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Respiratory Diseases and Their Diagnosis in Dogs: A Review

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ABSTRACT

Respiratory affections are common in dogs. Very young and older dogs are at greater risk as compared to the adult ones. Constant exposure of the respiratory tract to the infectious agents, reaching the upper and lower respiratory tract aerogenously or hematogenously, makes the respiratory system vulnerable to injury. Clinical signs mainly seen in upper respiratory tract diseases involves nasal discharge (serous, mucopurulent or hemorrhagic), sneezing, facial deformity, stertor, lethargy, inappetence and rarely, central nervous system signs whereas additional signs present in lower tract diseases range from dyspnoea, costal or abdominal respiration, cough, nasal discharge and congestion, edema, consolidation of lungs and weight loss. Advanced tests involved in diagnosis of respiratory problems in veterinary practicpe are rhinoscopy, bronchoscopy, transthoracic fine needle aspiration cytology (FNAC) transtracheal wash and bronchoalveolar lavage fluid cytology and culture. This review discusses the causes of upper and lower respiratory tract disorders of canines and various diagnostic tests involved in their diagnosis.

Key words: Bronchoalveolar lavage, Chronic bronchitis, Rhinitis, Tracheobronchitis, Transtracheal wash.

Dogs perform a wide array of roles for humans, so most of the people are keeping them for different purposes without much knowledge on the zoonoses and therefore increasing the zoonotic risk (Omudu *et al*. 2010). Respiratory diseases are common clinical problem in dogs especially those housed in pet shops, shelters, breeding and boarding kennels, research facilities or veterinary clinics. Very young and older dogs have higher risk of respiratory infections as compared to adult dogs (Kuehn, 2018).

The respiratory system is one of the four major systems of the body. It consists of the upper airways (pharynx, larynx and trachea) and the lower airways (bronchi, bronchiole and alveoli). The pharynx being a common pathway for respiratory as well as gastrointestinal system explains the comparatively frequent occurrence of the aspiration pneumonia. The luminal diameter of the pharynx is the widest, followed by the larynx and the trachea. The tracheal diameter and the thoracic inlet height (TD:TI) ratio is relatively independent of size of animal and the respiration phase (Kneller, 2007; Regier *et al*. 2020). Mineralization of the laryngeal and tracheal cartilages observed on radiography in clinically normal older dogs and younger large breed dogs, helps in delineating variations within the normality (Alexander, 2018). The invasion of the respi-ratory tract by the harmful pathogens is normally prevented by physical, chemical and immunologic barriers including mucus and mucociliary clearance, various innate antimicrobial factors, alveolar macrophages and the pulmonary immune response. The whole respiratory tree is lined by ciliated epithelial cells except the bronchioles which are lined by non-ciliated granular secretary cells called *club cells*. To fulfill goal of respiratory system, respiration is divided into four major functions which includes pulmonary ventilation; diffusion of oxygen and carbon dioxide between the alveoli and the blood; transport of oxygen and carbon dioxide in the blood and body fluids to and from the body's tissue cells and regulation of ventilation and other factors of respiration (Reece, 2015). The pulmonary alveoli are the principle sites for gas diffusion between the air and the blood and are highly susceptible to injury if defense mechanisms are impaired (Vegad and Katiyar, 2004; Kia'i and Bajaj, 2019). This indicates a need for an emergency treatment for respiratory diseases.

Constant exposure of the respiratory tract to the infectious agents, that can reach the upper and lower respiratory tract aerogenously or hematogenously, makes the respiratory system vulnerable to injury. These pathological changes will impair the normal homeostasis and manifest clinically as respiratory dysfunction (Vieson *et al*. 2012; Lopez and Martinson, 2017). Respiratory diseases were found predominant in earlier age groups, the female dogs and the pug breed dogs. The highest prevalence of the respiratory diseases in dogs was recorded in the cold season and the common clinical symptoms were dyspnoea, nasal discharge, cough and fever (Ayodhya *et al*. 2013).

A variety of syndromes such as rhinitis, sinusitis, sinonasal tumor, tracheal collapse, infectious tracheobronchitis, bacterial and viral pneumonia and lung lobe torsion have

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been observed in dogs. Clinical signs in chronic respiratory diseases range from dyspnoea, costal or abdominal respiration, cough, nasal discharge and congestion, edema, consolidation of lungs, lethargy and weight loss (Ayodhya *et al*. 2013; Bajtos and Kozar, 2021). Normal respiration pattern seen in canines is thoracic or coastal and the abdominal respiration predominates mainly during the painful conditions of the thorax such as pleuritis, *etc* (Reece, 2015; Ettinger *et al*. 2017). Coughing being an important physiological function used to expel harmful substances, such as foreign bodies, mucus or debris, from the airways and preserve the normal health of the respiratory tract (Mazzone, 2005). Cough can be elicited by stimulation of coughing receptors present in the larynx, trachea or bronchi whereas irritation of smaller bronchi, bronchioles and alveoli does not produce coughing. Also, the luminal flow in the lower respiratory tract would be too low to generate enough shear forces to clear airway mucus and debris or to produce cough (Widdicombe, 2003). On the whole, respiratory signs can be vague, varying from mild unproductive cough to severe pneumonia accompanied with systemic changes (Vieson *et al*. 2012). Other non-malignant and non-infectious causes of chronic cough in dogs include airway collapse and inflammatory airway diseases, such as chronic bronchitis and eosinophilic bronchopneumopathy. The evaluation of the clinical signs, along with the physical examination findings, provides an initial step in guiding the diagnostic workup (Ettinger *et al*. 2017; Nelson and Couto, 2019).

Respiratory diseases

Diseases of the nasal cavity and paranasal sinuses characteristically cause nasal discharge (serous, mucopurulent or hemorrhagic), sneezing, facial deformity, stertor, lethargy, inappetence, weight loss and rarely, central nervous system signs. Brachycephalic breeds are more predisposed to upper respiratory tract (URT) disorders due to stenotic nares, enlarged tonsils, elongated soft palate, everted laryngeal saccules, narrowed rima glottides, collapse of the larynx and tracheal hypoplasia (Roedler *et al*. 2013; Vilaplana-Grosso *et al*. 2015; Regier *et al*. 2020). Though, rhinitis is a primary inflammatory disease but chronic nasal disease can arise from fungal infection, neoplasia, remnant foreign body or oral disease (Cooke, 2005, Vieson *et al*. 2012). Common diagnoses in canine nasal diseases are the inflammatory and neoplastic diseases (Pietra *et al*. 2010). Chronic inflammatory rhinitis is often present in dogs with chronic nasal disease and is mainly characterized by the lymphoplasmacytic infiltrates in the nasal mucosa and absence of any obvious etiological process (Windsor and Johnson, 2006; Lobetti, 2014). Approximately 1 percent of the all canine tumours are intranasal with comparatively more incidence in dolichocephalic breeds and dogs from urban areas (Malinowski, 2006; Wilson, 2017; Cohn, 2020). Squamous cell carcinoma, adenocarcinoma and the undifferentiated carcinoma are the common intranasal tumors in dogs (Lana and Withrow, 2001). About 80 percent of sinonasal tumors, occurring in older dogs of more than 8 years, are malignant and carry a poor long-term prognosis (Meler *et al*. 2008; Wilson, 2017; Cohn, 2020).

Infectious rhinitis can be caused by bacterial, viral and mycotic infections. Primary bacterial rhinitis is very rare in dogs. Canine viral rhinitis is mainly caused by canine distemper virus and rarely by adenovirus, reovirus, herpesvirus and influenza virus (Nelson and Couto, 2019). *Aspergillus* and *Penicillium* species are the fungal causes of canine rhinitis, although canine nasal aspergillosis is seen more frequent (Mathews, 2004; Peeters and Clercx, 2007). Dolichocephalic and mesocephalic breeds are found to be more susceptible to the infection, while brachycephalic breeds are very rarely affected (Peeters and Clercx, 2007; Cohn, 2020).

Allergic rhinitis is associated with a hypersensitivity reaction to the airborne antigens present in the nasal cavity and sinuses. Clinical signs include sneezing, nasal congestion and serous or mucopurulent nasal discharge which can be seasonal, continuous or intermittent and acute or chronic (Nelson and Couto, 2019). Allergic rhinitis was reported in adult female German shepherd with history of intermittent epistaxis and sneezing from 3 months, which responded well to removal of suspected antigen, antihistaminic therapy and vitamin C supplementation (Kaur *et al.* 2020). Parasitic rhinitis is rare in dogs and the common nasal parasites include mites (*Pneumonyssoides caninum)* and nematodes (*Capillaria boehmi*) (Ettinger *et al*. 2017; Nelson and Couto, 2019).

Nasal foreign bodies (like grass awns, twigs and penetrating foreign bodies) can be inhaled via external nares or through the posterior choanae following gagging or vomiting episodes. Clinical signs commonly include an acute onset of paroxysmal sneezing, head shaking, pawing at the nose and acute unilateral serous or purulent nasal discharge or the epistaxis (Elie and Sabo, 2006; Ettinger *et al*. 2017; Cohn, 2020).

Coughing can be differentiated on the basis of body weight, as animal will be normal or obese with the respiratory diseases and thin or weight loss with the cardiac diseases (Atkins, 2001). Two most common forms of chronic trachea-bronchial diseases in the dogs are tracheobronchial collapse and chronic bronchitis. Tracheal collapse is defined as the progressive, dorsoventral flattening of the tracheal lumen. The highest incidence of tracheal collapse was found in middle-aged, small-breed dogs but also has been reported in large breed dogs. Clinical signs are proportional to the degree of collapse, ranging from mild airway irritation and paroxysmal "goose-honking" coughing to respiratory distress and dyspnoea (Sura and Durant, 2012; Tappin, 2016; Rozanski, 2020). Association of obesity, pollutants, environmental allergens and kennel cough has been seen with the disease progression (Oskouizadeh *et al*. 2011).

Chronic bronchitis (CB) in dogs is defined as chronic inflammatory pulmonary disease resulting in cough and can also lead to exercise intolerance and respiratory distress (Rozanski, 2020). Expiratory wheezes are considered as the hallmark of chronic bronchitis. Narrowing of airway lumen, due to airway thickening and excessive mucus production and accumulation, result in increased airway resistance in dogs with chronic bronchitis (Kumrow and Rozanski, 2012; Nelson and Couto, 2019; Rozanski, 2020).

Infectious tracheobronchitis (ITB) is an acute contagious respiratory disease in dogs affecting the larynx, trachea, bronchi and occasionally the lower respiratory tract. Multiple agents have been reported as potential aetiological agents (Buonavoglia and Martella, 2007; Carey, 2019; Reagan and Sykes, 2020). The principal pathogens causing kennel cough include *Bordetella bronchiseptica*, canine parainfluenza virus (PI) and canine adenovirus type-2 (CAV-2). Other pathogens causing kennel cough include bacteria (*Pasturella multocida, Streptococcus zooepidemicus* and *Mycoplasma cynos*) and viruses (canine herpes virus, canine influenza virus and canine respiratory corona virus) (Sykes, 2013; Priestnall *et al*. 2014; Cave *et al*. 2015; Carey, 2019; Reagan and Sykes, 2020).

In dogs with acute or chronic respiratory diseases, bacterial pneumonia continues to be one of the most frequent clinical diagnosis. Bacterial pneumonia is characterized by colonization of the airways or pulmonary parenchyma with bacteria, resulting in exudation and lung consolidation. Common causes of bacterial pneumonia include aspiration of gastrointestinal tract contents, decreased ciliary function and infection with opportunistic pathogens secondary to immune-suppression (Mitsushima *et al*. 2002; Ford, 2009; Dear, 2020). The common bacteria involved in respiratory infections in dogs include *Bordetella bronchiseptica, Escherichia coli*, *Klebsiella*, *Streptococcus, Staphylococcus, Pasteurella, Proteus* and *Pseudomonas* species (Adaszek *et al*. 2009; Attili *et al*. 2012; Ayodhya *et al*. 2013; Johnson *et al*. 2013; Taha-Abdelaziz *et al*. 2016; Bajtos and Kozar, 2021). Aspiration pneumonia is a serious life-threatening inflammatory lung process which occurs due to esophageal disease, prolonged anesthesia, seizures, refractory vomiting and laryngeal dysfunction (Tart *et al*. 2010; Proulx *et al*. 2014). Pathologic damage to the lungs leads to ventilation-perfusion mismatch and hypoxemia (Sykes, 2013).

Infectious or community acquired pneumonias commonly occur with viral colonization and infection of the upper respiratory tract (canine respiratory coronavirus, pneumovirus, herpesvirus and parainfluenza virus) in dogs living in overcrowded, stressful environments. Mostly these diseases are acute and self-limiting, but these organisms affect the host's immune defences and predispose it to infection with bacterial respiratory pathogens (Radhakrishnan *et al*. 2007; Brownlie *et al*. 2013; Dear, 2020).

Inhaled foreign bodies (grass awns or plastic material) mostly carry a mixed population of bacterial and fungal organisms (*Streptococcus, Pasteurella, Nocardia, Actinomyces* and anaerobic bacteria) into the lungs and cause focal pneumonias that are mostly initially responsive to antimicrobial therapy but relapse shortly after suspension of the therapy. Mostly foreign material remains at carina or enters the caudodorsal principal bronchi (Schultz and Zwingenberger, 2008; Workman *et al*. 2008; Tenwolde *et al*. 2010; Dear, 2020). Ventilator associated pneumonia (VAP) is a very common reason of hospital acquired pneumonia in humans, however, there are only few veterinary reports in literature (Epstein *et al*. 2010; Dear, 2020).

Bronchiectasis is defined as a permanent and debilitating consequence to the chronic or severe airway injury resulting in progressive and irreversible dilatation of the airways. The highest prevalence of Bronchiectasis is recorded in Cocker spaniels and Miniature poodles and the older dogs of various breeds (Hawkins *et al*. 2003; Chan and Iseman, 2016).

Lung lobe torsion (LLT) is the rotation of a lung lobe along its long axis with twisting of the bronchovascular pedicle at the hilus. Right middle lobe has been seen most affected in dogs due to its long narrow shape and loose attachment to the mediastinum, thoracic wall and adjacent lobes. Torsion can be categorized as idiopathic or secondary to tumours, trauma, pleural effusions or preceding thoracic surgery. Young male dogs of pug breed are seen more predisposed to develop lung lobe torsion whereas factors contributing to the development of LLT in Pugs are unknown (Rooney *et al*. 2001; Murphy and Brisson, 2006).

Angiostrongylus vasorum and *Crenosoma vulpis* are the common canine lungworms in European countries whose larvae can be examined in faecal samples through the baermann funnel technique (Taubert *et al*. 2009) but rarely reported in India.

Interstitial lung diseases (ILDs) are the diffuse parenchymal lung diseases which form a large heterogenous group of the non-infectious, non-neoplastic disorders categorized by diverse patterns of inflammation and fibrosis (Travis *et al*. 2008). ILDs classification in dogs includes three major groups: idiopathic interstitial pneumonias (IIPs), ILDs secondary to known causes and miscellaneous ILDs (Travis *et al*. 2008). Non-specific interstitial pneumonia (NSIP) belonging to IIPs group in humans, is a distinct clinical disorder showing a highly diverse clinical course that may be evident as cellular or fibrotic forms (Travis *et al*. 2013). In dogs and cats, ILDs secondary to known causes, occur as a result of exposure via inhalational routes or secondary to the drugs, radiation and immune-mediated disorders. Pneumoconiosis is defined as an inflammatory and fibrotic ILD instigated by exposure to environmental factors which include mineral dusts and fibers including silica, asbestos, coal dust and other small particulate matter (Jp *et al*. 2017). Repeated exposure to polluted air or inhalation of smoke or coal dust results in deposition of carbon/black dust particles leading to development of anthracosis (a minor form of pneumoconiosis) (Mirsadraee, 2014). Presence of macrophages with engulfed blackish pigment or carbon like particles in the lung tissue/lavage fluid is suggestive of anthracosis (Amoli, 2009; Kaur, 2019). In veterinary medicine, ILDs in miscellaneous category include eosinophilic pneumonia (EP), diffuse alveolar haemorrhage syndromes (DAH), pulmonary alveolar proteinosis (PAP), pulmonary hyalinosis (PH), lipid pneumonia (LP), pulmonary alveolar microlithiasis (PAM) and histiocytic disorders (Reinero 2019).

Eosinophilic bronchopneumopathy (EBP) is characterized by eosinophilic infiltration of lung and bronchial mucosa and was earlier referred as pulmonary infiltrates with eosinophilia (PIE). Breeds that are primarily prone to EBP are Siberian Huskies and Alaskan Malamutes. However, the exact cause of EBP is not known, but a hypersensitivity to the aeroallergens is suspected (Clercx and Peeters, 2007; Kaur, 2019).

Diagnosis

The diagnosis in chronic respiratory diseases is always challenging. In veterinary practice, evaluation of animals for respiratory diseases is limited to chest auscultation, complete blood count, serum biochemistry, thoracic radiography, arterial blood gas analysis, fecal examination, nasal swabs culture, bronchoscopy, transtracheal wash and BAL fluid cytology and culture.

Haematology and biochemistry shows unremarkable or non-specific changes in dogs suffering with respiratory diseases. The haematological and biochemistry profiles mainly help to uncover any systemic or metabolic diseases that might be affecting the respiratory system (acid-base imbalance, anemia). But in some cases, hematological and biochemical analysis plays significant role in providing differential diagnosis. The major haematological finding reported in the respiratory diseases was eosinophilia and the leucocytosis (Piva *et al*. 2010). Leucocytosis with left shift is generally present in animals having moderate to severe airway inflammation, infection or neoplasia, however, leucopenia is commonly seen in animals with acute bacterial bronchopneumonia or sepsis. Eosinophilia is usually present in animals with parasitic airway disease, asthma, bronchitis or pulmonary infiltration whereas basophilia is usually associated with the heartworm infection. Polycythemia has been usually noticed due to chronic hypoxia (Corcoran, 2000; Dear, 2020).

Hypoalbuminaemia mainly results from increased pulmonary and systemic capillary permeability (Ettinger *et al*. 2017). In veterinary pathology, the albumin is the only negative acute phase protein that is found useful and its concentration decreases during the inflammatory response (Eckersall and Bell, 2010). Positive acute phase proteins (APPs) (*e.g*. C-reactive protein [CRP], fibrinogen, haptoglobin, serum amyloid A, alpha-1-acid glycoprotein and ceruloplasmin) level increases during the inflammatory response of body whereas the negative APPs (*e.g*. albumin, transferrin) level decreases (Viitanen *et al*. 2014). Plasma fibrinogen was considered as a potent biomarker of the respiratory diseases due to the significant association between plasma fibrinogen and pulmonary function (Shibata *et al*. 2013). In dogs, C-reactive proteins level increases in different infectious disease processes as well as in neoplastic and immune-mediated diseases (Viitanen *et al*. 2014; Canonne *et al*. 2021).

An arterial blood gas measurement allows the most definitive assessment of overall pulmonary function as it directly assesses the gas exchange. Most common site used for arterial blood gas measurement in dogs is the femoral artery and the other alternative sites include the dorsal metatarsal, carotid, brachial and the auricular arteries (King and Hendricks, 1995; Ettinger *et al*. 2017). PaO_2 level in a normal dog at sea level should be greater than 80 mmHg and the conditions leading to decrease in PaO_2 include hypoventilation, decrease in the partial pressure of atmospheric O_2 (high altitude) or with the venous admixture. Most common cause of hypoxemia is venous admixture occurring with venous shunting (lung atelectasis, pneumonia) or physiologic dead space (PTE) (Haskins, 2004) whereas other causes include low inspired oxygen fraction, hypoventilation, thickened respiratory barrier and shunting of pulmonary blood (Rozanski and Chan, 2005). Pulse oximetry measurements help to regulate the need of oxygen administration. In dogs and cats, the normal hemoglobin saturation is 95 to 100 percent. Tumor infiltration in the lungs can lead to hindrance in the oxygenation, causing increased respiratory effort and exercise intolerance (Nelson and Couto, 2019). The degree of ventilation-perfusion mismatch present in the bacterial bronchopneumonia cases was recorded through blood gas analysis (Corcoran, 2000; Dear, 2020). Hypoxemia was recorded in more than 75 percent of dogs with aspiration pneumonia (Kogan *et al*. 2008; Tart *et al*. 2010) with PaO_2 levels between 69 to 77 mmHg (Peeters *et al*. 2000). Mild hypoxemia ($PaO2<80$ mmHg) was documented in the dogs with chronic bronchitis (Kumrow and Rozanski, 2012; Rozanski, 2020).

Fecal examination should be done in cases suspected for lung worm (*Oslerus osleri*, *Crenosoma vulpis and Aelurostrongylus abstrusus)* infestation (Ettinger *et al*. 2017; Cork and Lejeune, 2019). Faecal flotation is the most commonly used diagnostic technique for detection of respiratory parasitic infestations in veterinary practice. Lungworm larvae are usually recognized through the Baermann technique whereas *O. osleri* larvae are identified by the zinc sulfate flotation method (Taubert *et al*. 2009; Cork and Lejeune, 2019; Nelson and Couto, 2019).

Nasal radiographs are quite beneficial for identifying the severity of the disease, pinpointing the sites for biopsy within the nasal cavity and prioritizing the differential diagnosis. Nasal radiographs are assessed for the loss of turbinates, increased fluid density, lysis of the facial bones, presence of the radiodense foreign bodies and the radiolucency at the tips of the tooth roots. Rhinoscopic visualization or examination of nasal flushings also contribute in making the definitive diagnosis (Elie and Sabo, 2006; Ashbaugh *et al*. 2011; Nelson and Couto, 2019; Cohn, 2020; Bajtos and Kozar, 2021).

Thoracic radiography is a good diagnostic tool for lower airway diseases in dogs (Sharp and Rozanski, 2013). Thoracic radiographs provides important information related to cardiac size, gross chamber abnormalities, alteration in the size and appearance of great vessels, abnormalities of the chest wall, pleural space and the lung itself particularly the bronchi, interstitial spaces and the alveolar tissues (Fox, 2007). Radiographs help in differentiating primary cardiac disease from respiratory problems in coughing dogs (Spier, 2011). Types of lung patterns include alveolar, bronchial, vascular and interstitial (nodular and diffuse) (Spasov *et al*. 2018). Though, radiography is a good diagnostic tool but has less utility for soft tissue pathology and requires expertise. Most common cause of occurrence of an alveolar lung pattern includes bacterial and aspiration pneumonia and pulmonary contusion, pulmonary thromboembolism, neoplasia, fungal pneumonia and systemic coagulopathy (Levy *et al*. 2019; Nelson and Couto, 2019; Dear, 2020). Bronchial pattern (doughnuts or tram lines or train tracks) occurs in case of canine chronic bronchitis, allergic bronchitis, canine infectious tracheobronchitis and rarely in bacterial and parasitic infection (Spasov *et al*. 2018; Nelson and Couto, 2019; Rozanski, 2020). Common causes of reticular interstitial pattern include infection (viral, bacterial, mycotic and toxoplasmosis), idiopathic interstitial pneumonia and neoplasia whereas common causes of nodular pattern include mycotic infections, tumors and abscesses (Nelson and Couto, 2019).

Transtracheal wash and BAL fluid cytology are the modern techniques used for diagnosis of lower respiratory tract affections, now a days along with bronchoscopy. The results of nasal swabs and sputum culture are not much reliable as they include nasal and oropharyngeal normal microflora contamination. Bronchoscopy is an important aid in evaluation and management of canine respiratory diseases. It is used to diagnose respiratory anomalies which include the assessment of the structural diseases (such as tracheobronchial collapse, intraluminal mass and stricture), traumatic injuries and inflammatory conditions (such as pneumonia, chronic bronchitis) (Tenwolde *et al*. 2010). Bronchoalveolar lavage is an acceptable airway-sampling technique available to be used with bronchoscopy. In veterinary medicine, therapeutic use of bronchoscopy is primarily constrained to foreign body removal (Elie and Sabo, 2006; Ettinger *et al*. 2017; Dear, 2020; Bajtos and Kozar, 2021). Flexible bronchoscopy is a minimally invasive and therapeutic procedure for the successful removal of bronchial foreign bodies in dogs and cats. Bronchoscopy was found comparatively less successful for removing airway foreign material in smaller animals due to their smaller airway diameter and also in animals with long standing respiratory problems (Elie and Sabo, 2006; Tenwolde *et al*. 2010).

Transthoracic fine needle aspiration cytology (FNAC) has also proved to be a simple, economical, precise and reasonably safer procedure providing a direct approach, with a high degree of correctness, towards all types of non-resolving pneumonias (Sirpal, 1997; Mohideen Haji, 2016).

The trachea and main stem bronchi constitute a central site of exposure to all inhaled materials and central airway sampling from these sites could enhance the confirmation of airway inflammation (Zhu *et al*. 2015; Graham *et al*. 2021). Tracheal wash aspiration is the minimally invasive procedure which predominantly samples the larger airways along with a certain amount of sample from the lower airways and the alveoli, for cytologic and culture analysis. Contributing factors for better sample extraction includes mucociliary clearance and cough reflex (Cohn and Reinero, 2007; Finke, 2013; Graham *et al*. 2021). Cytological interpretation should include estimated cellularity, differential cell counts and morphologic description of the cells encountered (Creevy, 2009). Tracheal aspirate of clinically normal animals comprised of alveolar macrophages as predominant cells, respiratory epithelial cells, lymphocytes (5-14 per cent), neutrophils (5-8 per cent), eosinophils (<5 per cent), rarely mast cells (<2%) and mucus (Dunn, 2010; Graham *et al*. 2021). On transtracheal wash (TTW) cytology, neutrophilic or the mixed inflammation is the most common abnormality found in dogs with spontaneous respiratory disease (Finke, 2013). Neutrophilic inflammation is observed in majority of dogs with bacterial infection and in few dogs, intracellular bacteria and degenerative changes in neutrophils can also be seen (Dunn, 2010). In dogs with chronic bronchitis, transtracheal wash (TTW) cytology, revealed increased cellularity with moderate increase in neutrophils, presence of mucus and sloughed hyperplastic epithelial cells (Rozanski, 2020; Kaur *et al.* 2021). Severe eosinophilia (50-60%) was observed in tracheal wash cytology of dogs suffering with eosinophilic bronchpneumopathy (Clercx *et al*. 2000; Kaur, 2019).

Bronchoalveolar lavage is an inexpensive, minimally invasive examination that allows the cytological and microbiological examination of lower airways (Peeters *et al*. 2000; English *et al*. 2009). The predominant cell type in BAL fluid in normal dog is the alveolar macrophage and the fluid is highly cellular and allows high-quality cytologic specimen preparation (Peeters *et al*. 2000; Zhu *et al*. 2015). Infectious organisms, including bacteria and fungi, are more commonly found in cytology of BAL samples than in tracheal wash specimens. Normal BAL fluid cytology consists of alveolar macrophages (70-80 per cent), lymphocytes (7-12 per cent), neutrophils (5-10 per cent), eosinophils (6-11 per cent), mast calls (1-2 per cent) and epithelial cells (1-2 per cent) (Finke, 2013). On the basis of differential cytology, BAL fluid cytology can be categorized as normal, lymphocytic (>50% lymphocytes), neutrophilic (>50% neutrophils), eosinophilic (>50% eosinophils) or as mixed inflammation (Peeters *et al*. 2000; Zhu *et al*. 2015; Dear, 2020).

The main aim of the therapy is to reduce the volume and viscosity of the secretions and to assist their elimination which can be done by control of infection and inflammation, alteration of the secretions and also if possible improve the postural drainage and mechanically remove the material (Aiello and Moses, 2016; Ettinger *et al*. 2017). Therapeutic protocols include alteration of the inspired air (nebulization), oxygen therapy and administration of expectorants (guaifenesin, N-acetylcysteine, bromhexine), bronchodilators (theophylline, aminophylline, terbutaline and albuterol), antimicrobials (enrofloxacin, amoxicillin/clavulanic acid, ampicillin-sulbactam, azithromycin, amikacin, cefazolin, cefadroxil, cephalexin, clindamycin, gentamicin, trimethoprim-sulfamethoxazole and doxycycline), antitussives (codeine, hydrocodone, dextromethorphan, butorphanol), diuretics (furosemide) and glucocorticoids (prednisone, fluticasone). The diversity of microbial organisms that colonizes/invades the respiratory tract during disease process poses challenges in therapeutic management of respiratory diseases. Ideal selection of drug is based on predicted microbial susceptibility, distribution of the drug in the respiratory tract and safety of the patient (Olsen, 2000; Reagan and Sykes, 2020). The treatment must aim to solve the underlying problem if possible and controlling the infectious component is an important part of the therapy. In emergency situations the selection of antimicrobial agents for the first line treatment must be based on empirical data on bacterial prevalence and then based on the culture sensitivity results. Hydration of the airways is also important to facilitate the mucociliary clearance (Kuehn, 2018; Nelson and Couto, 2019; Dear, 2020) and the use of antihistamines is highly recommended to lessen the bronchoconstriction caused by release of histamine (Aiello and Moses, 2016). Minimizing the exposure of dog to the airway irritants and the correctness of obesity is recommended for management of respiratory problems (Ettinger *et al*. 2017; Rozanski, 2020).

CONCLUSION

This review discusses the aetiologies of different upper and lower respiratory tract disorders along with their presenting signs. The assessment of the clinical indicators and the results of the physical examination serve as a first step in directing the diagnostic workup. Historical and the current advanced diagnostic tests for diagnosis of canine respiratory affections has been summed up in this article.

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