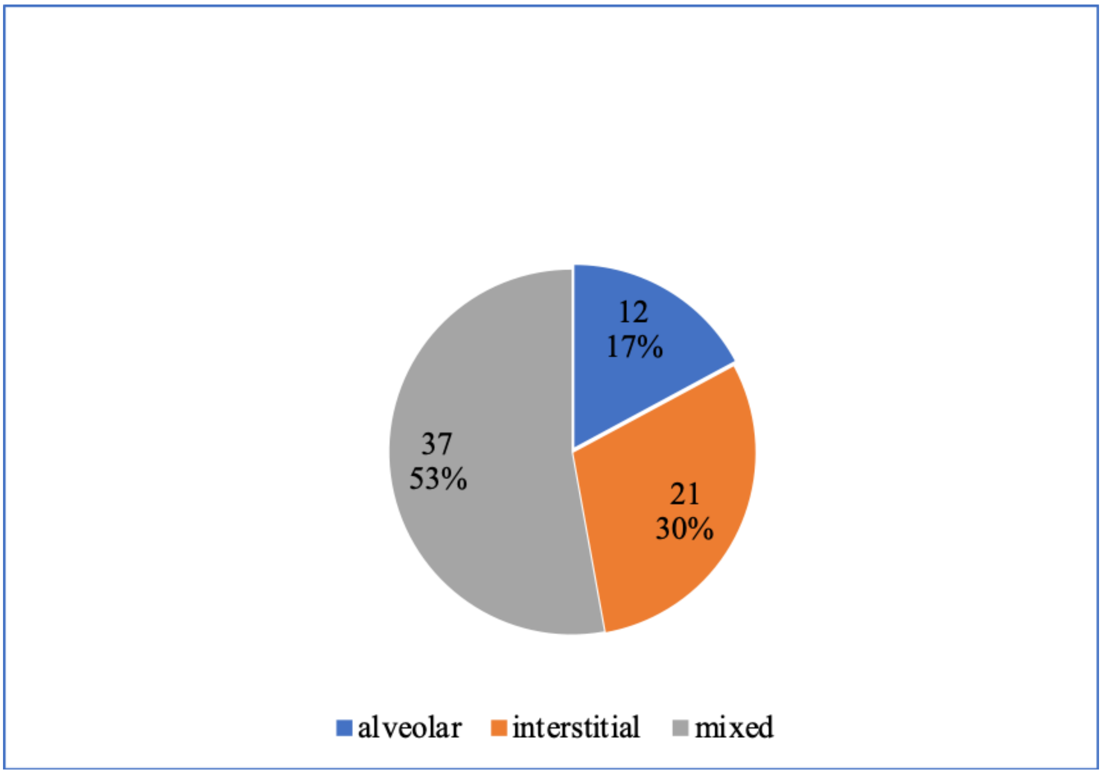



**Fig. 28: Distribution of dogs with pulmonary disorders (N=70) on the basis of lung patterns**

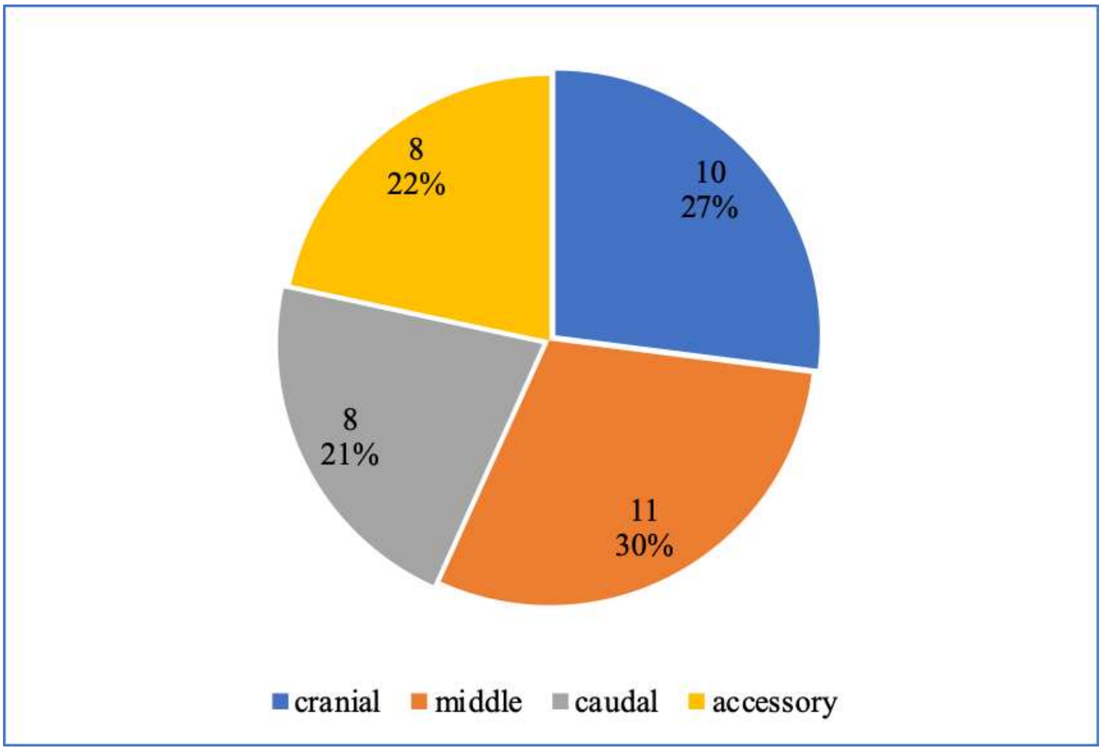



**Fig. 29: Distribution of affected lung lobes in dogs with alveolar pattern (N=12)**

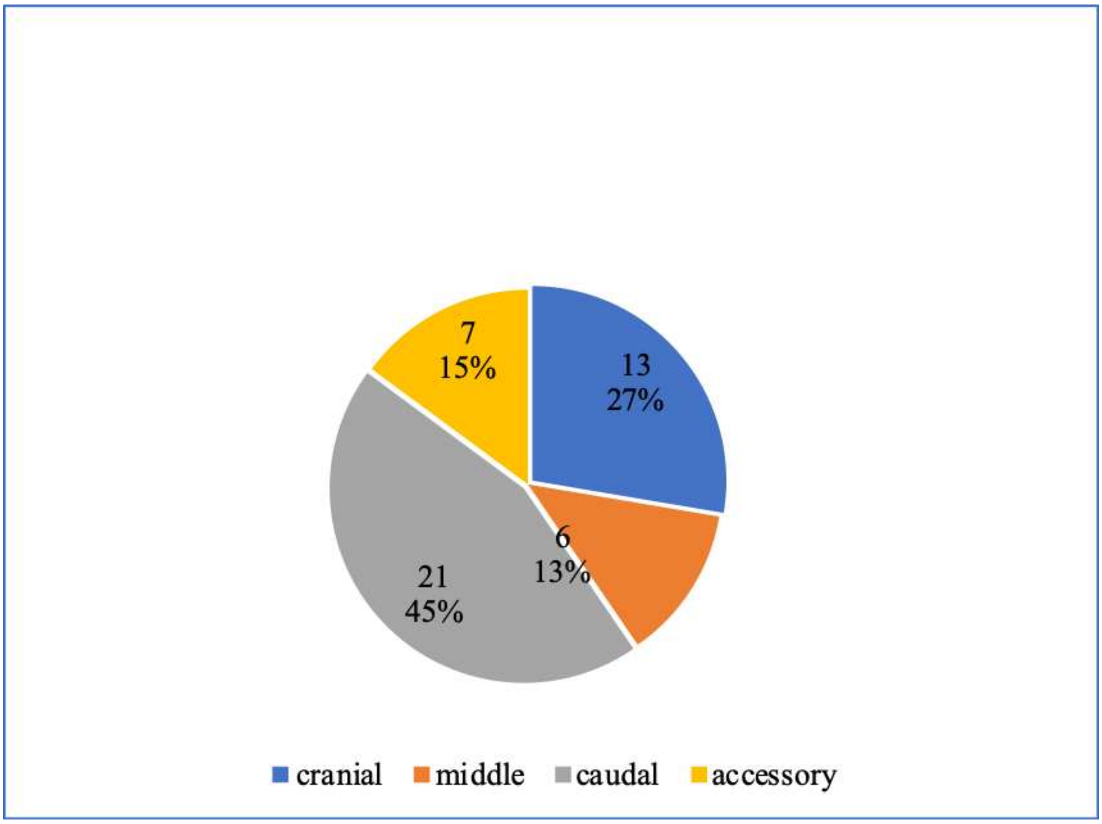



**Fig. 30: Distribution of affected lung lobes in dogs with interstitial pattern (N=21)**

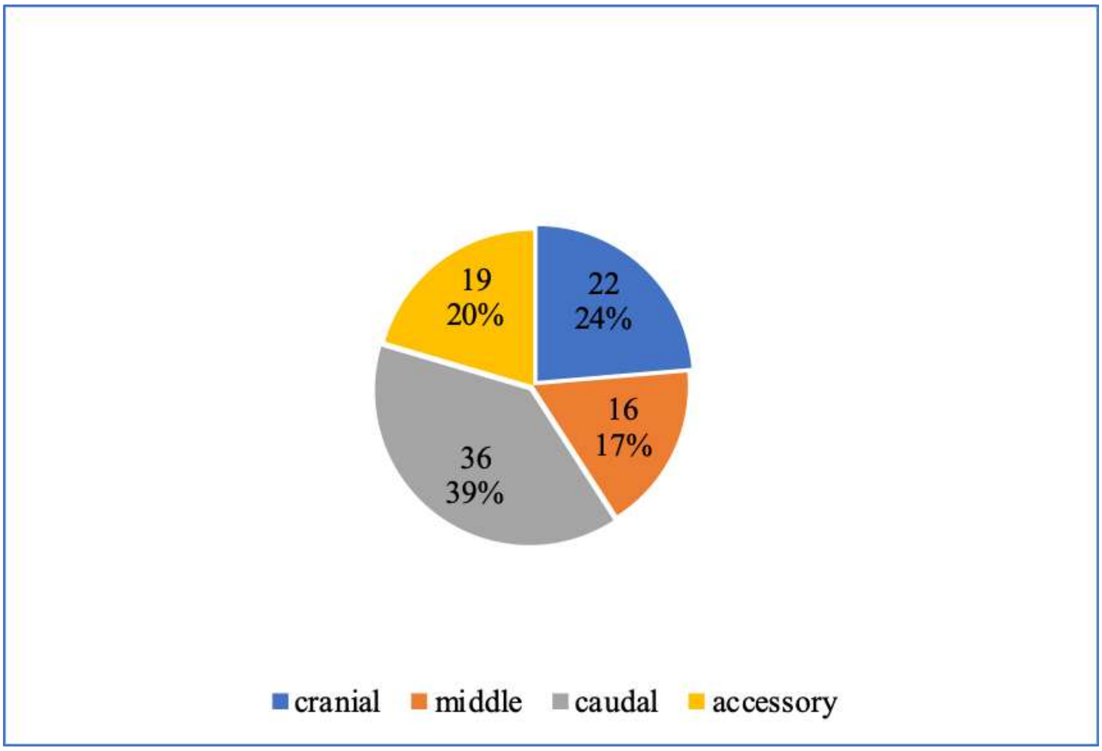



**Fig. 31: Distribution of affected lung lobes in dogs with mixed pattern (N=37)**

In the present study out of 70 dogs, 10 dogs were subjected to thoracic radiography to rule out metastasis secondary to a superficial tumour or tumour involving some other body part. All these cases showed interstitial or mixed pattern and were diagnosed as metastatic. Kealy and McAllister (2000) also stated that majority of the cases presented with the cancerous growth, subjected to radiological examination, revealed metastatic lesions involving part or entire portion of lungs.

**Evaluation of various parameters of heart**

The shape of the cardiac silhouette was normal i.e. oval or elliptical (like lopsided egg) in 51 dogs as described earlier in group 1 (Farrow 2003, Muhlbauer and Kneller 2013; Thrall 2013). However, the cardiac silhouette was not appreciable in 19 dogs which might be due to border effacement discussed later. All the dimensions of various parameters of heart were measured and expressed in mm (Table 15).

The mean ±SE value of VHS was 9.98±0.19 in right lateral and 10.27±0.14 in left lateral radiographs of brachycephalic breeds and ranged from 8.25-11.00. This was considered within the normal reference range for brachycephalic dogs. In mesocephalic breeds, the mean ±SE value of VHS was 9.90±0.13 in right lateral and 9.94±0.13 in left lateral radiographs with a range of 8.25- 11.00. Similarly, in

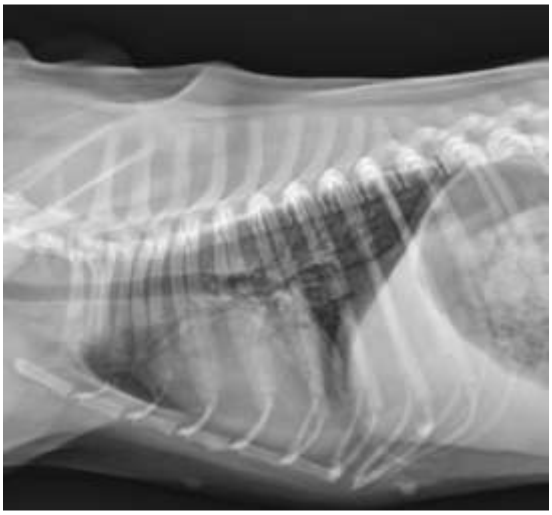


**Fig. 32: Right lateral radiograph of a brachycephalic dog, showing broncho interstitial pattern**

**Fig. 33: Right lateral radiograph of a brachycephalic dog showing alveolar pattern with pleural effusions**

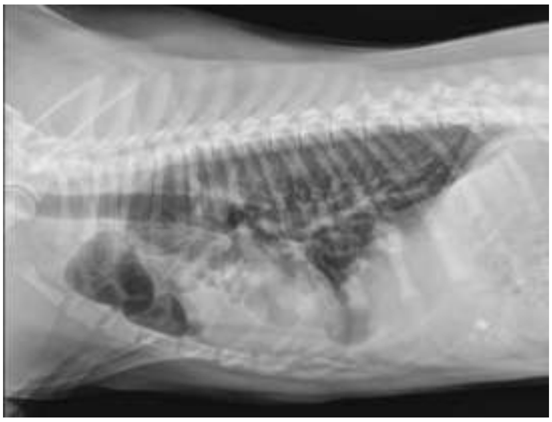


**Fig. 34: Right lateral radiograph of a mesocephalic dog showing bronchoalveolar pattern**

**Fig. 35: Right lateral radiograph of a mesocephalic dog showing alveolar pattern (retracted lung lobes) with fissure lines**

**Fig. 36: Right lateral radiograph of a dolichocephalic dog showing nodular interstitial pattern with consolidation**


**Fig. 37: Right lateral radiograph of a dolichocephalic dog showing interstitial pattern with tracheobronchial lymph nodes enlargement**


**Fig. 38: Ventrodorsal radiograph of a brachycephalic dog showing alveolar pattern**


**Fig. 39: Dorsoventral radiograph of a brachycephalic dog showing broncho interstitial pattern**


**Fig. 40: Ventrodorsal radiograph of a mesocephalic dog showing bronchial pattern**

**Fig. 41: Ventrodorsal radiograph of a mesocephalic dog showing broncho interstitial pattern**


**Fig. 42: Ventrodorsal radiograph of a dolichocephalic dog showing interstitial pattern**

**Fig. 43: Dorsoventral radiograph in a dolichocephalic dog showing alveolo-interstitial pattern**

dolichocephalic breeds, the mean ±SE value of VHS was 9.63 ±0.41 in right lateral and 9.55 ±0.33 in left lateral radiographs and ranged from 8.75-10.75. Slightly lower values of VHS were recorded in left lateral recumbency, in mesocephalic and dolichocephalic breeds. This was similar to the findings of Greco *et al* (2008), Whereas value of VHS in brachycephalic breeds were higher in left lateral recumbency as compared to right lateral recumbency. In contrast Gugjoo *et al* (2013) reported, no significant difference in VHS when animal was radiographed in either left or right lateral recumbency. In the present study, the mean VHS values of animals suffering from pulmonary disorders remained within the normal reference range of 8.5 – 10.5 as proposed by Buchanan and Bucheler (1995), similar VHS had been reported by Bodh et al (2016) and Sharma (2018). This confirmed no cardiac involvement in the animals included in this group.

In brachycephalic breeds, the mean ±SE value of percentage of cardiac silhouette in thoracic cavity was 58.07±1.73 in right lateral and 60.97±1.65 in left lateral radiographs with a range of 50.67-66.44. The mean ±SE value in mesocephalic breeds was 58.48±0.93 in right lateral and 59.59±0.96 in left lateral radiographs and ranged from 44.07 - 67.00. In dolichocephalic breeds, the mean ±SE value was 56.69 ±2.51 in right lateral and 55.53 ±2.66 in left lateral radiographs which ranged from 48.47-64.65 (Table 15). Irrespective of the breed type the percentage space occupied by the cardiac silhouette in the thoracic cavity on VD/DV views was within the normal range of 60-65% as proposed by Poteet (2001)

Border effacement of cardiac silhouette was seen in 19 dogs suffering from pulmonary disorders. This could be attributed to pleural effusions or lung lobe pneumonia. Thrall (2013) opined that border effacement could result from pathologies like lung lobe pneumonia and pleural effusions. Border effacement in the present study might also be attributed to regional or localized infection which could hinder visualization of cardiac silhouette from any aspect regionally or completely (Farrow 2003). In the present study, animals showing border effacement of cardiac silhouette showed involvement of lung and pleural space all around the heart, predominantly in right hemithorax on lateral and VD recumbencies, respectively (Figs. 44-47). Similar findings have been reported by Breton *et al* (1986) who found bilateral pleural effusion on ventro-dorsal radiographs that was more abundant in right hemithorax.

In brachycephalic breeds, the mean ±SE value of ICS occupied was 2.86±0.11 intercostal spaces in right lateral and 2.95±0.11 in left lateral radiographs with a range of 2-3.5. The mean ±SE value of ICS occupied in mesocephalic breed was 2.75±0.06 in right lateral and 2.74±0.07 in left lateral radiographs which ranged from 2-3.5. Similarly, in dolichocephalic breeds, the mean ±SE value of ICS occupied was 2.90 ±0.10 in right lateral and 2.90 ±0.10 in left lateral radiographs with a range of 2-3. The value of ICS occupied was higher in brachycephalic breeds in comparison to mesocephalic and dolichocephalic breeds. The values of ICS occupied followed a similar trend as for apparently normal dogs (Group 1) in the present study and have been discussed earlier. This further confirmed no cardiac involvement in animals with pulmonary disorders.

In brachycephalic breeds, the mean ±SE value of sternal contact of the cardiac silhouette was 2.93±0.12 in right lateral and 2.83±0.11 in left lateral radiographs with a range of 2.25-3.5. In mesocephalic breeds, the mean ±SE value of sternal contact was 2.65±0.05 in right lateral and 2.63±0.05 in left lateral radiographs having a range of 2.0-3.5. Similarly, the mean ±SE value of sternal contact in dolichocephalic breeds was 2.25 ±0.19 in right lateral and 2.15 ±0.22 in left lateral radiographs, ranging from 1.75-3.0. Mean values of sternal contact in brachycephalic group was significantly higher from the mean values of sternal contact in mesocephalic and dolichocephalic group, whereas there was no significant difference between the mean values of sternal contact in mesocephalic and dolichocephalic group in both right and left lateral radiographs. Sharma (2018) also reported upright heart in Doberman Pinscher which is a dolichocephalic breed. Farrow (2003), Thrall (2013) and Muhlbauer and Kneller (2013) also reported similar sternal contact values in dogs with normal heart. This again confirmed no cardiac involvement in dogs grouped under pulmonary disorders in the present study.


**Fig 44 : Right lateral radiograph showing cranial border effacement**

**Fig 45 : Ventrodorsal radiograph showing border effacement in right hemithorax**


**Fig 46: Left lateral radiograph showing numerous small nodules widespread throughout lungs (snowstorm pattern)**

**Fig 47: Ventrodorsal radiograph showing border effacement all around the cardiac silhouette**

**Table 15: Radiographic dimensions of heart in dogs with pulmonary disorders belonging to different breeds**

| Breed type | VHS | | Percentage of cardiac silhouette in thoracic cavity | | ICS | | Sternal contact | |
|---|---|---|---|---|---|---|---|---|
| | R | L | VD | DV | R | L | R | L |
| Brachycephalic (N=15) | 9.98±0.19 (8.25-11) | 10.27±0.14 (9.5-11) | 58.07±1.73 (50.67-65.47) | 60.97±1.65 (51.88-66.44) | 2.86±0.11 (2-3.5) | 2.95±0.11 (2.5-3.5) | 2.93±0.12$^{a}$ (2.25-3.5) | 2.83±0.11$^{a}$ (2.25-3.5) |
| Mesocephalic (N=49) | 9.90±0.13 (8.25-11) | 9.94±0.13 (8.25-11) | 58.48±0.93 (44.07-67.00) | 59.59±0.96 (44.07-67.00) | 2.75±0.06 (2-3.5) | 2.74±0.07 (2-3.5) | 2.65±0.05$^{bc}$ (2-3.5) | 2.63±0.05$^{bc}$ (2-3.25) |
| Dolichocephalic (N=6) | 9.63±0.41 (8.75-10.75) | 9.55±0.33 (9-10.50) | 56.69±2.51 (48.47-63.56) | 55.53±2.66 (49.07-64.65) | 2.90±0.10 (2.5-3) | 2.90±0.10 (2-3) | 2.25±0.19$^{c}$ (2-3) | 2.15±0.22$^{c}$ (1.75-3) |

Figures in parentheses indicate range

Values with different superscripts$^{(a,b,c)}$ indicate significant difference between the breed types.

**Correlation between different parameters of heart**

Pearson's data analysis revealed significant ($p \leq 0.05$) positive correlation of VHS with percentage of cardiac silhouette with ICS occupied by the heart (Table 16).

**Table 16: Correlation between different parameters of heart in dogs with pulmonary disorders (Group 2)**

| | | **VHS** | **% of cardiac silhouette** | **Intercostal space** |
|---|---|---|---|---|
| Percentage of cardiac silhouette in thoracic cavity | r | 0.264 | | |
| | p | 0.073 | | |
| | N | 47 | | |
| Intercostal space | r | .306* | .344* | |
| | p | 0.028 | 0.014 | |
| | N | 52 | 50 | |
| Sternal contact | r | 0.011 | 0.079 | 0.196 |
| | p | 0.939 | 0.583 | 0.144 |
| | N | 52 | 51 | 57 |

*values differ significantly ($p \leq 0.05$)

**values differ significantly ($p \leq 0.01$)

**Evaluation of mediastinum:**

All the dimensions of cranial and caudal mediastinal structures were measured and expressed in mm. Sixty-five dogs had a normal cranial mediastinum with no space occupying lesion (SOL) whereas in 5 dogs, space occupying lesion was apparently visible in the cranial mediastinum (Fig. 48) along with soft tissue in the perihilar region. The SOL may be due to lymphadenopathy (Smith and O'Brien 2012, Epperly *et al* 2018), cranial mediastinal mass (Liptak *et al* 2008) or bronchogenic cyst (Dahl *et al* 2002). Caudal mediastinum in 69 dogs was normal with no SOL whereas one dog had SOL in the caudal mediastinum on lateral view (Fig. 49a) and VD view (Fig. 49b) which was suspected for involvement of tracheobronchial lymph nodes (Geyer *et al* 2010).

Oesophagus was apparently not visible in any radiograph irrespective of the view. In brachycephalic breeds, the mean ±SE value of carina diameter was 13.05


**Figure 48:** **Right lateral radiograph showing space occupying lesion present in the cranial mediastinum (Group -2)**


**Fig. 49:** **Radiographs showing space occupying lesion present in the caudal mediastinum in lateral view (49a) and in VD view (49b)**

±1.45 mm in right lateral and 10.66 ±1.23 mm in left lateral radiographs with a range of 3.6-21.94. In mesocephalic breeds, the mean ±SE value was 16.97 ±0.77 in right lateral and 16.53 ±0.76 in left lateral radiographs and ranged from 5.18 - 35.55. While in dolichocephalic breeds, the mean ±SE value of carina diameter was 20.18 ±1.68 in right lateral and 19.08 ±1.65 in left lateral radiographs with a range of 14.27-26.79 (Table 17). Overall, the carina diameter was lower in brachycephalic breeds as compared to other groups and followed similar trend as in apparently normal animals (group 1) (Kealy and Mc Allister 2000, Farrow 2003, Muhlbauer and Kneller 2013, Thrall 2013, Brown and Brown 2014, Sharma 2018).

Tracheal course was normal in 67 dogs, dorsally deviated at intersection with cranial mediastinum in 2 dogs and ventrally deviated at carina in 1 dog as shown in Figs. 49a and 50. The dorsal deviation in 2 dogs was considered artefactual and could have occurred due to extension of neck. The ventral deviation seen at carina in 1 case was attributed to the SOL in the caudal mediastinum (Fig. 49a) thereby displacing carina ventrally.

In brachycephalic breeds, the mean ±SE value of trachea diameter (TD) was 10.65 ±1.23 mm in right lateral and 9.83 ±1.23 mm in left lateral radiographs with a range of 3.76-18.47. In mesocephalic breeds, the mean ±SE value was 13.99 ±0.59 in right lateral and 14.25±0.66 in left lateral radiographs which ranged from 5.20-25.80. Similarly, the TD In dolichocephalic breeds was 17.80 ±1.27 in right lateral and 17.92 ±2.22 in left lateral radiographs with a range of 11.63-26.77. The tracheal diameter in dolichocephalic and mesocephalic breed were significantly ($P \leq 0.05$) higher than brachycephalic which could be attributed to their large body size.

In brachycephalic breeds, the mean ±SE value (mm) of thoracic inlet (TI) diameter was 62.66 ± 5.80 in right lateral and 56.25 ±5.66 in left lateral radiographs with a range of 31.58-99.47. In mesocephalic breeds, the mean ±SE value (mm) was 70.12 ±2.00 in right lateral and 70.91 ±2.06 in left lateral radiographs which ranged from 36.01-97.33 mm. In dolichocephalic breeds, the mean ±SE values (mm) were 83.55 ±5.75 mm in right lateral and 84.86 ±5.63 mm in left lateral radiographs which ranged from 60.62-108.90. The thoracic inlet diameter in right lateral radiographs was significantly ($P \leq 0.05$) lower in brachycephalic and dolichocephalic group whereas no statistical difference was found between mesocephalic and brachycephalic group.

Tracheal diameter: thoracic inlet diameter (TD TI) ratio in brachycephalic breeds, was 0.17 ±0.01 in right lateral and 0.17 ±0.01 in left lateral radiographs which ranged from 0.12-0.24. The TD: TI in mesocephalic breeds was 0.20 ±0.01 in right lateral and 0.20 ±0.01 in left lateral radiographs with a range of 0.10-0.32. While in dolichocephalic breeds, TD: TI was 0.21 ±0.01 in right lateral and 0.20 ±0.02 in left lateral radiographs with a range of 0.16-0.29. In right lateral radiographs, the mean value of TD: TI was significantly higher in brachycephalic and dolichocephalic group whereas, no statistically significant difference was found between mean values of mesocephalic and brachycephalic groups. However, on left lateral radiographs the TD: TI was statistically similar for all the breed types.

Proximal 1/3rd of 3rd rib diameter in brachycephalic breeds was 5.61 ±0.80 in right lateral and 5.06 ±0.68 in left lateral radiographs with a range of 1.81-10.6. In mesocephalic breeds, it was 5.91 ±0.24 in right lateral and 6.18 ±0.27 in left lateral radiographs and ranged from 2.88-11.13 while in dolichocephalic breeds the mean ±SE value was 8.03 ±0.87 in right lateral and 7.77 ±0.91 in left lateral radiographs with a range of 4.56-11.82. The values in different breed types followed a similar trend as for normal dogs belonging to group 1.

Trachea diameter: proximal 1/3rd of 3rd rib diameter ratio (TD: R3) in brachycephalic breeds was 2.06 ±0.13 in right lateral and 2.02 ±0.15in left lateral radiographs with a range of 1.31-3.22. In mesocephalic breeds the TD: R3 was 2.52 ±0.14 in right lateral and 2.47 ±0.14 in left lateral radiographs which ranged from 1.00-5.40 and in dolichocephalic breeds it was 2.20 ±0.09 in right lateral and 2.33 ±0.15 in left lateral radiographs with a range of 1.86-3.00. The TD: R3 ratio in the present study was as low as 1.31 in brachycephalic breeds to as high as 5.40 in mesocephalic breeds. The mean values irrespective of the breed type however, remained around 2.50 and were similar to the apparently normal dogs (group1). This was in contrast to Muhlbauer and Kneller (2013) who reported that TD: R3 should be approximately 3.0 in normal dogs.

**Figure 50: Right lateral radiograph showing dorsally deviated carina at the level of cranial mediastinum**

**Table 17: Radiographic dimensions of mediastinal structures in dogs with pulmonary disorders belonging to different breeds**

| **Breed type** | **Carina diameter (in mm)** | | **Trachea diameter Td (in mm)** | | **Thoracic inlet diameter Ti (in mm)** | | **Td: Ti** | | **Proximal 1/3rd of 3rd rib diameter (in mm)** | | **Tracheal diameter: Proximal1/3rd of 3rd rib diameter:** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **R** | **L** | **R** | **L** | **R** | **L** | **R** | **L** | **R** | **L** | **R** | **L** |
| Brachy-cephalic | 13.05±1.45$^{a}$ (3.6-21.94) | 10.66±1.23$^{a}$ (4.12-17.54) | 10.65±1.23$^{a}$ (3.76-18.47 | 9.83±1.23$^{a}$ (3.76-17.93) | 62.66±5.80$^{a}$ (32.02-99.47) | 56.25±5.66$^{a}$ (31.58-92.62) | 0.17±0.01$^{a}$ (0.12-0.24) | 0.17±0.01 (0.12-0.24) | 5.61±0.80$^{a}$ (1.81-10.62) | 5.06±0.68$^{a}$ (1.94-9.52) | 2.06±0.13 (1.31-3.17) | 2.02±0.15 (1.38-3.22) |
| Meso-cephalic | 16.97±0.77$^{ab}$ (5.18-35.55) | 16.53±0.76$^{bc}$ (6.47-29.64) | 13.99±0.59$^{ab}$ (6.98-25.8) | 14.25±0.66$^{bc}$ (5.20-22.39) | 70.12±2.00$^{ab}$ (36.96-97.33) | 70.91±2.06$^{bc}$ (36.01-94.45) | 0.20±0.01$^{ab}$ (0.12-0.32) | 0.20±0.01 (0.10-0.32) | 5.91±0.24$^{ab}$ (2.95-9.94) | 6.18±0.27$^{ab}$ (2.88-11.13) | 2.52±0.14 (1.25-5.39) | 2.47±0.14 (1.00-5.40) |
| Dolicho-cephalic | 20.18±1.68$^{b}$ (14.27-26.79) | 19.08±1.65$^{c}$ (14.32-23.66) | 17.80±1.27$^{c}$ (11.63-23.17) | 17.92±2.22$^{c}$ (12.70-26.77) | 83.55±5.75$^{b}$ (60.62-108.90) | 84.86±5.63$^{c}$ (66.69-106.64) | 0.21±0.01$^{b}$ (0.18-0.23) | 0.20±0.02 (0.16-0.29) | 8.03±0.87$^{c}$ (5.73-11.82) | 7.77±0.91$^{b}$ (4.56-10.64) | 2.20±0.09 (1.88-2.52) | 2.33±0.15 (1.86-3.00) |

Figures in parentheses indicate range

Values with different superscripts$^{(a,b,c)}$ indicate significant difference between the breed types.

**Correlation between various parameters of mediastinal structures**

Pearson's analysis as shown in Table 18 revealed that the Carina diameter and TI had a significant ($p \leq 0.05$) positive correlation with each other and with all other mediastinal structure i.e. trachea diameter, TD: TI, proximal 1/3$^{rd}$ of 3$^{rd}$ rib, TD: proximal 1/3$^{rd}$ rib. Thoracic inlet diameter had a significant ($p \leq 0.05$) positive correlation with the proximal 3$^{rd}$ rib while the TD: R3 had significant positive ($p \leq 0.05$) correlation with TD: TI and proximal 1/3$^{rd}$ of 3$^{rd}$ rib.

**Table 18: Correlation between radiographic dimensions of mediastinal structures in dogs with pulmonary disorders (Group 2)**

| | | Carina diameter | Trachea diameter TD | Thoracic inlet diameter Ti | TD: Ti | Proximal 1/3rd of 3rd rib diameter |
|---|---|---|---|---|---|---|
| Trachea diameter TD | r | .834** | | | | |
| | p | 0 | | | | |
| | N | 64 | | | | |
| Thoracic inlet diameter Ti | r | .697** | .669** | | | |
| | p | 0 | 0 | | | |
| | N | 63 | 69 | | | |
| TD: Ti | r | .460** | .715** | -0.009 | | |
| | p | 0 | 0 | 0.944 | | |
| | N | 63 | 69 | 69 | | |
| Proximal 1/3rd of 3rd rib diameter | r | .512** | .542** | .838** | 0.043 | |
| | p | 0 | 0 | 0 | 0.727 | |
| | N | 64 | 70 | 69 | 69 | |
| Trachea diameter: proximal 1/3rd of 3rd rib diameter | r | .323** | .455** | -0.183 | .691** | -.462** |
| | p | 0.009 | 0 | 0.133 | 0 | 0 |
| | N | 64 | 70 | 69 | 69 | 70 |

*values differ significantly ($p \leq 0.05$)

**values differ significantly ($p \leq 0.01$)

**Evaluation of pleural space**

Out of 70 dogs with pulmonary disorders, pleural space was found normal in 53 dogs while fluid and fissure lines were present in 15 and 2 dogs respectively as shown in Figure 51a and 51b. Pleural effusions and fissure lines may be a result of chronic or recurrent conditions involving pleura. In the present study, 2 cases which showed fissure lines/thickened pleura were geriatric dogs above 8.5 years. Farrow (2003), Muhlbauer and Kneller (2013), Thrall (2013), Brown and Brown (2014) also proposed that chronic or recurrent pleural effusions may result in fibrinous membrane covering the lungs that was termed as pleural peel or fibrosis.

Border effacement due to pleural fluid was more prominent in DV view as compared to VD view in the present study. This could be attributed to gravitation of fluid ventrally on DV view thereby superimposing the cardiac silhouette. However, in VD view the pleural fluid remains in dorsal aspect of thorax and does not make contact with heart (Brinkman *et al* 2006, Muhlbauer and Kneller 2013, Thrall 2013)

**Evaluation of parameters of various vascular structures in the thoracic cavity**

The dimensions of major vessels viz. Aorta diameter, Caudal vena cava diameter and their relationship with Length of T6 vertebra are presented in Table 19. All the dimensions were measured and expressed in mm.

In brachycephalic breeds, the mean ±SE value of aorta diameter (mm) was 11.03 ±3.34 in right lateral and 16.95 ±2.69 in left lateral radiographs with a range of 5.09-21.59. In mesocephalic breeds, aorta diameter was 17.53 ±0.77 in right lateral and 17.21 ±0.80 in left lateral radiographs which ranged from 11.90-25.03. The mean aorta diameter in dolichocephalic breeds was 20.85 ±0.76 in right lateral and 21.06 ±1.41 in left lateral radiographs with a range of 16.64-23.29.

The mean ±SE value of caudal vena cava (CVC) diameter in brachycephalic breeds, was 10.75 ±2.24 in right lateral and11.90 ±1.47 in left lateral radiographs with a range of 3.28-21.60. In mesocephalic breeds, CVC diameter was12.81 ±0.73 in right lateral and 13.96 ±0.76 in left lateral radiographs ranged from 7.91-20.70 and in dolichocephalic breeds it was19.91 ±1.92 in right lateral and 20.21 ±1.84 in left lateral radiographs with a range of 14.42-23.44.

In brachycephalic breeds, the mean ±SE value of length of T6 was 14.30 ±1.38 in right lateral and 13.34 ±1.48 in left lateral radiographs with a range of 6.86-24.78. The mean ±SE value in mesocephalic breeds, was 17.47 ±0.39 in right lateral and 17.60 ±0.42 in left lateral radiographs which ranged from 10.06-23.87. In dolichocephalic breeds, the mean ±SE value of length of T6 was 21.04 ±1.20 in right lateral and 20.19 ±1.10 in left lateral radiographs with a range of 15.63-23.62.

The dimensions of the major vessels followed a similar trend as recorded in apparently normal dogs in the study (group 1).

Aorta: Length of T6 (AO: T6) ratio in brachycephalic breeds was 0.94 ±0.10 in right lateral and 0.88 ±0.05 in left lateral radiograph and ranged from 0.74-1.05. Similarly, in mesocephalic breeds, the AO: T6 ratio was 0.95 ±0.02 in right lateral and 0.93 ±0.03 in left lateral radiograph with a range of 0.73-1.21 while in dolichocephalic breeds, the ratio was 0.92 ±0.03 in right lateral and 0.99 ±0.05 in left lateral radiograph ranged from 0.79-1.09. However, due to various lung patterns and other reasons like pleural effusions etc. the aorta could not be visualised in some of the animals.

Caudal vena cava: Length of T6 (CVC: T6 ratio) in brachycephalic breeds was 0.77 ±0.09 in right lateral and 0.71 ±0.02 in left lateral radiographs which ranged from 0.30-9.09. However slightly lower values were recorded in mesocephalic breeds which was 0.72 ±0.03 in right lateral and 0.80 ±0.03 in left lateral radiographs with a range of 0.45-1.10. In dolichocephalic breeds, the CVC: T6 ratio was higher and was 0.88 ±0.07 in right lateral and 0.79 ±0.16 in left lateral radiographs which ranged from 0.31-1.01. The mean± SE values of aorta, caudal vena cava, length of T6, Aorta: length of T6, CVC: length of T6 followed the same trend as in animals of group 1(apparently normal animals).

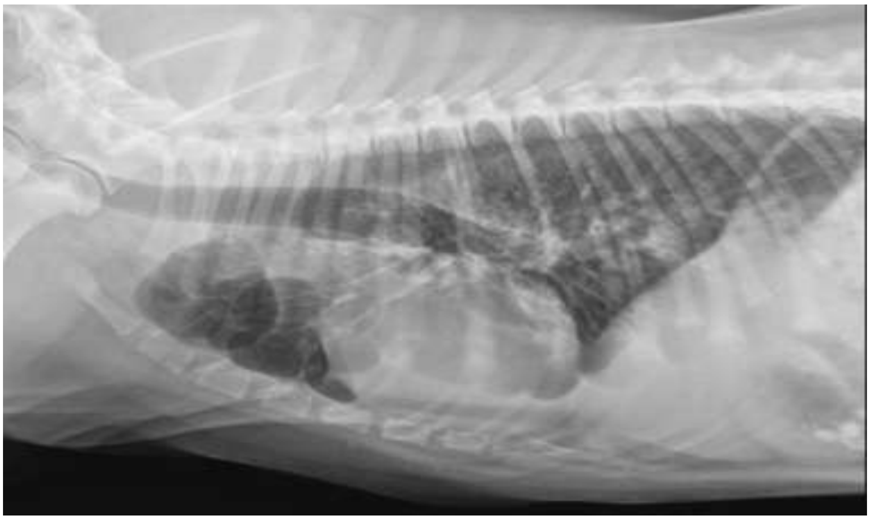


**Fig. 51a: Lateral radiograph showing fluid in pleural space**


**Figure 51b: Ventrodorsal radiograph showing thickened pleura (fissure lines) seen in right hemithorax in 8.5-year-old Labrador Retriever**

**Table 19: Radiographic dimensions of aorta, caudal vena cava and T6 in dogs with pulmonary disorders belonging to different breeds**

| Breed type | Aorta diameter (in mm) | | Caudal vena cava diameter (in mm) | | Length of T6 (in mm) | | Aorta diameter: Length of T6 | | Caudal vena cava diameter: Length of T6 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | R | L | R | L | R | L | R | L | R | L |
| Brachy-cephalic | 11.03±3.34$^{a}$<br>(5.09-16.64) | 16.95±2.69<br>(9.53-21.59) | 10.75±2.24$^{a}$<br>(3.28-21.60) | 11.90±1.47$^{a}$<br>(8.50-15.74) | 14.30±1.38$^{a}$<br>(6.86-24.40) | 13.34±1.48$^{a}$<br>(7.81-24.78) | 0.94±0.10<br>(0.74-1.05) | 0.88±0.05<br>(0.80-0.97) | 0.77±0.09<br>(0.30-1.09) | 0.71±0.02<br>(0.63-0.76 |
| Meso-cephalic | 17.53±0.77$^{bc}$<br>(12.89-21.51) | 17.21±0.80<br>(11.90-25.03) | 12.81±0.73$^{ab}$<br>(9.16-19.77) | 13.96±0.76$^{ab}$<br>(7.91-20.70) | 17.47±0.39$^{b}$<br>(10.06-23.87) | 17.60±0.42$^{bc}$<br>(10.24-23.23) | 0.95±0.02<br>(0.82-1.03) | 0.93±0.03<br>(0.73-1.21) | 0.72±0.03<br>(0.54-0.91) | 0.80±0.03<br>(0.45-1.10) |
| Dolicho-cephalic | 20.85±0.76$^{c}$<br>(18.82-22.39) | 21.06±1.41<br>(16.64-23.29) | 19.91±1.92$^{c}$<br>(14.42-22.79) | 20.21±1.84$^{c}$<br>(15.19-23.44) | 21.04±1.20$^{c}$<br>(15.63-23.62) | 20.19±1.10$^{c}$<br>(15.98-23.11) | 0.92±0.03<br>(0.82-0.96 | 0.99±0.05<br>(0.79-1.09) | 0.88±0.07<br>(0.67-0.98) | 0.79±0.16<br>(0.31-1.01) |

Figures in parentheses indicate range

Values with different superscripts$^{(a,b,c)}$ indicate significant difference between the breed types.

**Correlation between Radiographic dimensions of aorta, caudal vena cava and T6**

The aorta diameter had a significant (p≤0.05) positive correlation with CVC diameter and length of T6 while the CVC diameter had significant positive (p≤0.05) correlation with T6 length and CVC: length of T6 ratio (Table 20).

**Table 20: Correlation between radiographic dimensions of aorta, caudal vena cava and T6 in dogs with pulmonary disorders (Group 2)**

| | | Aorta diameter | Caudal vena cava diameter | Length of T6 | Aorta: Length of T6 diameter |
|---|---|---|---|---|---|
| Caudal vena cava diameter | r | .780** | | | |
| | p | 0 | | | |
| | N | 16 | | | |
| Length of T6 | r | .959** | .846** | | |
| | p | 0 | 0 | | |
| | N | 18 | 28 | | |
| Aorta: Length of T6 diameter | r | 0.405 | -0.144 | 0.147 | |
| | p | 0.095 | 0.596 | 0.562 | |
| | N | 18 | 16 | 18 | |
| Caudal vena cava: Length of T6 diameter | r | 0.295 | .722** | 0.269 | -.505* |
| | p | 0.267 | 0 | 0.166 | 0.046 |
| | N | 16 | 28 | 28 | 16 |

*values differ significantly (p≤0.05)

**values differ significantly (p≤0.01)

**Evaluation of cranial pulmonary vasculature:**

The dimensions of cranial pulmonary vessels and their relationship with width of proximal one third of $4^{th}$ rib is presented in Table 21. All the dimensions were measured and expressed in mm.

The mean ±SE value of cranial pulmonary artery diameter (mm) in brachycephalic breeds was 3.15 ±0.44 in right lateral and 4.07 ±0.58 in left lateral radiographs with a range of 1.24-6.52. In mesocephalic breeds, the mean ±SE value was 3.55 ±0.17 in right lateral and 4.42 ±0.21 in left lateral radiographs ranged from 1.81-6.72. In dolichocephalic breeds, the mean ±SE value was 3.99 ±0.58 in right lateral and 4.78 ±0.45 in left lateral radiographs which ranged from 2.13-6.04.

The cranial pulmonary vein diameter (mm) in brachycephalic breeds was 3.06 ±0.44 in right lateral and 3.56 ±0.56 in left lateral radiographs and ranged from 1.33-6.75. In mesocephalic breeds, the mean ±SE value was 3.83 ±0.18 in right lateral and 4.05 ±0.18 in left lateral radiographs and ranged from 1.741-7.32. Similarly, in dolichocephalic breeds, the mean ±SE diameter of cranial pulmonary vein was 4.49 ±0.61 in right lateral and 5.54 ±0.41in left lateral radiographs with a range of 2.95-6.23.

In brachycephalic breeds, the mean ±SE value of proximal 1/3rd of 4th rib (R4) width was 5.53 ±0.73 in right lateral and 5.51 ±0.74 in left lateral radiographs with a range of 1.94-10.70. In mesocephalic breeds, the R4 width was 6.79 ±0.26 in right lateral and 7.17 ±0.29 in left lateral radiographs ranged from 2.93-12.21 while in dolichocephalic breeds, the mean ±SE value was 9.05 ±1.62 in right lateral and 9.18 ±1.73 in left lateral radiographs with a range of 4.78-16.79. The reasons for greater dimensions of above structures in dolichocephalic breeds and smaller dimensions in brachycephalic breeds have been discussed earlier.

The ratio of cranial pulmonary artery diameter: proximal 1/3rd of 4th rib (CrPA: R4) in brachycephalic breeds was 0.58 ±0.06 in right lateral and 0.72 ±0.06 in left lateral radiograph which ranged from 0.32-0.89. In mesocephalic breeds the ratio was 0.53 ±0.03 in right lateral and 0.57 ±0.03 in left lateral radiograph with a range of 0.21-0.86 while in dolichocephalic breeds it was 0.50 ±0.09 in right lateral and 0.50 ±0.06 in left lateral radiographs ranged from 0.30-0.88.

The ratio of Cranial Pulmonary vein diameter: proximal 1/3rd of 4th rib (CrPV: R4) in brachycephalic breeds was 0.56 ±0.05 in right lateral and 0.73 ±0.10 in left lateral radiographs and ranged from 0.35-1.30. In mesocephalic breeds, the mean ±SE value of CrPA: R4 was 0.58 ±0.04 in right lateral and 0.58 ±0.03 in left lateral radiographs with a range of 0.24-1.26. While in dolichocephalic breeds the ratio was recorded to be 0.53 ±0.08 in right lateral and 0.57 ±0.06 in left lateral radiographs which ranged from 0.31-0.75. The ratios of CrPA and CrPV with the proximal 3rd of 4th rib were within the reference range as reported by Muhlbauer and Kneller (2013). Other workers have also reported that the cranial pulmonary vessels should not be greater in width as compared to the width of proximal 1/3rd of the 4th rib (Thrall 2013, Oui et al 2015 and Sharma 2018).

**Table 21: Radiographic dimensions of cranial pulmonary vessels and 4$^{th}$ rib in dogs with pulmonary disorders belonging to different breeds**

| Breed type | Cranial pulmonary artery diameter (in mm) | | Cranial pulmonary vein diameter (in mm) | | Proximal1/3rd of 4th rib diameter (in mm) | | Cranial Pulmonary artery diameter: Proximal1/3rd of 4th rib | | Cranial Pulmonary vein diameter: Proximal1/3rd of 4th rib | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **R** | **L** | **R** | **L** | **R** | **L** | **R** | **L** | **R** | **L** |
| Brachycephalic | 3.15 ±0.44 (1.24-5.90) | 3.67 ±0.58 (1.62-6.52) | 3.06 ±0.44$^{a}$ (1.33-6.11) | 3.56 ±0.56$^{a}$ (1.60-6.75) | 5.53 ±0.73$^{a}$ (1.97-10.70) | 5.51 ±0.74$^{a}$ (1.94-9.89) | 0.58 ±0.06 (0.32-0.89) | 0.72 ±0.06$^{a}$ (0.47-0.88) | 0.56 ±0.05 (0.35-0.75) | 0.73 ±0.10 (0.44-1.30) |
| Mesocephalic | 3.55 ±0.17 (1.81-5.60) | 4.07 ±0.21 (2.15-6.72) | 3.83 ±0.18$^{ab}$ (1.74-5.32) | 4.05 ±0.18$^{ab}$ (2.29-7.32) | 6.79 ±0.26$^{ab}$ (2.93-10.98) | 7.17 ±0.29$^{ab}$ (3.23-12.21) | 0.53 ±0.03 (0.21-0.86) | 0.57 ±0.03$^{ab}$ (0.21-0.86) | 0.58 ±0.04 (0.27-1.26) | 0.58 ±0.03 (0.24-0.99) |
| DolichoCephalic | 3.99 ±0.58 (2.13-6.04) | 4.78 ±0.45 (3.66-5.76) | 4.49 ±0.61$^{b}$ (2.95-6.10) | 5.54 ±0.41$^{c}$ (3.32-6.23) | 9.05 ±1.62$^{c}$ (5.58-16.79) | 9.18 ±1.73$^{b}$ (4.78-15.22) | 0.50 ±0.09 (0.30-0.88) | 0.50 ±0.06$^{b}$ (0.30-0.88) | 0.53 ±0.08 (0.31-0.75) | 0.57 ±0.06 (0.33-0.70) |

Figures in parentheses indicate range

Values with different superscripts$^{(a,b,c)}$ indicate significant difference between the breed types.

Correlation between various radiographic dimensions of cranial pulmonary vessels and width of proximal third of 4th rib (R4) are presented in Table 22. The cranial pulmonary artery diameter and cranial pulmonary vein diameter, R4, CrPA: R4 had a significant ($p \leq 0.05$) positive correlation among each other. The cranial pulmonary vein diameter had a significant ($p \leq 0.05$) positive correlation with R4 width and CrPV: R4. The CrPA: R4 had a significant ($p \leq 0.05$) positive correlation with CrPV: R4.

**Table 22: Correlation between radiographic dimensions of cranial pulmonary vessels and 4th rib in dogs with pulmonary disorders (Group 2)**

| | | Cranial pulmonary artery diameter | Cranial pulmonary vein diameter | Proximal1/3rd of 4th rib diameter | Cranial Pulmonary artery diameter: Proximal1/3rd of 4th rib |
|---|---|---|---|---|---|
| Cranial pulmonary vein diameter | r | .815** | | | |
| | p | 0 | | | |
| | N | 50 | | | |
| Proximal1/3rd of 4th rib diameter | r | .492** | .484** | | |
| | p | 0 | 0 | | |
| | N | 51 | 50 | | |
| Cranial Pulmonary artery diameter: Proximal1/3rd of 4th rib | r | .359** | 0.24 | -.575** | |
| | p | 0.01 | 0.094 | 0 | |
| | N | 51 | 50 | 51 | |
| Cranial Pulmonary vein diameter: proximal 1/3rd of 4th rib | r | 0.197 | .415** | -.524** | .806** |
| | p | 0.171 | 0.003 | 0 | 0 |
| | N | 50 | 50 | 50 | 50 |

*values differ significantly ($p \leq 0.05$)

**values differ significantly ($p \leq 0.01$)

**Evaluation of caudal pulmonary vasculature:** The dimensions of caudal pulmonary vessels and their relationship with width of 9th rib at the point of intersection are presented in Table 23. All the dimensions were measured and expressed in mm.

The mean ±SE value of CdPA diameter in brachycephalic breeds was 5.24 ± 0.70 in ventrodorsal and 4.73 ±0.60 in dorsoventral radiographs which ranged from 1.94-9.40. In mesocephalic breeds, the mean ±SE value was 5.98 ±0.34 in ventrodorsal and 5.67 ±0.30 in dorsoventral radiographs with a range of 1.87-9.32. Similarly, in dolichocephalic breeds, the mean ±SE value was 6.96 ±1.04 in ventrodorsal and 6.51 ±1.52 in dorsoventral radiographs and the values had a range from 4.33-9.4.

The diameter of the caudal pulmonary vein (CdPV) in brachycephalic breeds was 4.76 ±0.60 in ventrodorsal and 4.69 ±0.51 in dorsoventral radiographs which ranged from 2.42-9.00. In mesocephalic breeds, the mean ±SE value was 5.96 ±0.31 in ventrodorsal and 5.98 ±0.28 in dorsoventral radiographs ranged from 2.59-9.85. In dolichocephalic breeds, diameter of the CdPV was 6.41 ±1.27 in ventrodorsal and 7.85 ±1.29 in dorsoventral radiographs with a range of 4.00-10.27.

In brachycephalic breeds, the mean ±SE value of 9th rib diameter at intersection with artery was 4.87 ±0.57 in ventrodorsal and 5.09 ±0.58 in dorsoventral radiographs ranged from 2.10-8.28. In mesocephalic breeds, the mean ±SE value was 5.71 ±0.24 in ventrodorsal and 5.93 ±0.21 in dorsoventral radiographs with a range of 2.24-8.83. In dolichocephalic breed, the mean ±SE value was 6.79 ±1.35 in ventrodorsal and 6.00 ±1.42 in dorsoventral radiographs with a range of 4.67-8,85.

In brachycephalic breeds, the mean ±SE value of 9th rib diameter at intersection with vein was 4.83 ±0.64 in ventrodorsal and 4.96 ±0.60 in dorsoventral radiographs ranged from 2.58-8.50. In mesocephalic breeds, the mean ±SE value was 5.64 ±0.24 in ventrodorsal and 6.08 ±0.20 in dorsoventral radiographs with a range of 2.78-8.64. In dolichocephalic breeds, the mean ±SE value was 6.89 ±0.86in ventrodorsal and 6.48 ±1.18in dorsoventral radiographs ranged from 3.46-10.65. There was no significant relationship between the mean values of CdPA, CdPV, R9 with artery and R9 with vein in ventrodorsal and dorsoventral radiographs in any breed type.

Caudal pulmonary artery diameter:9th rib ratio (CdPA: R9) in brachycephalic breeds was 1.16 ±0.11 in ventrodorsal and 0.96 ±0.06 in dorsoventral radiographs ranged from 0.69-1.79. In mesocephalic breeds, the mean ±SE value was 1.07 ±0.05 in ventrodorsal and 0.94 ±0.04 in dorsoventral radiographs with a range of 0.42-1.74. In dolichocephalic breeds, the mean ±SE value was 0.97 ±0.04 in ventrodorsal and 0.99 ±0.05 in dorsoventral radiographs ranged from 0.83-1.08. No major difference in the CdPA:R9 ratio was seen between the two views.

Caudal pulmonary vein diameter: 9th rib (CdPV:R9) ratio in brachycephalic breeds was 1.00 ±0.09 in ventrodorsal and 0.94 ±0.05 in dorsoventral radiographs with a range of 0.68-1.59. The ratio in mesocephalic breeds was 1.05 ±0.04 in ventrodorsal and 1.03 ±0.04 in dorsoventral radiographs and it ranged from 0.57-1.65 while in dolichocephalic breeds, the CdPV:R9 ratio was 0.94 ±0.02 in ventrodorsal and 1.38 ±0.16 in dorsoventral radiographs which ranged from 0.88-1.70. In the present study the ratios of CdPA:R9 and CdPV:R9 did not exceed 1.0 and were similar to the findings in apparently normal animals included in group 1. (Muhlbauer and Kneller (2013), Thrall (2013), Oui *et al* (2015) were of the opinion that the width of the caudal pulmonary vessels should not exceed width of the $9^{th}$ rib at the point where vessels and rib intersect.

**Correlation between Radiographic dimensions of caudal pulmonary vessels and $9^{th}$ rib (Table 24)**

The caudal pulmonary artery diameter and caudal pulmonary vein diameter, 9th rib diameter at intersection with artery, 9th rib diameter at intersection with vein, Caudal pulmonary artery diameter:9th rib had significant ($p \leq 0.05$) positive correlation. Caudal pulmonary vein diameter and 9th rib diameter at intersection with artery, 9th rib diameter at intersection with vein, caudal pulmonary vein diameter:9th rib had significant ($p \leq 0.05$) positive correlation. The caudal pulmonary artery diameter:9th rib and Caudal pulmonary vein diameter: 9th rib had significant ($p \leq 0.05$) positive correlation.

**Table 23: Radiographic dimensions of caudal pulmonary vessels and 9$^{th}$ rib in dogs with pulmonary disorders belonging to different breeds**

| Breed type | Caudal pulmonary artery diameter (in mm) | | Caudal pulmonary vein diameter (in mm) | | 9th rib diameter (in mm) artery | | 9th rib diameter (in mm) vein | | Caudal pulmonary artery diameter: 9th rib | | Caudal pulmonary vein diameter: 9th rib | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | VD | DV | VD | DV | VD | DV | VD | DV | VD | DV | VD | DV |
| Brachy-cephalic | 5.24±0.70 (1.94-9.40) | 4.73±0.60 (2.25-7.83) | 4.76±0.60 (2.42-9.00) | 4.69±0.51[a] (2.87-7.11) | 4.87±0.57 (2.10-8.28) | 5.09±0.58 (2.25-7.92) | 4.83±0.64[a] (2.58-8.50) | 4.96±0.60 (3.03-8.00) | 1.16±0.11 (0.81-1.79) | 0.96±0.06 (0.69-1.39) | 1.00±0.09 (0.68-1.59) | 0.94±0.05[a] (0.68-1.35) |
| Meso-cephalic | 5.98±0.34 (1.87-9.32) | 5.67±0.30 (2.58-9.11) | 5.96±0.31 (2.59-9.39) | 5.98±0.28[ab] (3.18-9.85) | 5.71±0.24 (2.24-8.71) | 5.93±0.21 (2.09-8.83) | 5.64±0.24[ab] (2.82-8.20) | 6.08±0.20 (2.78-8.64) | 1.07±0.05 (0.56-1.74) | 0.94±0.04 (0.42-1.50) | 1.05±0.04 (0.70-1.65) | 1.03±0.04[ab] (0.57-1.65) |
| Dolicho-cephalic | 6.96±1.04 (4.33-9.41) | 6.51±1.52 (4.49-9.48) | 6.41±1.27 (4.09-10.00) | 7.85±1.29[b] (5.88-10.27) | 6.79±1.35 (4.67-8.85) | 6.00±1.42 (4.83-8.77) | 6.89±0.86[b] (4.33-10.65) | 6.48±1.18 (3.46-8.38) | 0.97±0.04 (0.83-1.06) | 0.99±0.05 (0.93-1.08) | 0.94±0.02 (0.88-1.02) | 1.38±0.16[c] (1.20-1.70) |

Figures in parentheses indicate range

Values with different superscripts[(a,b,c)] indicate significant difference between the breed types.

**Table 24: Correlation between radiographic dimensions of caudal pulmonary vessels and 9th rib in dogs with pulmonary disorders (Group 2)**

| | | Caudal pulmonary artery diameter | Caudal pulmonary vein diameter | 9th rib diameter at artery | 9th rib diameter at vein | Caudal pulmonary artery diameter:9th rib |
|---|---|---|---|---|---|---|
| Caudal pulmonary vein diameter | r | .778** | | | | |
| | p | 0 | | | | |
| | N | 47 | | | | |
| 9th rib diameter at artery | r | .695** | .766** | | | |
| | p | 0 | 0 | | | |
| | N | 47 | 46 | | | |
| 9th rib diameter at vein | r | .704** | .811** | .942** | | |
| | p | 0 | 0 | 0 | | |
| | N | 47 | 47 | 46 | | |
| Caudal pulmonary artery diameter:9th rib | r | .590** | 0.218 | -0.146 | -0.073 | |
| | p | 0 | 0.146 | 0.329 | 0.631 | |
| | N | 47 | 46 | 47 | 46 | |
| Caudal pulmonary vein diameter:9th rib | r | 0.261 | .488** | -0.116 | -0.093 | .472** |
| | p | 0.077 | 0.001 | 0.442 | 0.534 | 0.001 |
| | N | 47 | 47 | 46 | 47 | 46 |

*values differ significantly (p≤0.05)

**values differ significantly (p≤0.01)

**Evaluation of various extra thoracic structures**

Diaphragm was apparently normal in all the 70 dogs having pulmonary disorders (Fig. 34-43). Ribs were apparently normal in 69 dogs while one dog had irregular shape of rib (R2-R6) (Fig. 52), This could be an incidental finding and did not appear to be related with the pulmonary disorder. Sternebrae were normal in 67 with pectus carinatum (n=1) (Fig. 54), pectus excavatum (n=1) (Fig. 55) and intersternebral mineralization with lipping (n=1) in one dog each (Fig. 53). Vertebral spondylosis was seen in few dogs which were considered to be age related. The lesions in the Sternebrae were incidental and not appear to be related to the pulmonary disorder. The features of pectus carinatum included ventrally protruded sternum on its distal portion forming a step between the thorax and abdomen. (Fig. 54) This was in accordance to earlier report of Souza et al (2009) and Komsta *et al* (2019). The features of pectus excavatum included dorsal depression of the caudal portion of sternum and the sternum at that point projected into the thorax, reducing the dorsoventral diameter of the thoracic cavity (Fig. 55). This was in accordance to earlier report of Kealy and McAllister (2000), Muhlbauer and Kneller (2013). Vertebral column was normal in all the dogs (Fig. 32-37).

**CARDIOPULMONARY**

Twenty-five dogs with cardiac enlargement with or without pulmonary involvement as evidenced on radiography were included in this group. Out of a total of 25 dogs with cardiopulmonary disorders (Fig. 56), 5 were brachycephalic and all were Pug breed. Twenty were mesocephalic breeds which included Beagle (1), Cocker Spaniel (3), Labrador Retriever (14), Non-Descript (n=1) and Pomeranian (1). No dolichocephalic breed was presented with cardiopulmonary disorder during the course of the study. There were 7 female and 18 male dogs (Fig. 57) with age ranging between 2 to 12 years with mean ± SE value of 7.64 ± 0.64 years. Majority of dogs presented with cardiopulmonary disorders were geriatric. Similar findings were reported by Kibar and Alkan (2005) who concluded that cardiac diseases are common in the geriatric animals and frequently lead to clinical problems. The mean ± SE weight of the dogs in the present study was 28.7 ± 3.93 Kg.


**Fig. 52: Ventrodorsal radiograph showing irregular shape of right 2$^{nd}$ to 6$^{th}$ ribs (R2-R6).**


**Fig. 53: Right lateral radiograph showing intersternebral mineralization with lipping.**

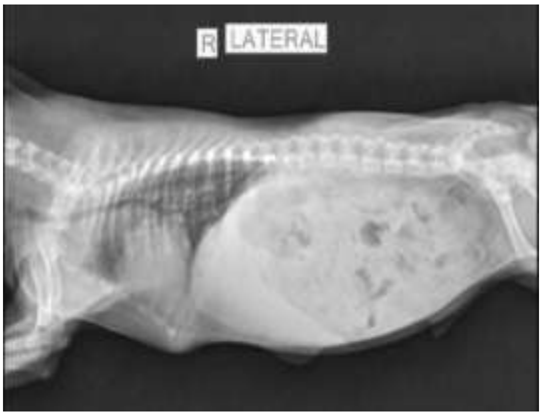



**Fig. 54: Right lateral radiograph showing pectus carinatum in 3 months old Shih Tzu pup**

**Fig. 55: Left lateral radiograph showing pectus excavatum in 1.5 months old American Bully pup**

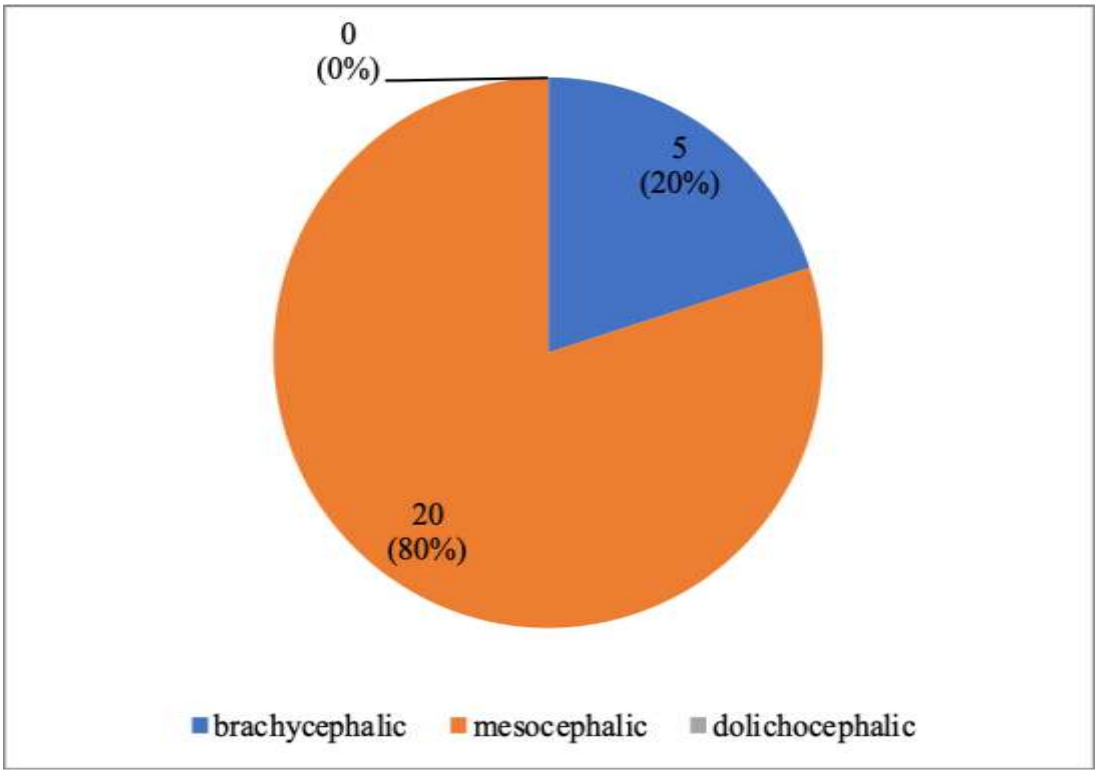



**Fig. 56: Distribution of dogs with cardiopulmonary disorders (N=25) on the basis of breed type**

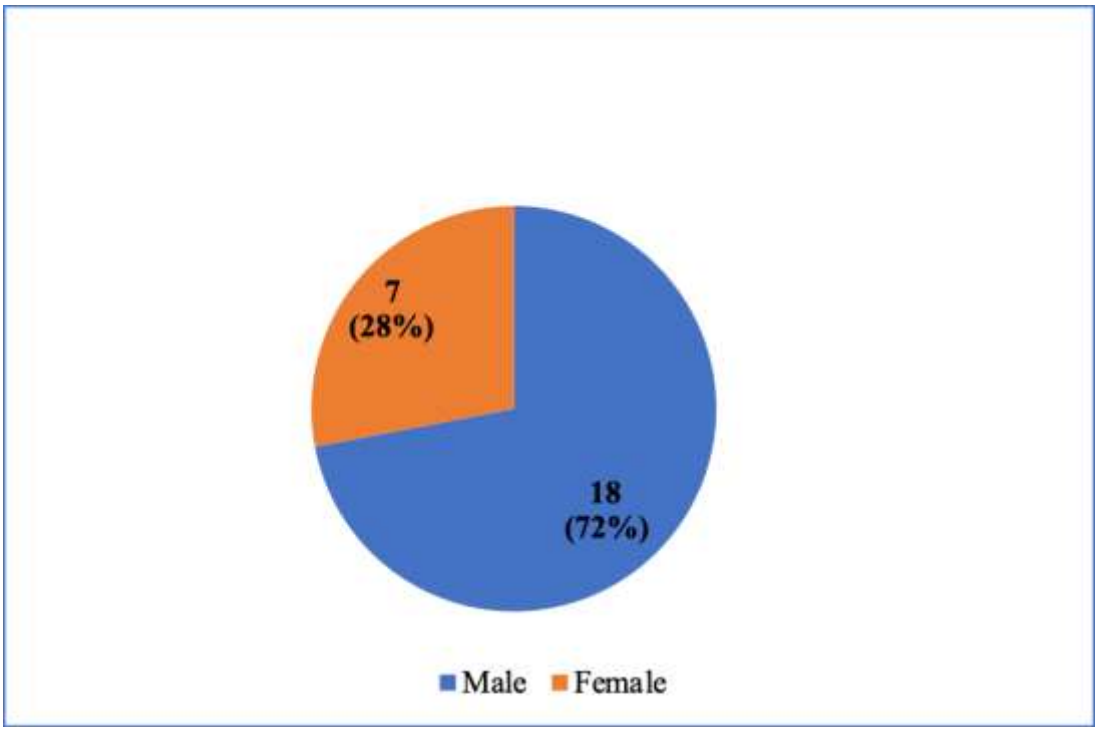



**Fig. 57: Distribution of dogs with cardiopulmonary disorders (N=25) on the basis of gender**

A set of 3-4 views were taken for all the dogs belonging to this group which included left lateral, right lateral, ventrodorsal and dorsoventral projections.

**Evaluation of lungs**

The lungs in all the 25 dogs were evaluated for various lung patterns and it was found that all the dogs had some or other lung pattern. The lung patterns appreciable on the radiographs included interstitial (n=7), alveolar(n=3), bronchial, vascular or mixed(n=15) pattern (Fig. 58). Seven of the 25 dogs i.e. 28 percent (Fig. 58) showed interstitial pattern which was characterized by loss of clarity in the outline of vessels ang general loss of contrast in the lung field (Fig. 61) **(**Kealy and McAllister 2000). In the present study multiple lung lobes were seen having interstitial pattern in majority of cases (Fig. 59). Out of the 7 dogs with interstitial pattern, caudal lung lobes were predominantly involved in all the 7 cases, 3 had interstitial pattern in each cranial and accessory lung lobe while no case showed interstitial pattern in the middle lung lobe.

Fifteen out of 25 dogs showed mixed pattern (Fig. 60) which included combinations of one or more patterns viz. alveolar, bronchial and interstitial (Kealy and Mc Allister 2000, Thrall 2013). Mixed pattern was seen involving multiple lung lobes in the present study in majority of cases (Fig. 60). Out of the 15 dogs with mixed pattern, caudal lung lobes were involved in all the patients, 9 had mixed pattern in cranial and accessory lung lobe each and 12 had mixed pattern involving the middle lung lobe (Fig. 61 and 62). The lung patterns seen in the present study are considered sequel to the various stages of progression of cardiac disease (**(**Kealy and McAllister 2000, Thrall 2013, Muhlbauer and Kneller 2013, Diana et al 2009) reported that interstitial pattern may progress into alveolar pattern in cases of cardiogenic pulmonary oedema. Alveolar pattern is indicative of cardiogenic pulmonary oedema secondary to cardiac disease (Thrall 2013). Some workers have reported increased peri bronchial infiltrates in case of cardiac disease thereby producing a bronchial pattern in the lungs. So, it may be challenging to differentiate pulmonary form cardiac disease.

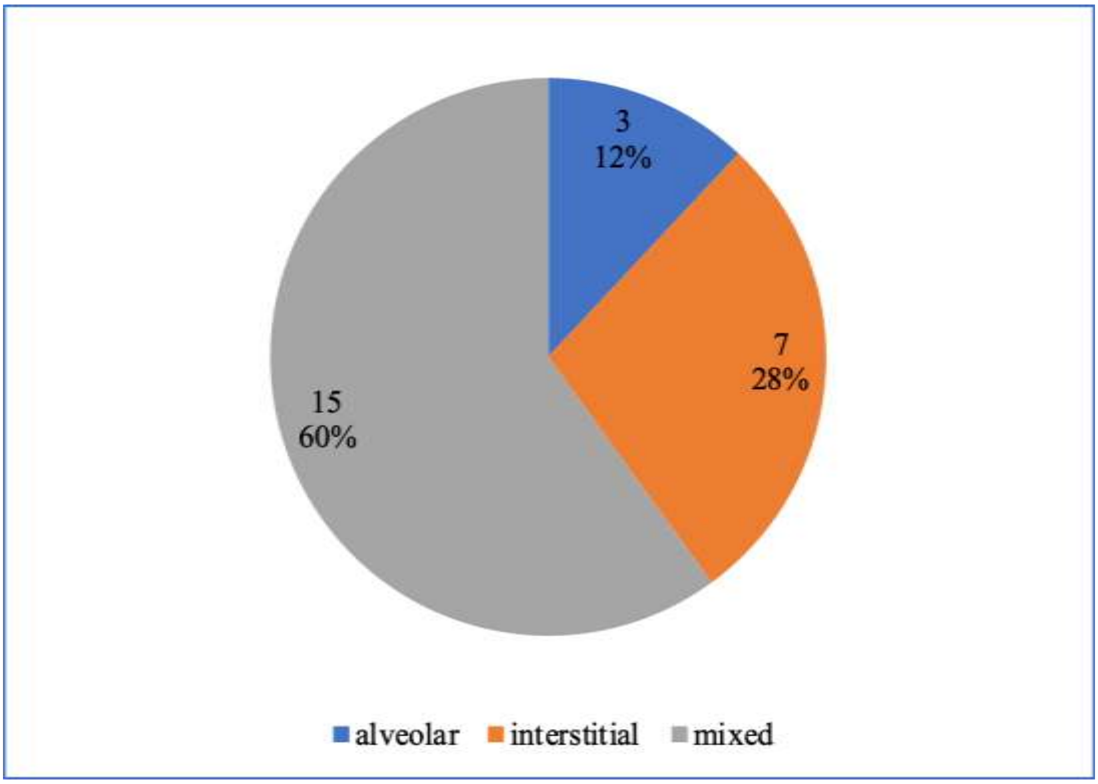



**Fig. 58: Distribution of dogs with cardiopulmonary disorders (N=25) on the basis of lung pattern**

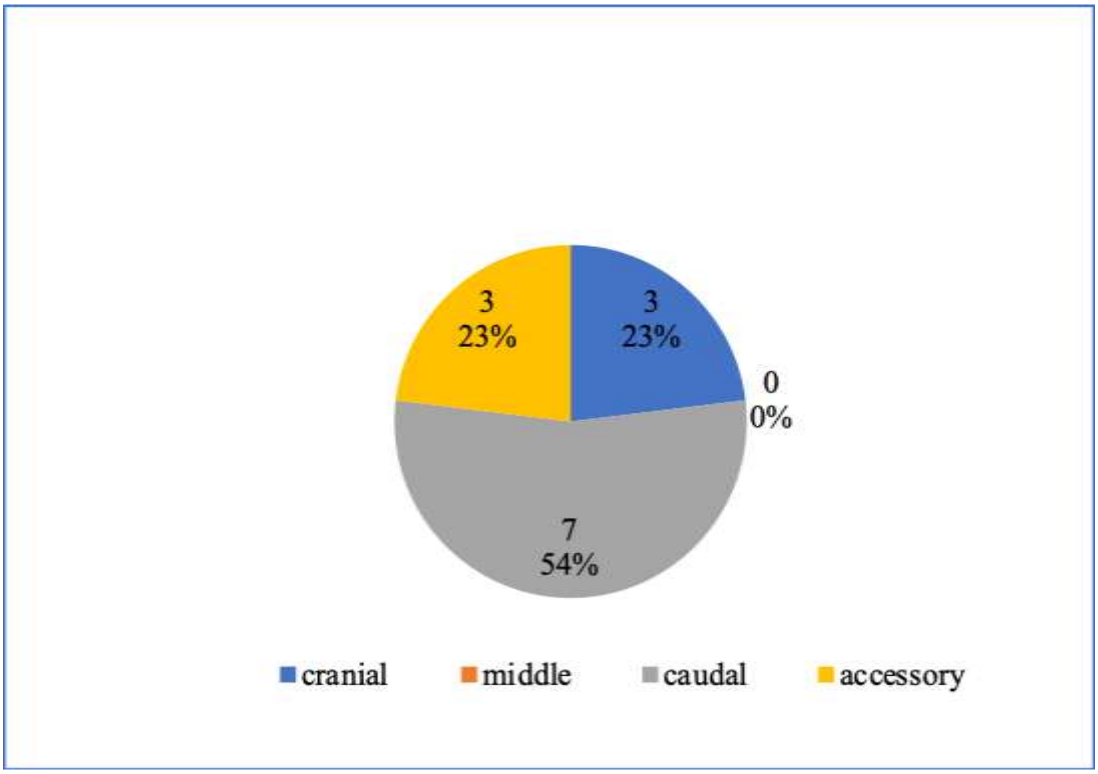



**Fig. 59: Distribution of affected lung lobes in dogs having interstitial pattern (n=7)**

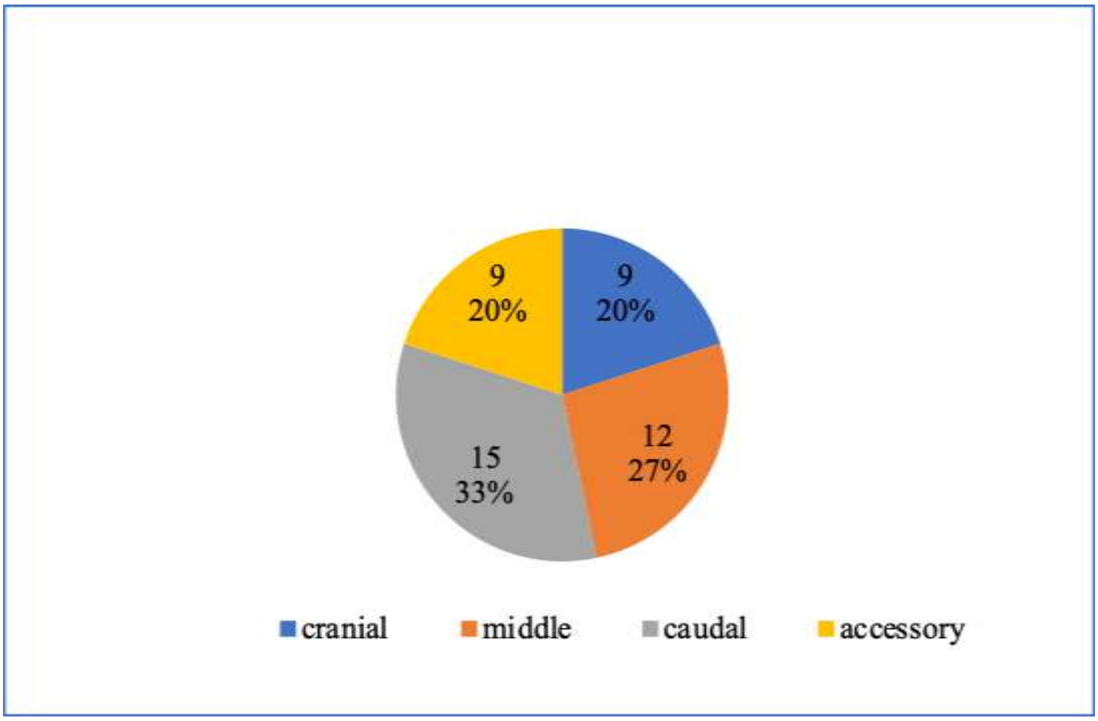



**Fig. 60: Distribution of affected lung lobes in dogs having mixed pattern (n=15)**

**Heart**

**Evaluation of various parameters of heart**

The heart was enlarged and globoid in all the cases (Fig. 63-70). Alteration in the shape and of cardiac silhouette, abnormal size, shape of pulmonary vessels and the presence of pulmonary oedema or ascites on thoracic radiographs are considered the hallmarks for radiographic diagnosis of cardiac diseases in dogs (Root and Bahr 2002).

All the dimensions of heart were measured and expressed in mm (Table 25). The mean ±SE value of VHS in brachycephalic breeds was 10.75±0.25 in right lateral and 11.13±0.54 in left lateral radiographs with a range of 9.5-11.75. In mesocephalic breeds, the mean ±SE value was 11.86±0.14 in right lateral and 11.80±0.19 in left lateral radiographs and the values ranged from 11-13. It was found that the VHS in dogs with cardiopulmonary disorders was markedly higher than the normal reference ranges reported by Buchanan and Bucheler (1995) thereby indicating cardiomegaly. Accuracy of the VHS in the diagnosis of cardiac disease was first evaluated by Lamb *et al* (2001). Gugjoo *et al* (2013) observed that VHS increased significantly in dilated


**Fig. 61: Right lateral radiograph showing bronchoalveolar and interstitial (mixed) pattern in a brachycephalic dog**


**Fig. 62: Ventrodorsal radiograph showing alveolar-interstitial pattern in a mesocephalic dog**



**Fig. 63: Right lateral radiograph showing enlarged heart in a brachycephalic dog**

**Fig. 64: Right lateral radiograph showing enlarged heart in a mesocephalic dog**


**Fig. 65:Left lateral radiograph showing enlarged heart in a brachycephalic dog**

**Fig. 66: Left lateral radiograph showing enlarged heart in a mesocephalic dog**


**Fig. 67: Ventrodorsal radiograph showing enlarged heart in a brachycephalic dog**


**Fig. 68: Ventrodorsal radiograph showing enlarged heart in a mesocephalic dog (diagnosed as dilated cardiomyopathy)**


**Fig. 69: Dorsoventral radiograph showing enlarged heart in a brachycephalic dog**


**Fig. 70: Dorsoventral radiograph showing enlarged heart in a mesocephalic dog (diagnosed as pericarditis)**


**Fig. 71a: Right lateral radiograph showing no border effacement of cardiac silhouette**

**Fig.71b: Right lateral radiograph showing border effacement of cardiac silhouette**

cardiomyopathy and the values of VHS can be used to diagnose such conditions very effectively.

In brachycephalic breeds, the mean ±SE value of percentage of cardiac silhouette occupying the thoracic cavity was 66.58±2.51 in right lateral and 67.70±4.82 in left lateral radiographs ranging from 58.58-75. In mesocephalic breeds, the mean ±SE value was 72.04±1.97 in right lateral and 69.14±0.88 in left lateral radiographs with a range of 57.21-87.39. This was higher than the earlier reports for normal dogs where 60-65% has been reported as the upper limit of percentage of cardiac silhouette in the thoracic cavity (Poteet 2001). This confirmed that there was cardiomegaly in the cases included under this group. Myocardial dysfunction is a common cause of generalized cardiomegaly. In such cases, the cardiac silhouette appears larger than expected, but specific chamber enlargement may or may not be evident (Boswood 2010).

Border effacement was apparently seen in 4 dogs (Fig. 71b) and no border effacement was seen in 21 dogs (Fig. 71a). The border effacement in 4 cases seen in the present study could be attributed to pleural effusions or alveolar lung pattern.

The mean ±SE value of ICS occupied in brachycephalic breeds was 3.10±0.06 in right lateral and 3.05±0.05 in left lateral radiographs ranged from 3-3.5. In mesocephalic breeds, the mean ±SE value was 3.43±0.14 in right lateral and 3.48±0.13 in left lateral radiographs with a range of 2.5-5. A general guideline of 2.5-3.5 intercostal spaces for dogs with a deep and wide thorax respectively has seen used as an indicator of normal heart size in lateral radiographic views (Owens 1985 and Kealy and McAllister 2000). In the present study, the dogs with cardiac diseases showed normal range of ICS coverage. Occasionally the ICS coverage was as high as 5 ICS in one animal which was confirmatory of cardiac enlargement.

The sternal contact in brachycephalic breeds was 2.70±0.20 in right lateral and 2.70±0.20 in left lateral radiographs with a range of 2-3. In mesocephalic breeds, the mean ±SE value was 3.03±0.10 in right lateral and 2.90±0.12 in left lateral radiographs ranged from 2-4.

**Table 25: Radiographic dimensions of heart in dogs with cardiopulmonary disorders belonging to different breeds**

| **Breed type** | **VHS** | | **Percentage of cardiac silhouette in thoracic cavity** | | **ICS** | | **Sternal contact** | |
|---|---|---|---|---|---|---|---|---|
| | **R** | **L** | **VD** | **DV** | **R** | **L** | **R** | **L** |
| Brachy-cephalic | 10.75 ±0.25 (10.5-11) | 11.13 ±0.54 (9.5-11.75) | 66.58 ±2.51 (59.4-74.29) | 67.70 ±4.82 (58.58-75) | 3.10 ±0.06 (3-3.25) | 3.05 ±0.05 (3-3.25) | 2.70 ±0.20 (2.5-3) | 2.70 ±0.20 (2-3) |
| Meso-cephalic | 11.86 ±0.14 (11-12.75) | 11.80 ±0.19 (10.75-13) | 72.04 ±1.97 (57.21-86.3) | 69.14 ±0.88 (59-87.39) | 3.43 ±0.14 (2.5-5) | 3.48 ±0.13 (2.5-4.5) | 3.03 ±0.1 (2.25-4) | 2.90 ±0.12 (2-3.5) |

Figures in parentheses indicate range

It was found that the percentage of cardiac silhouette (heart diameter) had a significant ($p \leq 0.05$) positive correlation with VHS and ICS occupied (Table 26).

**Table 26: Correlation between radiographic dimensions of heart in dogs with cardiopulmonary disorders (Group 3)**

| | | VHS | Percentage of cardiac silhouette in thoracic cavity | Intercostal space |
|---|---|---|---|---|
| Percentage of cardiac silhouette in thoracic cavity | r | .557* | | |
| | p | 0.016 | | |
| | N | 18 | | |
| Intercostal space | r | 0.428 | .450* | |
| | p | 0.06 | 0.041 | |
| | N | 20 | 21 | |
| Sternal contact | r | 0.2 | 0.052 | 0.094 |
| | p | 0.413 | 0.827 | 0.679 |
| | N | 19 | 20 | 22 |

*values differ significantly ($p \leq 0.05$)

**values differ significantly ($p \leq 0.01$)

**Evaluation of Mediastinum**

The various mediastinal structures were evaluated and presented in Table 27. All the dimensions of cranial and caudal mediastinum were measured and expressed in mm. Twenty-four dogs had normal mediastinum with no apparent abnormality. Space occupying lesion (SOL) was seen in 1 dog in cranial mediastinum as shown in Fig. 72. This dog also showed diffused alveolar pattern involving the lung lobes. All the 25 dogs had a normal caudal mediastinum with no apparent abnormality.

Oesophagus was apparently not visible in any radiograph irrespective of the breed.

The mean ±SE value of carina diameter in brachycephalic breeds was 9.38 ±0.11 in right lateral and 8.53 ±0.68 in left lateral radiographs which ranged from 6.52-11.07. In mesocephalic breeds, the carina diameter was 16.72 ±0.96 in right lateral and 15.72 ±0.93 in left lateral radiographs with a range of 8.77-27.2. The tracheal course was normal in 4 dogs while it was dorsally deviated at carina in 21 dogs as shown in Fig. 73. The dorsal deviation of trachea in dogs with cardiomegaly in present study was similar to the findings of Thrall (2013), Muhlbauer and Kneller (2013), Brown and Brown (2014), Sharma (2018).

The tracheal diameter (TD), in brachycephalic breeds, was 7.70 ±0.89 in right lateral and 7.03 ±0.94 in left lateral radiographs with a range of 4.08-10.64 while in mesocephalic breeds, the TD was higher and was recorded as 14.52 ±0.93 in right lateral and 14.17 ±0.74 in left lateral radiographs having a range of 7.9-22.73.

In brachycephalic breeds, the mean ±SE value of thoracic inlet diameter (TI) was 48.30 ±1.98 in right lateral and 49.68 ±1.86 in left lateral radiographs ranged from 44.02-54.27. In mesocephalic breeds, the mean ±SE value was 74.30 ±2.74 in right lateral and 73.24 ±2.81in left lateral radiographs with a range of 49.54-90.72.

Similarly, the proximal 1/3$^{rd}$ of 3$^{rd}$ rib diameter (R3) in brachycephalic breeds was 3.42 ±0.23 in right lateral and 3.40 ±0.22 in left lateral radiographs and ranged from 2.62-4.18 while in mesocephalic breeds, the mean ±SE value was 5.70 ±0.26 in right lateral and 5.89 ±0.27in left lateral radiographs 3.26-8.23. Brachycephalic breeds were having significantly lower dimensions of the TD, TI and R3 as compared to the mesocephalic breeds which could be attributed to the smaller size of the brachycephalic dogs.

The ratios of tracheal diameter: thoracic inlet diameter (TD: TI) in brachycephalic dogs was 0.16 ±0.02 in right lateral and 0.14 ±0.02 in left lateral radiograph which ranged from 0.8-0.23. In mesocephalic breeds, TD: TI was 0.19 ±0.01 in right lateral and 0.19 ±0.01 in left lateral radiograph with a range of 0.13-0.27.

In brachycephalic breeds, the mean ±SE value of trachea diameter: proximal 1/3$^{rd}$ of 3$^{rd}$ rib diameter ratio (TD: R3) was 2.28 ±0.27 in right lateral and 2.12 ±0.34 in left lateral radiographs which ranged from 1.24-3.31. In mesocephalic breeds, the mean ±SE value of TD: R3 was 2.56 ±0.12 in right lateral and 2.44 ±0.10 in left lateral radiographs with a range of 1.24-3.85. There was no marked difference between the TD: TI and TD: R3 ratios among the two breed types.

**Correlation between Radiographic dimensions of mediastinal structures**

Pearson's analysis as shown in Table 28 revealed that the Carina diameter had a significant ($p \leq 0.05$) positive correlation with TD, TI, TD: TI, R3, TD: R3. Since, Carina diameter and TD had a significant positive correlation, so all the parameters which were correlated with Carina diameter were similarly correlated with TD. TI and R3 had a significant ($p \leq 0.05$) positive correlation. The TD: TI ratio and TD: R3 ratio had a significant ($p \leq 0.05$) positive correlation.


**Fig. 72: Right lateral radiograph showing space occupying lesion in the cranial mediastinum**

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**Fig. 73: Right lateral radiograph showing dorsal deviation of trachea at carina**

**Table 27: Radiographic dimensions of mediastinal structures in dogs with cardiopulmonary disorders belonging to different breeds**

| **Breed type** | **Carina diameter (in mm)** | | **Trachea diameter Td (in mm)** | | **Thoracic inlet diameter Ti (in mm)** | | **Td: Ti** | | **Proximal 1/3rd of 3rd rib diameter (in mm)** | | **Tracheal diameter: proximal 1/3rd of 3rd rib diameter** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **R** | **L** | **R** | **L** | **R** | **L** | **R** | **L** | **R** | **L** | **R** | **L** |
| Brachy-cephalic | 9.38±1.00<br>(6.52-11.07) | 8.53±0.68<br>(6.98-10.29) | 7.70±0.89<br>(5.69-10.64) | 7.03±0.94<br>(4.08-8.79) | 48.30±1.98<br>(44.22-54.27) | 49.68±1.86<br>(44.02-53.38) | 0.16±0.02<br>(0.12-0.23) | 0.14±0.02<br>(0.8-0.19) | 3.42±0.23<br>(2.62-3.97) | 3.40±0.22<br>(2.85-4.18) | 2.28±0.27<br>(1.8-3.31) | 2.12±0.34<br>(1.24-2.86) |
| Meso-cephalic | 16.72±0.96<br>(10.17-27.2) | 15.72±0.93<br>(8.77-22.74) | 14.52±0.93<br>(7.9-22.73) | 14.17±0.74<br>(8.58-20.93) | 74.30±2.74<br>(49.84-90.45) | 73.24±2.81<br>(49.54-90.72) | 0.19±0.01<br>(0.13-0.27) | 0.19±0.01<br>(0.14-0.24) | 5.70±0.26<br>(3.26-7.68) | 5.89±0.27<br>(3.48-8.23) | 2.56±0.12<br>(1.45-3.85) | 2.44±0.10<br>(1.24-3.39) |

Figures in parentheses indicate range

**Table 28: Correlation between radiographic dimensions of mediastinal structures in dogs with cardiopulmonary disorders (Group 3)**

| | | Carina diameter | Trachea diameter TD | Thoracic inlet diameter TI | TD: TI | Proximal 1/3rd of 3rd rib diameter |
|---|---|---|---|---|---|---|
| Trachea diameter TD | r | .802** | | | | |
| | p | 0 | | | | |
| | N | 23 | | | | |
| Thoracic inlet diameter TI | r | .690** | .800** | | | |
| | p | 0 | 0 | | | |
| | N | 22 | 24 | | | |
| TD: TI | r | .609** | .804** | 0.312 | | |
| | p | 0.003 | 0 | 0.138 | | |
| | N | 22 | 24 | 24 | | |
| Proximal 1/3rd of 3rd rib diameter | r | .658** | .768** | .874** | 0.4 | |
| | p | 0.001 | 0 | 0 | 0.053 | |
| | N | 23 | 25 | 24 | 24 | |
| Trachea diameter: proximal 1/3rd of 3rd rib diameter | r | .505* | .657** | 0.224 | .821** | 0.055 |
| | p | 0.014 | 0 | 0.294 | 0 | 0.795 |
| | N | 23 | 25 | 24 | 24 | 25 |

*values differ significantly (p≤0.05)

**values differ significantly (p≤0.01)

**Evaluation of pleural space**

Pleural space was found normal in 17 dogs while fluid, fissure line was present in 6, and 2 dogs respectively as shown in Fig. 74. Pleural effusions are generally manifested secondary to right side heart disease and congestive heart failure cases (Sherding and Birchard 2006; Muhlbauer and Kneller 2013)

**Evaluation of Vascular structures**

All the dimensions of vascular structures were measured and expressed in mm (Table 29). Aorta was not appreciable in any radiograph. This could be due to the interstitial or other pulmonary patterns associated with the cardiac disease, cardiac enlargement which may have caused border effacement of the aorta thereby making it inconspicuous.

The diameter of caudal vena cava (CVC) in brachycephalic, was 9.24 ±0.30 in right lateral and 9.58 ±1.61 in left lateral radiographs which ranged from 7.97-11.19. In mesocephalic breeds, the mean ±SE value was 17.11 ±2.32 in right lateral and 19.66 ±1.17 in left lateral radiographs with a range of 11.46-23.17. These values were greater than those recorded for apparently normal mesocephalic dogs in the present study (Group-1) Dilation of the caudal vena cava (CVC) on lateral thoracic radiographs is often interpreted as right-sided congestive heart failure Lehmkuhl *et al* (1997).

The mean ±SE value of length of T6 in brachycephalic breed was 11.35 ±0.24 in right lateral and 11.29 ±0.74 in left lateral radiographs ranged from 9.58-13.79. In mesocephalic breeds, the mean ±SE value of T6 was 17.97 ±0.55 in right lateral and 18.29 ±0.56 in left lateral radiographs with a range of 13.68-22.94.

The mean ±SE value of diameter of CVC: T6 was 0.82 ±0.03 in right lateral and 0.96 ±0.21 in left lateral radiograph ranged from 0.75-1.17. In mesocephalic breeds, the mean ±SE value was 0.91 ±0.04 in right lateral and 1.08 ±0.05 in left lateral radiograph with a range of 0.75-1.22. The CVC: Aorta ratio and CVC: T6 ratio is considered as an important criterion for diagnosis of right-side heart disease (Lehmkuhll 1997, Sharma 2018). However, in the present study aorta was not visualised in any dog so the CVC: Ao ratio could not be worked out.

**Table 29: Radiographic dimensions of aorta, caudal vena cava and T6 in dogs with cardiopulmonary disorders belonging to different breeds**

| Breed type | Caudal vena cava diameter (in mm) | | Length of T6 (in mm) | | Caudal vena cava diameter: Length of T6 | |
|---|---|---|---|---|---|---|
| | **R** | **L** | **R** | **L** | **R** | **L** |
| Brachycephalic | 9.24 ±0.30 (8.94-9.54) | 9.58 ±1.61 (7.97-11.19) | 11.35 ±0.24 (10.5-11.87) | 11.29 ±0.74 (9.58-13.79) | 0.82 ±0.03 (0.78-0.85) | 0.96 ±0.21 (0.75-1.17) |
| Mesocephalic | 17.11 ±2.32 (11.46-21.21) | 19.66 ±1.17 (13.67-23.17) | 17.97 ±0.55 (13.68-22.11) | 18.29 ±0.56 (13.89-22.94) | 0.91 ±0.04 (0.78-0.85) | 1.08 ±0.05 (0.75-1.22) |

The aorta was not appreciable in any radiograph

Figures in parentheses indicate range

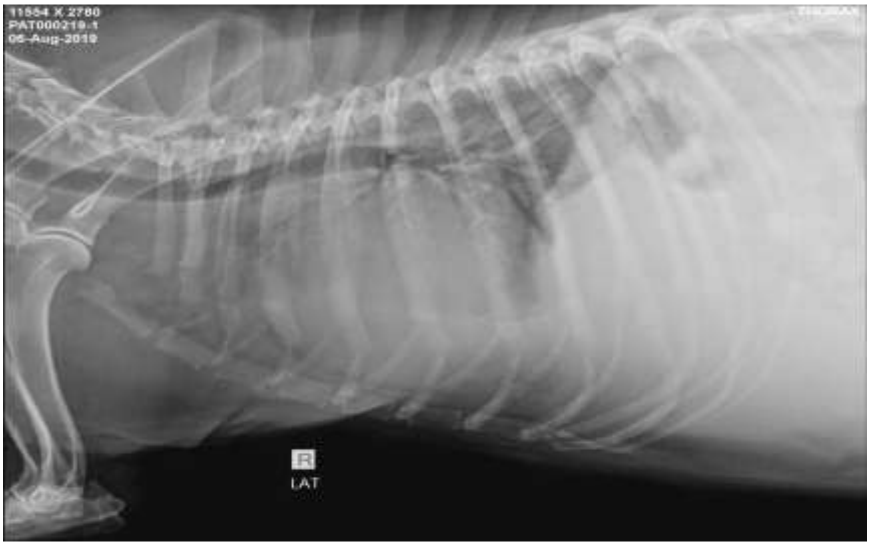

**Fig. 74: Right lateral radiograph showing fluid and fissure lines in the pleural cavity**

**Correlation between Radiographic dimensions of caudal vena cava and T6**

It is presented in Table 30. The CVC had a significant ($p \leq 0.05$) positive correlation with length of T6 and CVC: T6 ratio

**Table 30: Correlation between radiographic dimensions of aorta, caudal vena cava and T6 in dogs with cardiopulmonary disorders (Group 3)**

| | | Caudal vena cava diameter | Length of T6 |
|---|---|---|---|
| Length of T6 | r | .996** | |
| | p | 0 | |
| | N | 6 | |
| Caudal vena cava: Length of T6 diameter | r | .950** | .922** |
| | p | 0.004 | 0.009 |
| | N | 6 | 6 |

*values differ significantly ($p \leq 0.05$)

**values differ significantly ($p \leq 0.01$)

**Radiographic evaluation of cranial vasculature**

All the dimensions of cranial vasculature were measured and expressed in mm (Table 31). In brachycephalic breeds, the mean ±SE value of cranial pulmonary artery diameter (CrPA) was 2.08 ±0.33 in right lateral and 2.90 ±0.15 in left lateral radiographs ranged from 1.39-3.20. In mesocephalic breeds, the mean ±SE value was 3.80 ±0.28 in right lateral and 4.18 ±0.28 in left lateral radiographs which ranged from 2.66-6.09.

In brachycephalic breeds, the mean ±SE value of cranial pulmonary vein diameter (CrPV) was 2.70 ±0.41 in right lateral and 2.85 ±0.27 in left lateral radiographs with a range of 2.04-3.89. In mesocephalic breeds, the mean ±SE value was 4.04 ±0.32 in right lateral and 4.53 ±0.28 in left lateral radiographs ranged from 2.59-6.02. The p, cranial pulmonary vein was larger than the pulmonary artery in the present study. This could be attributed to the cardiac disease which may have resulted in enlarged pulmonary veins. Hamlin (2005) opined that the pulmonary artery or vein may become enlarged depending on the cardiac diseases such as the enlarged pulmonary artery may be found in pulmonary hypertension and venous congestion in mitral regurgitation or left heart disease (Thrall 2013)

In brachycephalic breeds, the mean ±SE value of proximal 1/3rd of 4th rib diameter (R4) was 3.92 ±0.18 in right lateral and 4.06 ±0.28 in left lateral radiographs ranged from 3.19-4.70. In mesocephalic breeds, the mean ±SE value of R4 was 6.29 ±0.34 in right lateral and 6.48 ±0.34 in left lateral radiographs with a range of 3.35-10.00.

In brachycephalic breeds, the mean ±SE value of Cranial Pulmonary artery diameter: proximal 1/3rd of 4th rib (CrPA: R4) was 0.54 ±0.08in right lateral and 0.75 ±0.06 in left lateral radiograph ranged from 0.43-0.87. In mesocephalic breeds, the mean ±SE value was 0.64 ±0.05 in right lateral and 0.65 ±0.05in left lateral radiograph with a range of 0.33-1.04.

In brachycephalic breeds, the mean ±SE value of Cranial Pulmonary vein diameter: proximal 1/3rd of 4th rib (CrPV: R4) was 0.71 ±0.10 in right lateral and 0.73 ±0.02 in left lateral radiographs ranged from 0.50-1.00. In mesocephalic breeds, the mean ±SE value was 0.67 ±0.04 in right lateral and 0.71 ±0.05 in left lateral radiographs with a range of 0.38-1.06. The ratio of the pulmonary vessels to the width of proximal $3^{rd}$ of $4^{th}$ rib is considered suitable for diagnosing enlargement of pulmonary vessels. In the present study the ratio of the cranial pulmonary vasculature with the width of the $4^{th}$ rib was normal. Earlier workers have reported that the cranial pulmonary vessels should not be greater in width as compared to the width of proximal $1/3^{rd}$ of the $4^{th}$ rib (Thrall 2013, Oui *et al* 2015 and Sharma 2018).

**Correlation between Radiographic dimensions of cranial pulmonary vessels and $4^{th}$ rib**

Table 32 revealed that CrPA had a significant ($p \leq 0.05$) positive correlation with CrPV, R4, CrPA: R4, CrPV: R4. Since Cranial pulmonary artery diameter and cranial pulmonary vein diameter have a strong positive correlation, so all the parameters which are correlated with cranial pulmonary artery diameter are similarly correlated with cranial pulmonary vein diameter. Moreover, CrPA: R4 and CrPV: R4 had a significant ($p \leq 0.05$) positive correlation amongst each other.

**Table 31: Radiographic dimensions of cranial pulmonary vessels and 4th rib in dogs with cardiopulmonary disorders belonging to different breeds**

| Breed type | Cranial pulmonary artery diameter (in mm) | | Cranial pulmonary vein diameter (in mm) | | Proximal 1/3rd of 4th rib diameter (in mm) | | Cranial Pulmonary artery diameter: proximal 1/3rd of 4th rib | | Cranial Pulmonary vein diameter: proximal 1/3rd of 4th rib | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **R** | **L** | **R** | **L** | **R** | **L** | **R** | **L** | **R** | **L** |
| Brachy-cephalic | 2.08±0.33 (1.39-2.99) | 2.90±0.15 (2.7-3.2) | 2.70±0.41 (2.04-3.89) | 2.85±0.27 (2.48-3.39) | 3.92±0.18 (3.26-4.36) | 4.06±0.28 (3.19-4.70) | 0.54±0.08 (0.43-0.77) | 0.75±0.06 (0.68-0.87) | 0.71±0.10 (0.50-1.00) | 0.73±0.02 (0.70-0.78) |
| Meso-cephalic | 3.80±0.28 (2.66-5.73) | 4.18±0.28 (3.12-6.09) | 4.04±0.32 (2.7-5.75) | 4.53±0.28 (2.59-6.02) | 6.29±0.34 (3.35-10) | 6.48±0.34 (4.04-9.06) | 0.64±0.05 (0.33-1.03) | 0.65±0.05 (0.43-1.04) | 0.67±0.04 (0.41-1.03) | 0.71±0.05 (0.38-1.06) |

Figures in parentheses indicate range

**Table 32: Correlation between radiographic dimensions of cranial pulmonary vessels and 4th rib in dogs with cardiopulmonary disorders (Group 3)**

| | | Cranial pulmonary artery diameter | Cranial pulmonary vein diameter | Proximal 1/3rd of 4th rib diameter | Cranial Pulmonary artery diameter: proximal 1/3rd of 4th rib |
|---|---|---|---|---|---|
| Cranial pulmonary vein diameter | r | .925** | | | |
| | p | 0 | | | |
| | N | 18 | | | |
| Proximal 1/3rd of 4th rib diameter | r | .533* | .588* | | |
| | p | 0.023 | 0.01 | | |
| | N | 18 | 18 | | |
| Cranial Pulmonary artery diameter: proximal 1/3rd of 4th rib | r | .764** | .629** | -0.108 | |
| | p | 0 | 0.005 | 0.67 | |
| | N | 18 | 18 | 18 | |
| Cranial Pulmonary vein diameter: proximal 1/3rd of 4th rib | r | .575* | .649** | -0.204 | .833** |
| | p | 0.013 | 0.004 | 0.416 | 0 |
| | N | 18 | 18 | 18 | 18 |

*values differ significantly ($p \leq 0.05$)

**values differ significantly ($p \leq 0.01$)

**Evaluation of Caudal pulmonary vessels**

All the dimensions of caudal pulmonary vasculature were measured and expressed in mm (Table 3).

In brachycephalic breeds, the mean ±SE value of caudal pulmonary artery diameter (CdPA) was 5.12 ±0.50 in ventrodorsal and 5.77 ±0.93 in dorsoventral radiographs which ranged from 4.13-8.82. In mesocephalic breeds, the mean ±SE value was 7.84 ±0.64 in ventrodorsal and 6.83 ±0.28 in dorsoventral radiographs with a range of 4.56-14.62. In the present study the caudal pulmonary vessels were better visualized in DV than in VD view. Brinkman *et al* (2006) also observed that in DV radiographic views, the caudal lobar pulmonary vessels were magnified, oriented more perpendicular to the primary X-ray beam and therefore were less distorted and therefore more conspicuous.

Caudal pulmonary vein diameter (CdPV) in brachycephalic breeds, was 5.42 ±0.52 in ventrodorsal and 6.02 ±0.51 in dorsoventral radiographs which ranged from 3.78-7.85. In mesocephalic breeds, the CdPV diameter was 7.92 ±0.68 in ventrodorsal and 7.59 ±0.46 in dorsoventral radiographs with a range of 4.24-15.6.

In brachycephalic breeds, the mean ±SE value of 9th rib diameter at intersection with artery was 3.79 ±0.25 in ventrodorsal and 3.57 ±0.27 in dorsoventral radiographs with a range of 2.57-4.43 while in mesocephalic breeds, it was 5.95 ±0.34 in ventrodorsal and 6.19 ±0.28 in dorsoventral radiographs and ranged from 3.48-8.80.

Similarly, the 9th rib diameter at intersection with vein in brachycephalic breeds was 3.29 ±0.22 in ventrodorsal and 3.89 ±0.29 in dorsoventral radiographs with a range of 2.59-4.73 while in mesocephalic breeds it was 5.74 ±0.35 in ventrodorsal and 6.01 ±0.29 in dorsoventral radiographs and ranged from 3.18-8.03.

The ratio of CdPA: 9th rib in brachycephalic breeds was 1.38 ±0.16 in ventrodorsal and 1.60 ±0.21 in dorsoventral radiographs which ranged from 0.99-2.35. While in mesocephalic breeds, the ratio was 1.36 ±0.11 in ventrodorsal and 1.14 ±0.07 in dorsoventral radiographs with a range of 0.97-2.35.

Similarly, the ratio of CdPV: 9th rib in brachycephalic breeds was 1.64 ±0.09 in ventrodorsal and 1.57 ±0.15 in dorsoventral radiographs with a range of 1.21-2.10. While in mesocephalic breeds, the ratio was 1.48 ±0.16 in ventrodorsal and 1.32 ±0.12 in dorsoventral radiographs which ranged from 1.07-2.51.

In the present study the caudal pulmonary vessels (Artery and Vein) were enlarged irrespective of breed type. This was evident from the CdPA:9$^{th}$ rib and CdPV:9$^{th}$ rib ratios which were greater than 1 in all the cases. The width of CdPA and CdPV should not exceed the width of 9$^{th}$ rib at the point where the vessels intercept with the 9$^{th}$ rib (Muhlbauer & Kneller 2013, Thrall 2013). Oui et al (2015) recommended using the accompanying pulmonary artery and 1.22 x the diameter of the 9$^{th}$ rib as a radiographic creation for assessing the size of the right caudal pulmonary vein.

**Correlation between Radiographic dimensions of caudal pulmonary vessels and 9$^{th}$ rib**

Table 34 revealed that the diameter of Caudal pulmonary vessels had a significant ($p \leq 0.05$) positive correlation with the 9$^{th}$ rib diameter

**Extra thoracic structures**

Diaphragm was apparently normal in 25 dogs; Ribs were apparently normal in 24 dogs with costochondral reactions in 1 dog (Fig. 75); Sternebrae were normal in 24 while one dog showed moulded or broken Sternebrae (Fig 76); Vertebral column was normal in 22 dogs and ankylotic spondylosis was seen in 3 dogs Fig. 77. All these findings were considered incidental.


**Fig 75:Left lateral radiograph showing ribs having costochondral reactions**

**Fig 76: Radiograph showing broken sternebrae**


**Fig 77: Right lateral radiograph showing ankylosing spondylosis**

**Table 33: Radiographic dimensions of caudal pulmonary vessels and 9th rib in dogs with cardiopulmonary disorders belonging to different breeds**

| Breed type | Caudal pulmonary artery diameter (in mm) | | Caudal pulmonary vein diameter (in mm) | | 9th rib diameter (in mm) artery | | 9th rib diameter (in mm) vein | | Caudal pulmonary artery diameter:9th rib | | Caudal pulmonary vein diameter: 9th rib | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | VD | DV | VD | DV | VD | DV | VD | DV | VD | DV | VD | DV |
| Brachy-cephalic | 5.12 ±0.50 (4.19-6.8) | 5.77 ±0.93 (4.13-8.82) | 5.42 ±0.52 (3.78-7.06) | 6.02 ±0.51 (5.17-7.85) | 3.79 ±0.25 (3.11-4.43) | 3.57 ±0.27 (2.57-4.18) | 3.29 ±0.22 (2.59-3.81) | 3.89 ±0.29 (3.08-4.73) | 1.38 ±0.16 (0.99-2.00) | 1.60 ±0.21 (1.15-2.35) | 1.64 ±0.09 (1.39-1.85) | 1.57 ±0.15 (1.21-2.10) |
| Meso-cephalic | 7.84 ±0.64 (5.95-14.62) | 6.83 ±0.28 (4.56-8.44) | 7.92 ±0.68 (4.93-15.6) | 7.59 ±0.46 (4.24-10.2) | 5.95 ±0.34 (3.48-8.8) | 6.19 ±0.28 (4.19-8.57) | 5.74 ±0.35 (3.18-8.03) | 6.01 ±0.29 (3.89-7.95) | 1.36±0.11 (0.99-2.14) | 1.14 ±0.07 (0.97-2.35) | 1.48 ±0.16 (1.11-2.50) | 1.32 ±0.12 (1.07-2.51) |

Figures in parentheses indicate range

**Table 34: Correlation between radiographic dimensions of caudal pulmonary vessels and 9th rib in dogs with cardiopulmonary disorders (Group 3)**

| | | Caudal pulmonary artery diameter | Caudal pulmonary vein diameter | 9th rib diameter at artery | 9th rib diameter at vein | Caudal pulmonary artery diameter:9th rib |
|---|---|---|---|---|---|---|
| Caudal pulmonary vein diameter | r | 0.438 | | | | |
| | p | 0.053 | | | | |
| | N | 20 | | | | |
| 9th rib diameter atartery | r | 0.156 | 0.086 | | | |
| | p | 0.512 | 0.717 | | | |
| | N | 20 | 20 | | | |
| 9th rib diameter at vein | r | .447* | 0.278 | -0.143 | | |
| | p | 0.048 | 0.235 | 0.547 | | |
| | N | 20 | 20 | 20 | | |
| Caudal pulmonary artery diameter:9th rib | r | .445* | 0.176 | -.604** | -0.065 | |
| | p | 0.049 | 0.457 | 0.005 | 0.784 | |
| | N | 20 | 20 | 20 | 20 | |
| Caudal pulmonary vein diameter:9th rib | r | 0.025 | .586** | 0.315 | -.589** | 0.138 |
| | p | 0.918 | 0.007 | 0.176 | 0.006 | 0.56 |
| | N | 20 | 20 | 20 | 20 | 20 |

*values differ significantly ($p \leq 0.05$)

**values differ significantly ($p \leq 0.01$)

**EXTRATHORACIC DISORDERS**

Only one dog was presented with extra thoracic disorder in the present study having radiographic lesion within the thorax. The animal was a 2-month-old German Shepherd male dog. Four radiographic views were taken which included left lateral, right lateral, ventrodorsal and dorsoventral projections. No lung pattern could be appreciated. A soft tissue opacity measuring 107.3*59.48 mm was visible in the region of right caudal lung lobe and left accessory lung lobe on lateral view (Fig. 78). extending up to right middle lung lobe on ventrodorsal view (Fig. 79) This was suspected to be a mediastinal mass. An additional right lateral radiograph with barium contrast was done to confirm involvement of oesophagus. It was found that the caudal oesophagus was dilated with filling defects suggestive of tumour or gastroesophageal intussusception similar radiographic features of gastroesophageal intussusception have been reported by earlier workers (Clark *et al* 1992, Greenfield et al 1997, Sellon and Willard 2003, Shibly *et al* 2014). The shape and size of heart were normal. VHS was 8.25 in both right lateral and left lateral radiograph**.** Percentage of cardiac silhouette in the thoracic cavity was 55.45 in right lateral and 58.49 in left lateral radiograph which were normal. Border effacement of the caudodorsal margin of the cardiac silhouette was seen. The cardiac silhouette was involving 2 ICS and had contact with one Sternebrae in both left and right lateral radiographs which was normal. No space occupying lesion was visible in the cranial mediastinum and it appeared normal. The oesophagus was abnormally dilated and the dog was suspected for mega oesophagus. Barium contrast showed enhanced radio-opacity in the caudal oesophagus **(**Fig. 80). Carina was not appreciable in both right and left lateral radiograph as it was superimposed with the soft tissue opacity. Trachea was ventrally deviated at the cranial mediastinum. The tracheal diameter in left lateral radiograph was 5.95 mm and the thoracic inlet diameter was 50.57 mm**.** The TD:TI ratio was 0.12 on left lateral radiograph which was smaller than the normal reported values, the reduced TD; TI ratio may have resulted due to ventral pressure on the trachea due to dilatated oesophagus. Proximal 1/3$^{rd}$ of 3$^{rd}$ rib diameter in left lateral radiograph was 4.86 mm**.** The Trachea diameter: proximal 1/3rd of 3rd rib ratio was 0.88 in left lateral radiograph which was smaller than normal dolichocephalic breeds recorded in Group

1 of the study. This was also markedly lower than earlier reports for normal dogs (approximately 3.0) in normal dogs.

The pleural space was normal with no fluid, air, fissure lines or mass apparently visible. Aorta and Caudal vena cava were not appreciable in both right and left lateral radiographs. The Length of T6 was 11.11 in right lateral and 11.32 in left lateral radiograph. Cranial pulmonary artery diameter was 1.58 mm in right lateral radiograph. It was not appreciable in the left lateral radiograph. Cranial pulmonary vein diameter was 2.44 mm in right lateral radiograph and was not appreciable in the left lateral radiograph. The larger cranial pulmonary vein as compared to artery may indicate pulmonary hypertension caused due to left side heart disease secondary to the mediastinal mass. Proximal 1/3$^{rd}$ of 4$^{th}$ rib diameter was 5.11 in left lateral and was not appreciable in the right lateral radiograph. Caudal pulmonary artery diameter was 3.7 and 3.64 mm in ventrodorsal and dorsoventral radiographs, respectively. Caudal pulmonary vein diameter was 3 mm in ventrodorsal radiograph and was not appreciable in dorsoventral radiograph. The 9$^{th}$ rib diameter at intersection of artery was 3.49mm in ventrodorsal radiograph and 3.69 mm in dorsoventral radiograph. While the 9$^{th}$ rib at intersection of vein was not appreciable in ventrodorsal radiograph. 9$^{th}$ rib at intersection of vein diameter was 4.24mm in dorsoventral radiograph. Caudal pulmonary artery diameter: 9th rib was 0.94 and 1.01 in ventrodorsal and dorsoventral radiographs, respectively which was normal.

In both right and left lateral radiographs, proximal half of the diaphragmatic crus was not apparently visible. In both ventrodorsal (Fig. 79) and dorsoventral (Fig. 81) radiographs, left crus were not visible due to presence of a soft tissue opacity between the heart and diaphragm. The ribs, sternebrae and the vertebral column were apparently normal in all radiographs. Upon surgery the case was confirmed as Gastro-oesophageal intussusception.

Based on the radiographic assessments in the present study the following SOP is proposed for evaluating a thoracic radiograph.

- Evaluate lungs for various patterns.
- Evaluate cranial mediastinum for carina, course of trachea, visibility of oesophagus, any SOL/Mass.


**Fig. 78: Left lateral radiograph showing soft tissue mass (107.3*59.48 mm) near caudal lung lobe**


**Fig. 79: Ventrodorsal radiograph showing soft tissue opacity extending up to right middle lung lobe**

**Fig. 80: Lateral radiograph showing positive contrast (barium) enhanced radio-opacity in the caudal oesophagus. Note the filling defects**


**Fig. 81: Dorsoventral radiograph showing soft tissue opacity superimposing the left crus**

- Evaluate cardiac silhouette for shape, size and border effacement.
- Evaluate caudal mediastinum for any SOL and visibility of oesophagus.
- Evaluate pleural space for fluid, air, fissure lines and any mass.
- Evaluate vascular structures for aorta, caudal vena cava, cranial and caudal pulmonary vessels.

Evaluate extra thoracic structures for vertebrae, sternebrae, diaphragm and ribs.

## CHAPTER V

# SUMMARY AND CONCLUSIONS

The present study was aimed to fabricate indigenous radiographic positioners for thoracic radiography in dogs, establish criteria for declaring a thoracic radiograph as normal and evaluate thoracic radiographs in relation to various disease conditions in dogs. The work was conducted on apparently healthy as well as diseased dogs presented to the department of Veterinary Surgery and Radiology, GADVASU, Ludhiana. The study was divided into 2 parts. Part 1 of the study was conducted on fabrication of different positioning devices like wedges, sand bags from economical and durable materials procured from the local market. Part 2 of the study was conducted on 507 thoracic radiographs taken from 134 dogs presented at University Veterinary Hospital, GADVASU, Ludhiana.

Three different kinds of foams i.e. expanded polyethylene (EPE) foam, Polyethylene foam and Polyurethane (PU)-foam were procured from the local market for fabrication of troughs and wedge and these were then tested for the two parameters- Strength and Opacity. Expanded polyethylene (EPE) foam showed mild radiopacity, Polyethylene foam showed moderate radiopacity while polyurethane (PU)-foam showed moderate radiopacity. Expanded polyethylene (EPE) foam was found to be tough and cushiony in comparison to Polyethylene foam and Polyurethane (PU)-foam. Hence Expanded polyethylene (EPE) was selected for the manufacture of wedges and troughs. The PVC American Matty was selected the best fit for fabrication of sandbags because of its good strength, thickness and mouldability. A set of 4 troughs, 1 wedge and 8 sandbags of different sizes was fabricated and the cost of the set was worked out to be Rs 12,440.

Part 2 of the study was conducted on 507 thoracic radiographs of dogs from 134 animals presented for screening or exhibiting particular clinical signs were classified into four groups according to radiographic findings regarding presence or absence of certain disorder i.e. normal dogs and dogs with pulmonary, cardiovascular (or cardiopulmonary) and extra thoracic disorders. Further dogs were categorized into sub groups on the basis of type of head i.e. brachycephalic, mesocephalic and dolichocephalic. The animals in various groups were evaluated on the basis of:

Signalment which included Age (years), gender, breed and also was classified into brachycephalic, dolichocephalic or mesocephalic on the basis of head shape.

At least three views viz: right lateral, left lateral and ventrodorsal/dorsoventral were taken in respective recumbencies for screening or assessment of thoracic disorders. The radiographs were evaluated for the following parameters:

Lung was evaluated in all dogs for any lung pattern i.e. alveolar/ interstitial/ bronchial/ vascular/mixed/ normal. Heart: Heart was evaluated for shape and size, vertebral heart score (VHS) on lateral view and in DV/VD projection, heart size was estimated as percentage of thoracic cavity occupied by the cardiac silhouette. The number of intercostal spaces occupied by the cardiac silhouette and the sterna contact along with the presence or absence of border effacement were also recorded. All the dimensions of structures in the thoracic cavity were measured and expressed in mm. Mediastinum was evaluated for thoracic inlet diameter (TI), Tracheal diameter (TD), TD:TI ratio, Carina diameter, T6 length, Aorta (Ao), Caudal vena cava (CVC), Width of the 4$^{th}$ rib (R4), Width of cranial pulmonary artery (CrPA), Width of cranial pulmonary vein (CrPV). In VD/DV view vascular structures included: Caudal pulmonary artery (CdPA), caudal pulmonary vein (CdPV), 9$^{th}$ rib diameter (R9). Space occupying lesion, oesophagus. Pleural space was evaluated for any fluid, air, fissure lines or mass. The extra thoracic structures viz. diaphragm, ribs, sternebrae, and vertebral column were evaluated. Standard operative procedure (SOP) for reading a thoracic radiograph was developed. Criteria for declaring the radiographs as normal was established.

In Part 2 of study, 29 out of 134 dogs were brachycephalic 95 were mesocephalic and 10 out were dolichocephalic. A total of 47 female and 87 male dogs of age ranging between 0.16 to 14 years and body weight ranging between 1.8 to 65 kg were included. 38 dogs out of 134 presented were found normal with no abnormality detected in thoracic radiographs and 70, 25 and 1 dogs were found with pulmonary, cardiopulmonary and extra thoracic disorders, respectively.

Out of a total of 38 normal dogs, 9 were brachycephalic, 26 were mesocephalic and 3 were dolichocephalic breeds. Age ranged from 0.2 to 14 years. No lung pattern was seen in any dog. Shape of heart was normal in all the dogs. In brachycephalic breeds, the VHS was 9.83±0.26 in right lateral and 10.25±0.37 in left lateral radiographs. In mesocephalic breeds, the VHS was 9.70 ±0.12 in right lateral and 9.50 ±0.13 in left lateral radiographs while in dolichocephalic breeds, VHS was 10.00 ±0.67 in right lateral and 9.75 ±0.50 in left lateral radiographs. In brachycephalic breeds, the percentage of cardiac silhouette in thoracic cavity was 58.22 ±1.99 in right lateral and 60.87 ±2.27 in left lateral radiographs. In mesocephalic breeds, the percentage of cardiac silhouette in thoracic cavity was 57.57 ±1.37 in right lateral and 58.45 ±1.42 in left lateral radiographs and in dolichocephalic breeds, it was 60.68 ±3.67 in right lateral and 59.02 ±2.83 in left lateral radiographs. No border effacement was seen in any dog. The ICS occupied in brachycephalic breeds was 2.72 ±0.09 in right lateral and 3.20 ±0.25 in left lateral radiographs. In mesocephalic breeds, it was 2.68 ±0.06 in right lateral and 2.79 ±0.06 in left lateral radiographs while in dolichocephalic breeds, the ICS occupied was 2.83 ±0.17 in right lateral and 2.83 ±0.16 in left lateral radiographs. In brachycephalic breeds, the sternal contact was 2.72 ± 0.12 in right lateral and 2.70 ±0.20 in left lateral radiographs. In mesocephalic breeds, it was 2.60 ±0.08 in right lateral and 2.52 ± 0.10 in left lateral radiographs and in dolichocephalic breeds, the sternal contact was 2.83 ±0.17 in right lateral and 2.83 ±0.17 in left lateral radiographs. No space occupying lesion was visible in any radiograph. Oesophagus was not visible in any radiograph. In brachycephalic breeds, the carina diameter was 10.44±1.83 in right lateral and 10.63±1.59 in left lateral radiographs. In mesocephalic breeds, the carina diameter was 17.81 ±0.93 in right lateral and 16.73 ±0.96 in left lateral radiographs while in dolichocephalic breeds, it was 23.73±2.91 in right lateral and 23.79 ±1.52 in left lateral radiographs. Trachea course was apparently normal in all radiographs. In brachycephalic breeds, trachea diameter (TD) was 8.60 ±1.48 in right lateral and 9.14 ±1.94 in left lateral radiographs. In mesocephalic breeds, the TD was 15.64 ±0.86 in right lateral and 14.86 ±0.90 in left lateral radiographs. In dolichocephalic breeds, the TD was 20.61±2.51 in right lateral and 20.14±2.70 in left lateral radiographs. The thoracic inlet diameter (TI) in brachycephalic breeds was 50.01 ±4.73 in right lateral and 52.29±6.39 in left lateral radiographs. In mesocephalic breeds, the TI was 69.72 ±2.58 in right lateral and 68.73 ±2.87 in left lateral radiographs. In dolichocephalic breeds, the TI was 90.92 ±5.65 in right lateral and 86.14±7.04 in left lateral radiographs. The TD:TI ratio in brachycephalic breeds was 0.17 ±0.02 in right lateral and 0.17 ±0.02 in left lateral radiographs. In mesocephalic breeds, the ratio was 0.22 ±0.01 in right lateral and 0.21 ±0.01 in left lateral radiographs while in dolichocephalic breeds TD:TI ratio was 0.23 ±0.04 in right lateral and 0.24 ±0.05 in left lateral radiographs.

In brachycephalic breeds, proximal 1/3rd of 3rd rib diameter (R3) was 3.99 ±0.44 in right lateral and 4.78 ±1.01 in left lateral radiographs. In mesocephalic breeds, the R3 width was 6.45 ±0.27 in right lateral and 6.61 ±0.37 in left lateral radiographs. While in dolichocephalic breeds, it was 8.66 ±0.47 in right lateral and 8.06 ±0.40 in left lateral radiographs. The TD: R3 ratio in brachycephalic breeds, was 2.18 ±0.23 in right lateral and 1.93 ±0.14 in left lateral radiographs. In mesocephalic breeds, the ratio was 2.45 ±0.12 in right lateral and 2.30±0.10 in left lateral radiographs while in dolichocephalic breeds, this ratio was 2.42 ±0.38 in right lateral and 2.54 ±0.44 in left lateral radiographs. There was no space occupying lesion in the caudal mediastinum. Pleural space was normal in all the dogs. In brachycephalic breeds, aorta diameter (Ao) was 12.95 ±2.52 in right lateral and 13.38 ±3.80 in left lateral radiographs. In mesocephalic breeds, Ao diameter was 17.19 ±0.72 in right lateral and 17.99 ±0.69 in left lateral radiographs. In dolichocephalic breeds, Ao diameter was 21.83 ±2.39 in right lateral and 19.66 ±0.59 in left lateral radiograph. In brachycephalic breeds, caudal vena cava diameter (CVC) was9.14 ±0.80 in right lateral and 11.87 ±2.72in left lateral radiographs. In mesocephalic breeds, CVC was 12.69 ±0.59 in right lateral and 13.14 ±0.57 in left lateral radiographs while in dolichocephalic breeds, it was19.41 ±2.62 in right lateral and 20.25 ±2.71 in left lateral radiographs. In brachycephalic breeds, length of T6 was 12.52 ±1.08 in right lateral and 13.04 ±1.69 in left lateral radiographs. The T6 length in mesocephalic breeds, was 17.98 ±0.60 in right lateral and 17.66 ±0.75 in left lateral radiographs and in dolichocephalic breeds, it was 22.11 ±0.84 in right lateral and 22.35 ±0.95 in left lateral radiographs. The AO; T6 ratio in brachycephalic breeds, was 0.95 ±0.05 in right lateral and 0.88 ±0.00 in left lateral radiograph. In mesocephalic breeds, the ratio was 0.89 ±0.02 in right lateral and 1.00 ±0.05 in left lateral radiograph while in dolichocephalic breeds, this ratio was 0.98±0.07 in right lateral and 0.88 ±0.03 in left lateral radiograph. The CVC: T6 ratio in brachycephalic breeds, was 0.73 ±0.03 in right lateral and 0.84 ±0.06 in left lateral radiographs. In mesocephalic breeds, the ratio was 0.71 ±0.03 in right lateral and 0.79 ±0.03 in left lateral radiographs. In dolichocephalic breeds, this ratio was 0.86 ±0.07 in right lateral and 0.90 ±0.09 in left lateral radiographs.

In brachycephalic breeds, cranial pulmonary artery diameter (CrPA) was 2.72 ±0.42 in right lateral and 3.05 ±0.62 in left lateral radiographs. In mesocephalic breeds, it was 3.99 ±0.24 in right lateral and 4.42 ±0.23 in left lateral radiographs. In dolichocephalic breeds, CrPA was 5.77 ±0.82 in right lateral and 6.75 ±1.75 in left lateral radiographs. The cranial pulmonary vein diameter (CrPV) in brachycephalic breeds, was 2.60 ±0.31 in right lateral and 3.16 ±0.52 in left lateral radiographs. In mesocephalic breeds, CrPV was 3.94 ±0.21 in right lateral and 4.71 ±0.26 in left lateral radiographs while in dolichocephalic breeds, CrPV diameter was5.70 ±0.61 in right lateral and 6.28 ±0.76 in left lateral radiographs. In brachycephalic breeds, proximal 1/3rd of 4th rib diameter (R4) was 4.39 ±0.70 in right lateral and 4.75 ±1.10 in left lateral radiographs. In mesocephalic breeds, the R4 diameter was 7.49 ±0.37 in right lateral and 7.09 ±0.40 in left lateral radiographs. In dolichocephalic breeds, the R4 diameter was 9.63 ±0.41 in right lateral and 9.45 ±0.88 in left lateral radiographs. The ratio of CrPA:R4 in brachycephalic breeds, was 0.62±0.04 in right lateral and 0.65 ±0.05 in left lateral radiograph. In mesocephalic breeds, the ratio was 0.54 ±0.03 in right lateral and 0.61 ±0.04 in left lateral radiograph while in dolichocephalic breeds, this ratio was 0.60 ±0.10 in right lateral and 0.69 ±0.11 in left lateral radiograph. The ratio of CrPV:R4 in brachycephalic breeds, was 0.61 ±0.03 in right lateral and 0.70 ±0.0 5in left lateral radiographs. In mesocephalic breeds, the ratio was 0.54 ±0.02 in right lateral and 0.65 ±0.04 in left lateral radiographs while in dolichocephalic breeds, this ratio was 0.59 ±0.06 in right lateral and 0.66 ±0.04 in left lateral radiographs. In brachycephalic breeds, caudal pulmonary artery diameter (CdPA) was 3.63 ±0.64 in ventrodorsal and 4.66 ±0.84 in dorsoventral radiographs. In mesocephalic breeds, the CdPA diameter was 5.49 ±0.31 in ventrodorsal and 5.77 ±0.62 in dorsoventral radiographs. In dolichocephalic breeds, the diameter of CdPA was 4.79 ±0.55 in ventrodorsal and 6.50 ±1.36 in dorsoventral radiographs. In brachycephalic breeds, caudal pulmonary vein diameter (CdPV) was3.77 ±0.59 in ventrodorsal and 4.96 ±1.01 in dorsoventral radiographs. In mesocephalic breeds, CdPV was 6.02 ±0.38 in ventrodorsal and 5.74 ±0.41 in dorsoventral radiographs. In dolichocephalic breeds, CdPV was 6.71 ±0.95 in ventrodorsal and 7.19 ±1.27 in dorsoventral radiographs. In brachycephalic breeds, 9th rib diameter (R9) at intersection with artery was 3.83 ±0.49 in ventrodorsal and 4.44 ±0.63 in dorsoventral radiographs. In mesocephalic breeds, the R9 at intersection with artery was 5.87 ±0.24 in ventrodorsal and 6.01 ±0.34 in dorsoventral radiographs while in dolichocephalic breeds, it was 6.89 ±0.69 in ventrodorsal and 7.76 ±0.77 in dorsoventral radiographs. In brachycephalic breeds, 9th rib diameter (R9) at intersection with vein was 4.17 ± 0.49 in ventrodorsal and 4.53 ±0.64 in dorsoventral radiographs. In mesocephalic breeds, the R9 at intersection with vein was 5.80 ±0.29 in ventrodorsal and 6.21 ±0.40 in dorsoventral radiographs while in dolichocephalic breeds, it was 6.76 ±0.67 in ventrodorsal and 8.22 ±0.57 in dorsoventral radiographs. The CdPA: R9 ratio in brachycephalic breeds, was 0.92 ±0.06 in ventrodorsal and 1.02 ±0.10 in dorsoventral radiographs. In mesocephalic breeds, the ratio was 0.95 ±0.05 in ventrodorsal and 0.96 ±0.07 in dorsoventral radiographs while in dolichocephalic breeds, this ratio was 0.70 ±0.09 in ventrodorsal and 0.82 ±0.12 in dorsoventral radiographs. The CdPV: R9 ratio in brachycephalic breeds, was 0.89 ±0.08 in ventrodorsal and 1.07 ±0.12 in dorsoventral radiographs. In mesocephalic breeds, the ratio was 1.06 ±0.06 in ventrodorsal and 0.93 ±0.04 in dorsoventral radiographs. In dolichocephalic breeds, this ratio was 0.99 ±0.06in ventrodorsal and 0.87 ±0.10 in dorsoventral radiographs. Extra thoracic structures were normal in all dogs.

Out of a total of 70 dogs with pulmonary disorders, 15 were brachycephalic 49 were mesocephalic. 6 were dolichocephalic There were 26 female and 44 male dogs with age ranging between 0.2 to 14 years. Alveolar(n=12), interstitial(n=21), bronchial, vascular or mixed(n=37) lung patterns were found in all the dogs.

Shape of heart were normal in 51 dogs and not appreciable in 19 dogs. The VHS was 9.98±0.19 in right lateral and 10.27±0.14 in left lateral radiographs of brachycephalic breeds. In mesocephalic breeds, the VHS was 9.90±0.13 in right lateral and 9.94±0.13 in left lateral radiographs. In dolichocephalic breeds, it was 9.63 ±0.41 in right lateral and 9.55 ±0.33 in left lateral radiographs. Percentage of cardiac silhouette in thoracic cavity in brachycephalic breeds was 58.07 ±1.73 in right lateral and 60.97±1.65 in left lateral radiographs. In mesocephalic breeds, it was 58.48 ±0.93 in right lateral and 59.59 ±0.96 in left lateral radiographs and in dolichocephalic breeds, the mean ±SE value was 56.69 ±2.51 in right lateral and 55.53 ±2.66 in left lateral radiographs.

Border effacement was seen in 19 dogs. In brachycephalic breeds, the ICS occupied was 2.86 ±0.11 in right lateral and 2.95 ±0.11 in left lateral radiographs. The ICS occupied in mesocephalic breed was 2.75 ±0.06in right lateral and 2.74 ±0.07in left lateral radiographs. In dolichocephalic breeds, the ICS occupied was 2.90 ±0.10 in right lateral and 2.90 ±0.10 in left lateral radiographs. The sternal contact was 2.93 ±0.12 in right lateral and 2.83 ±0.11 in left lateral radiographs in brachycephalic breeds. In mesocephalic breeds it was 2.65 ±0.05 in right lateral and 2.63 ±0.05 in left lateral radiographs while in dolichocephalic breeds, the sternal contact was 2.25 ±0.19 in right lateral and 2.15 ±0.22 in left lateral radiographs. In 5 dogs' space occupying lesions were visible in the cranial mediastinum. Oesophagus was not visible in any radiograph. In brachycephalic breeds, the carina diameter was 13.05 ±1.45 in right lateral and 10.66 ±1.23 in left lateral radiographs. In mesocephalic breeds, the mean ±SE value was 16.97 ±0.77in right lateral and 16.53 ±0.76 in left lateral radiographs. In dolichocephalic breeds, the mean ±SE value was 20.18 ±1.68 in right lateral and 19.08 ±1.65 in left lateral radiographs. Tracheal course was normal in 67 dogs, dorsally deviated at intersection with carina in 2 dogs, ventrally deviated at carina in 1 dog. In brachycephalic breeds, the trachea diameter (TD) was 10.65 ±1.23 in right lateral and 9.83 ±1.23 in left lateral radiographs. In mesocephalic breeds, it was 13.99 ±0.59 in right lateral and 14.25±0.66 in left lateral radiographs. In dolichocephalic breeds the TD was 17.80 ±1.27 in right lateral and 17.92 ±2.22 in left lateral radiographs. The thoracic inlet (TI) diameter in brachycephalic breeds was 62.66 ± 5.80 in right lateral and 56.25 ±5.66 in left lateral radiographs. In mesocephalic breeds, the TI was 70.12 ±2.00 in right lateral and 70.91 ±2.06 in left lateral radiographs while in dolichocephalic breeds it was 83.55 ±5.75 in right lateral and 84.86 ±5.63 in left lateral radiographs. In brachycephalic breeds, the TD:TI ratio was 0.17 ±0.01 in right lateral and 0.17 ±0.01 in left lateral radiographs. In mesocephalic breeds, the ratio was 0.20 ±0.01 in right lateral and 0.20 ±0.01 in left lateral radiographs while in dolichocephalic breeds, it was 0.21 ±0.01 in right lateral and 0.20 ±0.02 in left lateral radiographs. In brachycephalic breeds, the R3 diameter was 5.61 ±0.80 in right lateral and 5.06 ±0.68 in left lateral radiographs. In mesocephalic breeds, the R3 diameter was 5.91 ±0.24 in right lateral and 6.18 ±0.27 in left lateral radiographs while in dolichocephalic breeds, the mean ±SE value was 8.03 ±0.87 in right lateral and 7.77 ±0.91 in left lateral radiographs. The TD: R3 ratio in brachycephalic breeds was 2.06 ±0.13in right lateral and 2.02 ±0.15 in left lateral radiographs. In mesocephalic breeds, the TD: R3 ratio was 2.52 ±0.14 in right lateral and 2.47 ±0.14 in left lateral radiographs while in dolichocephalic breeds, the ratio was 2.20 ±0.09 in right lateral and 2.33 ±0.15 in left lateral radiographs.

Sixty-nine dogs had normal caudal mediastinum with no space occupying lesion, whereas in 1 dog space occupying lesion was visible. Pleural space was found normal in 53 dogs while fluid and fissure lines were present in 15 and 2 dogs respectively. In brachycephalic breeds, the aorta diameter was 11.03 ±3.34 in right lateral and 16.95 ±2.69 in left lateral radiographs. In mesocephalic breeds, Ao diameter was 17.53 ±0.77 in right lateral and 17.21 ±0.80 in left lateral radiographs, while in dolichocephalic breeds, the Ao diameter was 20.85 ±0.76 in right lateral and 21.06 ±1.41 in left lateral radiographs. In brachycephalic breeds, the CVC diameter was 10.75 ±2.24 in right lateral and 11.90 ±1.47 in left lateral radiographs. In mesocephalic breeds, the CVC diameter was 12.81 ±0.73 in right lateral and 13.96 ±0.76 in left lateral radiographs while in dolichocephalic breeds it was 19.91 ±1.92 in right lateral and 20.21 ±1.84 in left lateral radiographs. The length of T6 in brachycephalic breeds was14.30 ±1.38 in right lateral and 13.34 ±1.48 in left lateral radiographs. In mesocephalic breeds, T6 was 17.47 ±0.39 in right lateral and 17.60 ±0.42 in left lateral radiographs while in dolichocephalic breeds, the length of T6 was 21.04 ±1.20 in right lateral and 20.19 ±1.10 in left lateral radiographs. The Ao: T6 ratio in brachycephalic breeds was 0.94 ±0.10 in right lateral and 0.88 ±0.05 in left lateral radiograph. In mesocephalic breeds, ratio was 0.95 ±0.02 in right lateral and 0.93 ±0.03 in left lateral radiograph while in dolichocephalic breeds, the Ao-T6 ratio was 0.92 ±0.03 in right lateral and 0.99 ±0.05 in left lateral radiograph. In brachycephalic breeds, the CVC: T6 ratio was 0.77 ±0.09 in right lateral and 0.71 ±0.02 in left lateral radiographs. In mesocephalic breeds, this ratio was 0.72 ±0.03 in right lateral and 0.80 ±0.03 in left lateral radiographs and in dolichocephalic breeds, the ratio was 0.88 ±0.07 in right lateral and 0.79 ±0.16 in left lateral radiographs.

In brachycephalic breeds, the CrPA was 3.15 ±0.44 in right lateral and 3.67 ±0.58 in left lateral radiographs. In mesocephalic breeds, the CrPA was 3.55 ±0.17 in right lateral and 4.07 ±0.21in left lateral radiographs while in dolichocephalic breeds, the CrPA was 3.99 ±0.58 in right lateral and 4.78 ±0.45 in left lateral radiographs. In brachycephalic breeds, the CrPV was 3.06 ±0.44 in right lateral and 3.56 ±0.56 in left lateral radiographs. In mesocephalic breeds, the CrPV was3.83 ±0.18 in right lateral and 4.05 ±0.18 in left lateral radiographs. In dolichocephalic breeds, the CrPV was 4.49 ±0.61 in right lateral and 5.54 ±0.41 in left lateral radiographs. In brachycephalic breeds, the proximal 1/3rd of 4th rib diameter (R4) was 5.53 ±0.73 in right lateral and 5.51 ±0.74 in left lateral radiographs. In mesocephalic breeds, R4 width was 6.79 ±0.26 in right lateral and 7.17 ±0.29 in left lateral radiographs while in dolichocephalic breeds, it was 9.05 ±1.62 in right lateral and 9.18 ±1.73 in left lateral radiographs. The CrPA: R4 ratio in brachycephalic breeds, was 0.58 ±0.06 in right lateral and 0.72 ±0.06 in left lateral radiograph. In mesocephalic breeds, the ratio was 0.53 ±0.03 in right lateral and 0.57 ±0.03 in left lateral radiograph. In dolichocephalic breeds, the CrPA: R4 ratio was 0.50 ±0.09in right lateral and 0.50 ±0.06 in left lateral radiograph. The CrPV: R4 ratio in brachycephalic breeds was 0.56 ±0.05 in right lateral and 0.73 ±0.10 in left lateral radiographs. In mesocephalic breeds, this ratio was 0.58 ±0.04 in right lateral and 0.58 ±0.03 in left lateral radiographs and in dolichocephalic breeds it was0.53 ±0.08 in right lateral and 0.57 ±0.06 in left lateral radiographs.

In brachycephalic breeds, the CdPA diameter was 5.24 ±0.70 in ventrodorsal and 4.73 ±0.60 in dorsoventral radiographs. In mesocephalic breeds, CdPA was 5.98 ±0.34 in ventrodorsal and 5.67 ±0.30 in dorsoventral radiographs while in dolichocephalic breeds it was 6.96 ±1.04 in ventrodorsal and 6.51 ±1.52 in dorsoventral radiographs. The CdPV diameter in brachycephalic breeds, was 4.76 ±0.60 in ventrodorsal and 4.69 ±0.51 in dorsoventral radiographs. In mesocephalic breeds, the CdPV 5.96 ±0.31 in ventrodorsal and 5.98 ±0.28 in dorsoventral radiographs while in dolichocephalic breeds it was 6.41 ±1.27 in ventrodorsal and 7.85 ±1.29 in dorsoventral radiographs. The 9th rib (R9) diameter in brachycephalic breeds, at intersection with artery was 4.87 ±0.57 in ventrodorsal and 5.09 ±0.58 in dorsoventral radiographs. In mesocephalic breeds, it was 5.71 ±0.24 in ventrodorsal and 5.93 ±0.21 in dorsoventral radiographs while in dolichocephalic breed, R9 diameter was 6.79 ±1.35 in ventrodorsal and 6.00 ±1.42 in dorsoventral radiographs. In brachycephalic breeds, the 9th rib diameter at intersection with vein was 4.83 ±0.64 in ventrodorsal and 4.96 ±0.60 in dorsoventral radiographs. In mesocephalic breeds, the R9 diameter at intersection with vein was 5.64 ±0.24 in ventrodorsal and 6.08 ±0.20 in dorsoventral radiographs while in dolichocephalic breeds, it was 6.89 ±0.86 in ventrodorsal and 6.48 ±1.18 in dorsoventral radiographs.

The CdPA: R9 ratio in brachycephalic breeds, was 1.16 ±0.11 in ventrodorsal and 0.96 ±0.06 in dorsoventral radiographs. In mesocephalic breeds, the ratio was 1.07 ±0.05 in ventrodorsal and 0.94 ±0.04 in dorsoventral radiographs. In dolichocephalic breeds, the mean ±SE value was 0.97 ±0.04 in ventrodorsal and 0.99 ±0.05 in dorsoventral radiographs. Similarly, the CdPV: R9 ratio in brachycephalic breeds was 1.00 ±0.09 in ventrodorsal and 0.94 ±0.05 in dorsoventral radiographs. In mesocephalic breeds this ratio was 1.05 ±0.04 in ventrodorsal and 1.03 ±0.04 in dorsoventral radiographs while in dolichocephalic breeds, it was 0.94 ±0.02 in ventrodorsal and 1.38 ±0.16 in dorsoventral radiograph. Costochondral reactions were recorded in 2 dogs and irregular shape of R2-R6 in 1 dog. Pectus carinatum, pectus excavatum, and intersternebral mineralization and lipping were seen in 1 dog each. Ankylotic spondylosis was seen in 10 dogs.

Out of a total of 25 dogs with cardiopulmonary disorder, 5 were brachycephalic and 20 were mesocephalic. There were 7 female and 18 male dogs with age ranging between 2 to 12 years and mean weight of the animals was 28.7 ± 3.93. Lung patterns was seen in all dogs viz. interstitial (n=7), alveolar (n=3), bronchial, vascular or mixed (15) apparently visible. The heart was enlarged and globoid in all cases. In brachycephalic breeds, the VHS was 10.75 ±0.25 in right lateral and 11.13 ±0.54 in left lateral radiographs. In mesocephalic breeds, the VHS was 11.86 ±0.14 in right lateral and 11.80 ±0.19 in left lateral radiographs. In brachycephalic breeds, the percentage of cardiac silhouette in thoracic cavity was 66.58 ±2.51 in right lateral and 67.70 ±4.82 in left lateral radiographs. In mesocephalic breeds, the percentage was 72.04 ±1.97 in right lateral and 69.14±0.88 in left lateral radiographs. Border effacement was seen in 4 dogs.

In brachycephalic breeds, the ICS occupied was 3.10±0.06 in right lateral and 3.05±0.05 in left lateral radiographs. In mesocephalic breeds, the ICS was 3.43±0.14

in right lateral and 3.48±0.13 in left lateral radiographs. The sternal contact in brachycephalic breeds was 2.70±0.20 in right lateral and 2.70±0.20 in left lateral radiographs while in mesocephalic breeds it was 3.03±0.10 in right lateral and 2.90±0.12 in left lateral radiograph. Space occupying lesion was seen in 1 dog in cranial mediastinum. Oesophagus was not apparently visible in any radiograph. In brachycephalic breeds, the carina diameter was 9.38 ±0.11 in right lateral and 8.53 ±0.68 in left lateral radiographs. In mesocephalic breeds, the carina diameter was 16.72 ±0.96 in right lateral and 15.72 ±0.93 in left lateral radiographs. Tracheal course was normal in 4 dogs while it was dorsally deviated at carina in 21 dogs In brachycephalic breeds, the trachea diameter (TD) was 7.70 ±0.89 in right lateral 7.03 ±0.94 in left lateral radiographs. In mesocephalic breeds, the TD was 14.52 ±0.93 in right lateral and 14.17 ±0.74 in left lateral radiographs. The thoracic inlet diameter (TI) in brachycephalic breeds was 48.30 ±1.98 in right lateral and 49.68 ±1.86 in left lateral radiographs. In mesocephalic breeds, the TI was 74.30 ±2.74 in right lateral and 73.24 ±2.81 in left lateral radiographs. In brachycephalic breeds, the proximal 1/3rd of 3rd rib diameter (R3) was 3.42 ±0.23 in right lateral and 3.40 ±0.22 in left lateral radiographs while in mesocephalic breeds, R3 was 5.70 ±0.26 in right lateral and 5.89 ±0.27 in left lateral radiographs. The TD: TI ratio in brachycephalic breeds, was 0.16 ±0.02 in right lateral and 0.14 ±0.02 in left lateral radiograph while in mesocephalic breeds the ratio was 0.19 ±0.01 in right lateral and 0.19 ±0.01 in left lateral radiograph. The TD: R3 ratio in brachycephalic breeds was 2.28 ±0.27 in right lateral and 2.12 ±0.34 in left lateral radiographs while in mesocephalic breeds, this ratio was 2.56 ±0.12 in right lateral and 2.44 ±0.10 in left lateral radiographs. All 25 dogs had normal caudal mediastinum with no apparent abnormality. Pleural space was found normal in 17 dogs while fluid and fissure lines were present in 6 and 2 dogs respectively. Aorta was not appreciable in any radiograph

In brachycephalic breeds, the CVC diameter was 9.24 ±0.30 in right lateral and 9.58 ±1.61 in left lateral radiographs. In mesocephalic breeds, the CVC diameter was 17.11 ±2.32 in right lateral and 19.66±1.17 in left lateral radiographs. In brachycephalic breeds, the length of T6 was 11.35 ±0.24 in right lateral and 11.29 ±0.74 in left lateral radiography and in mesocephalic breeds it was 17.97 ±0.55 in right lateral and 18.29 ±0.56 in left lateral radiographs. The CVC: T6 ratio in brachycephalic breeds was 0.82 ±0.03 in right lateral and 0.96 ±0.21 in left lateral radiograph while in mesocephalic breeds, this ratio was 0.91 ±0.04 in right lateral and 1.08 ±0.05 in left lateral radiograph. In brachycephalic breeds, the CrPA was 2.08 ±0.33 in right lateral and 2.90 ±0.15 in left lateral radiographs. In mesocephalic breeds, the CrPA was 3.80 ±0.28 in right lateral and 4.18 ±0.28 in left lateral radiographs. The CdPA diameter in brachycephalic breeds was 2.70 ±0.41 in right lateral and 2.85 ±0.27 in left lateral radiographs while in mesocephalic breeds, the diameter was 4.04 ±0.32 in right lateral and 4.53 ±0.28 in left lateral radiographs. The diameter of the proximal 1/3rd of 4th rib (R4) in brachycephalic breeds, was 3.92 ±0.18 in right lateral and 4.06 ±0.28 in left lateral radiographs. In mesocephalic breeds, the R4 diameter was 6.29 ±0.34 in right lateral and 6.48 ±0.34 in left lateral radiograph. The ratio of CrPA: R4 in brachycephalic breeds was 0.54 ±0.08 in right lateral and 0.75 ±0.06 in left lateral radiograph while in mesocephalic breeds, the ratio was 0.64 ±0.05 in right lateral and 0.65 ±0.05 in left lateral radiograph. The CrPV: R4 ratio in brachycephalic breeds was 0.71 ±0.10 in right lateral and 0.73 ±0.02 in left lateral radiographs and in mesocephalic breeds this ratio was 0.67 ±0.04 in right lateral and 0.71 ±0.05 in left lateral radiograph.

In brachycephalic breeds, the CdPA diameter was 5.12 ±0.50 in ventrodorsal and 5.77 ±0.93 in dorsoventral radiographs. In mesocephalic breeds, CdPA was 7.84 ±0.64 in ventrodorsal and 6.83 ±0.28 in dorsoventral radiographs. The CdPV diameter in brachycephalic breeds was 5.42 ±0.52 in ventrodorsal and 6.02 ±0.51 in dorsoventral radiographs. In mesocephalic breeds, the CdPV was 7.92 ±0.68 in ventrodorsal and 7.59 ±0.46 in dorsoventral radiographs. The 9th rib diameter (R9) at intersection with artery, in brachycephalic breeds, was 3.79 ±0.25 in ventrodorsal and 3.57 ±0.27 in dorsoventral radiographs while in mesocephalic breeds it was 5.95 ±0.34 in ventrodorsal and 6.19 ±0.28 in dorsoventral radiographs. The 9th rib diameter (R9) at intersection with vein, in brachycephalic breeds, was 3.29 ±0.22 in ventrodorsal and 3.89 ±0.29 in dorsoventral radiographs. In mesocephalic breeds, the R9 diameter at intersection with vein was 5.74 ±0.35 in ventrodorsal and 6.01 ±0.29in dorsoventral radiograph. The CdPA: R9 ratio in brachycephalic breeds was 1.38 ±0.16 in ventrodorsal and 1.60 ±0.21 in dorsoventral radiographs while in mesocephalic breeds, the ratio was 1.36 ±0.11in ventrodorsal and 1.14 ±0.07 in dorsoventral radiographs. The CdPV: R9 ratio, in brachycephalic breeds, was 1.64 ±0.09 in ventrodorsal and 1.57 ±0.15 in dorsoventral radiographs while in mesocephalic breeds this ratio was 1.48 ±0.16 in ventrodorsal and 1.32 ± 0.12 in dorsoventral. Costochondral reactions were seen in 1 dog having cardiopulmonary affection. Sternebrae were moulded or broken in 1 dog. Ankylotic spondylosis in 3 dogs.

Only one dog was presented with extrathoracic affections (Group 4). The dog was 2-month-old German Shepherd male. No lung pattern was seen on the radiograph. Shape of heart were normal. VHS was 8.25 in both right lateral and left lateral radiograph. Percentage of cardiac silhouette in the thoracic cavity was 55.45 in right lateral and 58.49 in left lateral radiograph. ICS occupied by the heart was 2 in both left and right lateral radiographs and Sternal contact was 1 Sternebrae in both right and left lateral radiographs. Tracheal course was ventrally deviated at cranial mediastinum. Trachea was not appreciable in right lateral radiograph. Tracheal diameter in left lateral radiograph was 5.95 mm. Thoracic inlet was not appreciable in right lateral radiograph. Thoracic inlet diameter in left lateral radiograph was 50.57 mm. Trachea diameter: Thoracic inlet diameter was0.12 in left lateral radiograph. Proximal 1/3$^{rd}$ of 3$^{rd}$ rib was not appreciable in right lateral radiograph. Proximal 1/3$^{rd}$ of 3$^{rd}$ rib diameter in left lateral radiograph was 4.86 mm. Trachea diameter: proximal 1/3rd of 3rd rib diameterwas0.88 in left lateral radiograph. A space occupying lesion i.e. a mass measuring 107.3*59.48mm was seen in caudal mediastinum in right and left lateral radiographs which was also apparently visible in ventrodorsal and dorsoventral radiographs as soft tissue opacity. Pleural space was normal with no fluid, air, fissure lines or mass apparently visible. The aorta and Caudal vena cava were not appreciable in both right and left lateral radiographs. Length of T6 was 11.11 in right lateral and 11.32 in left lateral radiograph. CrPA was 1.58 mm in right lateral radiograph. CrPV was 2.44 mm in right lateral radiograph. Proximal 1/3$^{rd}$ of 4$^{th}$ rib diameter was 5.11 in left lateral and was not appreciable in the right lateral radiograph. Caudal pulmonary artery diameter was 3.7 and 3.64 mm in ventrodorsal and dorsoventral radiographs, respectively. Caudal pulmonary vein diameter was 3 mm in ventrodorsal radiograph and was not appreciable in dorsoventral radiograph. 9$^{th}$ rib diameter at intersection of artery was 3.49mm in ventrodorsal radiograph and 3.69 mm in dorsoventral radiograph.9$^{th}$ rib at intersection of vein was not appreciable in ventrodorsal radiograph. 9$^{th}$ rib at intersection of vein diameter was 4.24mm in dorsoventral radiograph. Caudal pulmonary artery diameter: 9th rib was 0.94 and 1.01 in ventrodorsal and dorsoventral radiographs, respectively. In both right and left lateral radiographs, proximal half of the diaphragmatic crus was not apparently visible. In both ventrodorsal and dorsoventral radiographs, left crus were not visible due to presence of a soft tissue opacity between heart and diaphragm. The ribs were apparently normal in all radiographs. The sternebrae were apparently normal in all radiographs. The vertebral column was apparently normal in all radiographs. The following SOP was proposed for evaluating thoracic radiographs in dogs:

Evaluate lungs for various Patterns, Evaluate cranial mediastinum for Carina, Course of trachea, Visibility of Oesophagus any SOL/Mass, Evaluate cardiac silhouette for Shape, Size and Border Effacement, Evaluate caudal mediastinum for any SOL and Visibility of Oesophagus, Evaluate pleural space for Fluid, Air, Fissure Lines and any Mass, Evaluate vascular structures for Aorta, CVC, Cranial and Caudal Pulmonary Vessels, Evaluate extra thoracic structures for Vertebrae, Sternebrae, Diaphragm, Ribs.

Based on the findings of the study the following conclusions were drawn:

1. Low cost indigenous troughs and wedge fabricated using EPE foam and sandbags fabricated using PVC American Matty filled with coarse gravel were suitable for positioning dogs for thoracic radiography in dogs.
2. Absence of lung pattern and associated values ranging from; Vertebral Heart Score: 8.25-11, % Coverage of heart: 49.1-60.92, Intercostal space: 2.5-3.5 , Sternal contact: 2-3, TD/TI: 0.10-0.26, Tracheal diameter/3rd rib ratio: 1.41-3.24, Aorta/T6: 0.88-1.05, Caudal Vena Cava/T6: 0.57-1.01, Cranial pulmonary vessels /4th rib ratio: 0.44-0.77, Caudal pulmonary vessels /9th rib: 0.56-1.20 were suggestive of normal thorax in brachycephalic dogs.
3. Absence of lung pattern and associated values ranging from; Vertebral Heart Score: 8.25-11, % Coverage of heart: 51.2-65.26, Intercostal space: 2.3-3.5, Sternal contact: 2-3.5, TD/TI: 0.16-0.32, Tracheal diameter/3rd rib ratio: 1.51-3.56, Aorta/T6: 0.75-1.46, Caudal Vena Cava /T6: 0.28- 1.03, Cranial pulmonary vessels /4th rib ratio: 0.31-0.76, Caudal pulmonary vessels /9th rib: 0.64-1.18 were suggestive of normal thorax in mesocephalic dogs.

4. Absence of lung pattern and associated values ranging from; Vertebral Heart Score: 8.75-11, % Coverage of heart: 55.12-64.58, intercostal space: 2.5-3, Sternal contact: 2.5-3, TD/TI: 0.15-0.32, TD/3rd rib ratio: 1.65-3.24, Ao/T6 ratio 0.83-1.10, Caudal Vena Cava/T6 ratio: 0.79-1.07, Cranial pulmonary vessels /4th rib ratio: 0.42-0.76, Caudal pulmonary vessels /9th rib: 0.57-1.11 were suggestive of normal thorax in dolichocephalic dogs.
5. Mesocephalic dogs were most commonly affected with pulmonary and cardiac disorders and Labrador Retriever breed was the most commonly affected breed.
6. Among the pulmonary disorders mixed lung pattern was most common followed by interstitial pattern and the caudal lung lobe was most commonly involved
7. All the dogs with cardiac disorders showed pulmonary involvement out of which mixed lung pattern was most common followed by interstitial pattern and the caudal lung lobe was most commonly affected.
8. Cardiopulmonary disorders were characterised by increased VHS, sternal contact, ICS occupied, percent coverage of cardiac silhouette and enlarged caudal pulmonary vessels
9. An SOP was proposed for evaluating thoracic radiographs in dogs.

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