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PNEUMONIA IN DROMEDARY CAMELS (*Camelus dromedarius*): A REVIEW OF CLINICO-PATHOLOGICAL AND ETIOLOGICAL CHARACTERISTICS

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ABSTRACT

The aim of this review article was to summarise relevant clinical, etio-epidemiological and pathological data available in the current literature regarding pneumonia in dromedary camels. Scientific resources such as Pubmed, Google scholar and Researchgate were searched for all published articles regarding bacterial and viral pneumonia in dromedary camels. The most common bacterial species isolated from lesions of pneumonic camels were *Staphylococcus aureus, Corynebacterium pyogenes, Streptococcus pyogenes, Escherichia coli, Klebsiella pneumonia, Pseudomonas aeruginosa, Arcanobacterium pyogenes, Mannheimia haemolytica* and *Pasteurella multocida*. The most common viral causes of pneumonia were parainfluenza 3 (PI-3), adenovirus, respiratory syncytial virus (RSV), bovine herpes virus-1 or infectious bovine rhinotracheitis (IBR) and pestivirus or bovine viral diarrhoea virus (BVD). Clinically, pneumonic camels were reported to suffer from fever, depression, nasal and ocular discharges and coughing. Affected animals were also reported to have anaemia, leukocytosis and increased levels of serum total protein, globulin, urea, creatinine, potassium and activities of hepatic enzymes. Pathological lesions in acute pneumonia were characterised by fibrinous bronchopneumonia, oedema and congestion while lesions in chronic pneumonia were characterised by fibrosis, proliferative bronchopneumonia, pleuropneumonia and abscessation. Ciprofloxacin, cephaloridine, penicillin, ampicillin, gentamicin and tetracycline were reported as the most effective antibacterial agents against most bacterial isolates.

Key words: Bacteria, dromedary camels, gross pathology, pneumonia

Lower respiratory tract infections or pneumonia is considered as remerging health problem in dromedary camels (Buchnev *et al*, 1987; Wernery and Kaaden, 2002; Zubair *et al*, 2004; Kane *et al*, 2005; Abubakar *et al,* 2010). Although, camels are well-adapted to dry and harsh environment and resistant to many disease causing organisms, respiratory disease can still cause considerable economical losses through loss of production, cost of treatment, condemnation of carcasses and even death of affected animals (Zubair *et al*, 2004; Kane *et al*, 2005; Dia, 2006; Bekele, 2008; Abubakar *et al,* 2010). In recent literature, there are no review articles that summarise current research and knowledge about bacterial and viral pneumonia in dromedary camels. In domestic animals including camels, pneumonia is usually caused by viruses, bacteria, fungi or a parasite (Ahmed *et al*, 2015).

Risk factors

Although, most of the microbiological agents that may cause pneumonia can be found in the upper respiratory tract of normal camels, in certain circumstances, these agents can cause serious disease (Ahmed *et al*, 2015). Many of the risk factors that are known to predispose animals to pneumonia are associated with poor management conditions such as environmental stress, crowdedness, poor sanitary conditions, poor nutrition and nutritional management, extreme climatic swings and general herd health (Abubakar *et al,* 2010; Ahmed and Musa 2015). In these reviewed articles, the most commonly reported risk factors for pneumonia caused by bacteria were age and season (Al-Tarazi, 2001; Ahmed and Musa, 2015; Nahed *et al*, 2016) (Table 1). The highest incidence of pneumonia was reported in autumn in adult camels (Ahmed and Musa 2015; Nahed *et al*, 2016). Al-Tarazi (2001) on the other hand, reported that proliferative bronchopneumonia and pleuropneumonia were more frequent in older camels (about 10 years of age) while interstitial pneumonia and lung abscesses were more frequent in younger camels (6 months to 4 years of age).

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Clinico-pathological findings

Clinically, affected animals may show non-specific signs of illness such as fever, depression and anorexia (Al-Tarazi, 2001; Ahmed *et al*, 2015; Gafer *et al*, 2015; Nahed *et al*, 2016) (Table 1). Specific respiratory signs are usually nasal and ocular discharge, rapid and shallow breathing and coughing (Al-Tarazi, 2001; Ahmad *et al*, 2015; Ahmed and Musa 2015; Gafer *et al*, 2015; Nahed *et al*, 2016). Depression, ruminal atony, ataxia and decreased milk production were also detected in some cases (Nahed *et al*, 2016).

Studies also showed that affected camels may have certain abnormal findings in the haematology and serum biochemistry analyses (Abubakar *et al*, 2011; Nahed *et al*, 2016). It is reported that pneumonic camels may have anaemia, leukocytosis and increased levels of serum total protein, globulin, urea, creatinine, potassium and activities of hepatic enzymes (Abubakar *et al*, 2011; Nahed *et al*, 2016).

Bacterial pathogens

Overall, there were 9 and 6 scientific studies published in refereed journals in the last 15 years reporting different bacterial and viral species respectively, which were isolated from pneumonic respiratory samples or pneumonic lesions from dromedary camels. The most common pathogenic bacteria were *Staphylococcus aureus, Corynebacterium pyogenes, Streptococcus pyogenes, Escherichia coli, Klebsiella pneumonia, Pseudomonas aeruginosa, Arcanobacterium pyogenes, Mannheimia haemolytica* and *Pasteurella multocida* (Al-Doughaym *et al*, 1999; Al-Tarazi, 2001; Abubakar *et al*, 2010; Abo-Elnaga and Osman, 2012; Wareth *et al*, 2014; Ahmed *et al*, 2015; Ahmed and Musa, 2015; Nahed *et al*, 2016) (Table 2). The most common samples that yielded bacterial isolates were nasal, nasopharyngeal, tracheal swabs and lung tissues.

Bacterial isolation in most of the reviewed studies was achieved using routine culture methods with different media such as nutrient agar, blood agar, brain heart infusion, mannitol salt agar, MacConkey agar and brilliant green agar followed by identification using morphological and biochemical characteristics of the isolated strains such as colony morphology, Gram staining, spore forming ability and acid-fast staining (Al-Doughaym *et al*, 1999; Al-Tarazi, 2001; Abubakar *et al*, 2010; Abo-Elnaga and Osman, 2012; Wareth *et al*, 2014; Ahmed *et al*, 2015; Ahmed and Musa, 2015; Nahed *et al*, 2016). Further testing was performed to determine the species of isolated bacteria such as catalase, oxidase, oxidation fermentation test (Al-Doughaym *et al*, 1999; Al-Tarazi, 2001; Abubakar *et al*, 2010; Abo-Elnaga and Osman, 2012; Wareth *et al*, 2014; Ahmed *et al*, 2015; Ahmed and Musa, 2015; Nahed *et al*, 2016). For Gram positive bacteria, species identification was performed in most of the studies using indole production, motility test, coagulase test, carbohydrates breakdown, Voges-Proskauer reaction, arginine hydrolysis, nitrate

Table 1. Risk factors and clinical signs of bacterial and viral caused pneumonia in dromedary camels.

Risk Factors	Clinical Signs	References
Bacterial Pneumonia		
- Highest incidence in autumn - Adult camels are more susceptible - Proliferative bronchopneumonia and pleuropneumonia are more frequent in older camels (about 10 years of age) - Interstitial pneumonia and lung abscesses are more frequent in young camels (6 months to 4 years of age)	- Moist painful harsh cough - Rhinitis - Congested mucous membranes - Serous or mucoid nasal discharges - Increased respiratory and pulse rates - Elevated rectal temperature - Depression - Ruminal atony - Ataxia - Decreased milk production	Al-Tarazi, 2001; Ahmed *et al,* 2015; Ahmad and Musa 2015; Nahed *et al,* 2016
Viral pneumonia		
- Young calves in BVD infections	- Fever (41.5^{o}C) - Anorexia - Listlessness - Dyspnoea - Hyperemia of the nasal mucosa - Nasal and ocular serous discharge	Gafer *et al*, 2015

Table 2. A review of the most common bacteria causing pneumonia in dromedary camels and *in vitro* most effective antibacterial agents.

Bacterial isolates	Samples	Most Effective Antibacterial	References
- *Staphylococcus aureus*	- Lung tissues - Tracheal swabs	- Ciprofloxacin - Cefazolin	Ahmed *et al*, 2015
- *Staphylococcus aureus* - *Corynebacterium pyogenes* - *Streptococcus pyogenes*	- Nasal swabs - Tracheal swabs - Lung tissues	- Penicillin - Ampicillin - Gentamicin	Al-Doughaym *et al*, 1999
- *Staphylococcus aureus* - *Escherichia coli* - *Klebsiella pneumonae*	- Lung tissues	NR	Wareth *et al*, 2014
- *Escherichia coli* - *Klebsiella pneumonae* - *Pseudomonas aeruginosa*	- Lung tissues	NR	Al-Tarazi, 2001
- *Klebsiella pneumonae* - *Staphylococcus aureus*	- Nasopharyngeal swabs - Lung tissues	NR	Nahed *et al*, 2016
- *Staphylococcus aureus* *Streptococcus pyogenes*	- Tracheal swabs - Lung tissues	NR	Ahmed and Musa, 2015
- *Staphylococcus aureus* - *Klebsiella pneumonae*	- Lung tissues	NR	Abo-Elnaga and Osman, 2012
- *Staphylococcus aureus* - *Arcanobacterium pyogenes* - *Mannheimia haemolytica* - *Pasteurella multocida*	- Lung tissue	NR	Abubakar *et al*, 2010

NR: information not reported

Table 3. A review of the most common viruses causing pneumonia in dromedary camels.

Viral agent	Samples	References
- Parainfluenza 3 (PI-3) - Adenovirus - Respiratory syncytial virus (RSV) - Pestivirus (BVD)	- Lung tissues	Muna *et al*, 2015
- Infectious bovine rhinotracheitis virus (bovine herpes virus-1) - Pestivirus (BVD)	- Nasal swabs - Lung tissues	Gafer *et al*, 2015
- Parainfluenza virus 3 (PI-3)	- Lung tissues	Intisar *et al*, 2010a
- Respiratory syncytial virus (RSV)	- Lung tissues	Intisar *et al*, 2010b
- Pestivirus (BVD)	- Lung tissues	Intisar *et al*, 2010c
- Infectious bovine rhinotracheitis virus (bovine herpes virus-1)	- Lung tissues	Intisar *et al*, 2009

reduction, growth in 6.5% NaCl broth, growth at 45°C, requirement of CO_2 for growth, sensitivity to bacitracin (0.1 unit), urease activity, gelatin liquefaction and aesculin hydrolysis (Al-Doughaym *et al*, 1999; Tarazi, 2001; Abubakar *et al*, 2010; Abo-Elnaga and Osman, 2012; Wareth *et al*, 2014; Al-Ahmed *et al*, 2015; Ahmed and Musa, 2015; Nahed *et al*, 2016). For identification of Gram negative bacteria, methods were used such as oxidase production, citrate utilisation, urease activity, growth in KCN medium, gelatin liquefaction and hydrogen sulphide production from the TSI medium, fermentation of sugars, growth at 42°C, growth on MacConkey agar, nitrate reduction, indole production, aesculin and arginine hydrolysis, Voges-Proskauer reaction and the methyl red test (Al-Doughaym *et al*, 1999; Al-Tarazi, 2001; Abubakar *et al*, 2010; Abo-Elnaga and Osman, 2012; Wareth *et al*, 2014; Ahmed *et al*, 2015; Ahmed and Musa, 2015; Nahed *et al*, 2016).

Bacterial resistance against commonly used antibiotics is being reported at an alarmingly high rate in recent literature. Antimicrobial resistance is not only important because of the high risk of treatment failures in affected animals but also because it puts human health at risk. During the last 16 years under review, there are only 2 articles that investigated antibacterial sensitivity of isolated bacterial strains (Al-Doughaym *et al*, 1999; Ahmad *et al*, 2015). The

laboratory methods of *in vitro* sensitivity tests that were used in these 2 studies were the disk diffusion methods (7 antibiotics), the broth diffusion test (4 antibiotics) and the Viteck 2 compact system (23 antibiotics) (Al-Doughaym *et al,* 1999; Ahmed *et al*, 2015). In the first study, results of the sensitivity tests showed that 87% of isolated *Staphylococcus aureus* were sensitive to ampicillin, while 83% of the isolates were sensitive to gentamicin ciprofloxacin and cephaloridine (Al-Doughaym *et al*, 1999). Ninty four per cent, 72% and 52% of *Corynebacterium pyogenes* isolates were sensitive to ampicillin, gentamicin and tetracycline, respectively (Al-Doughaym *et al*, 1999). *Klebsiella pneumonae* and *E. coli* had a similar sensitivity patterns with gentamicin and cephaloridine being the most effective (Al-Doughaym *et al*, 1999). In the second study, Gram positive bacteria were mostly sensitive to gentamicin and ciprofloxacin while most Gram negative strains such as *E. coli* and *Pseudomonas aeruginosa* were found resistant to most of the tested antibiotics (Ahmed *et al*, 2015).

Viral pathogens

The most common viruses that were found associated with pneumonia in the dromedary camel were parainfluenza 3, adenovirus, respiratory syncytial virus (RSV), infectious bovine rhinotracheitis (IBR; bovine herpes virus-1) and pestivirus or bovine viral diarrhoea virus (BVD) (Intisar *et al*, 2009; Intisar *et al*, 2010a,b,c; Gafer *et al*, 2015; Muna *et al*, 2015) (Table 3). The most common samples that yielded viral agents were nasal swabs and lung tissues.

In one camel with pneumonic lesions in Sudan, a mixed infection caused by parainfluenza 3, adenovirus, respiratory syncytial virus (RSV) was confirmed (Muna *et al*, 2015). Bovine viral diarrhoea virus (BVDV) and bovine herpes virus-1 (BHV-1) were isolated 11% and 14%, respectively from 33 clinically ill animals in Egypt confimed by immunofluorescence (IF) and immunoperoxidase (Gafer *et al*, 2015). In Sudan, out of 186 lung tissues samples examined for BVDV antigen, 13 were found positive (Intisar *et al*, 2010c). BHV-1 antigen was also detected 3 out of 186 lung tissues samples (Intisar *et al*, 2009). Parainfluenza virus 3 (PI-3) was detected in 6 out of the 281 lung samples in Sudan (Intisar *et al*, 2010a). Respiratory syncytial virus (RSV) was detected in 4 out of 280 lung tissue samples in Sudan (Intisar *et al*, 2010b).

Techniques that were used to detect pestivirus or bovine viral diarrhoea virus (BVD) and bovine herpes virus 1 were multiplex PCR assay, immunoflurescence and immunoperoxidase (Gafer *et al*, 2015). Bovine viral diarrhoea (BVD) virus was detected in serum using ELISA and positive samples were further tested using direct fluorescent antibody technique (FAT) or reverse transcriptase polymerase chain reaction (RT-PCR) (Intisar *et al*, 2010c).

For the detection of PI-3, direct immuno-fluorescent test (FAT) can be used to confirm the positive reactions for PI-3 by ELISA (Intisar *et al*, 2009). The polymerase chain reaction (RT-PCR) is also used for the detection of the PI-3 genome in lungs of camels (Intisar *et al*, 2010a). Isolation of PI-3 can also be attempted using MDBK cell culture (Intisar *et al*, 2010a). The cytopathic effect of the virus such as cell rounding, multinucleated cells, sloughing and elongation of cells and some syncytia can be observed from the 3rd to 7th day post-inoculation (Intisar *et al*, 2010a).

For the detection of respiratory syncytial virus (RSV), sandwich ELISA can be used to detect RSV antigen in lung tissues. Fluorescence antibody test (FAT) is then used to confirm the ELISA positives samples. Polymerase chain reaction (RT/PCR) can also be used for the detection of RSV genome in camel lungs (Intisar *et al*, 2010b).

Bovine herpes virus-1 (BHV-1) in camels can be detected in lung tissues of camels using sandwich ELISA technique. Direct fluorescent antibody test (FAT) is then used to confirm the BHV-1 ELISA positive samples. PCR can also be used to detect BHV-1 genome. BHV-1 can be isolated from lung tissues in MDBK cell culture (Intisar *et al*, 2009).

Pathological manifestations

Gross and histopathological lung lesions associated with bacterial pneumonia in camels have been well studied unlike that caused by viruses (Al-Tarazi, 2001; Bekele, 2008; Abubakar *et al*, 2011; Abo-Elnaga and Osman, 2012; Wareth *et al*, 2014; Ahmed *et al*, 2015; Nahed *et al*, 2016) (Table 4). In bacterial caused pneumonia, pulmonary lesions in acute pneumonia were characterised by fibrinous bronchopneumonia, oedema and congestion while lesions in chronic pneumonia were characterised by fibrosis, proliferative bronchopneumonia, pleuropneumonia and abscessation (Table 4). Fibrinous bronchopneumonia usually appears as a gray and red hepatisation with congestion of the interstitial capillaries. Suppurative bronchopneumonia is characterised by the presence of suppurative exudates in the lumen of bronchioles and

Table 4. The most common pulmonary pathological lesions associated with bacterial and viral caused pneumonia in dromedary camels.

Lesions	Causative Agent	
	Bacterial	Viral
Fibrinous pneumonia	Abubakar *et al,* 2011; Wareth *et al,* 2014; Ahmed *et al,* 2015	NR
Pulmonary abscesses	Abubakar *et al,* 2011; Al-Tarazi, 2001; Bekele, 2008; Wareth *et al,* 2014; Ahmed *et al,* 2015	NR
Suppurative bronchopneumonia	Ahmed *et al,* 2015	NR
Pleuropneumonia	Al-Tarazi, 2001; Ahmed *et al,* 2015	NR
Pulmonary emphysema	Abubakar *et al,* 2011; Wareth *et al,* 2014	NR
Interstitial pneumonia	Al-Tarazi, 2001; Abo-Elnaga and Osman, 2012; Wareth *et al,* 2014; Nahed *et al,* 2016	Ahmed *et al,* 2015; Gafer *et al,* 2015
Proliferative bronchopneumonia	Bekele, 2008; Abo-Elnaga and Osman, 2012; Wareth *et al,* 2014; Nahed *et al,* 2016	Ahmed *et al,* 2015

NR: information not reported

peribronchiolar tissues with partial replacement of the bronchiolar wall. Purulent exudates may accumulate focally to form variable sized abscesses. Adjacent areas may show variable degrees of atelectasis and emphysema in some cases. Acute interstitial pneumonia is characterised by the presence of oedema and leucocytic cellular infiltration with congestion in peri-alveolar capillaries resulting in thickening of the interalveolar septa. Chronic interstitial pneumonia is marked by thickening and fibrosis of the inter-alveolar tissues due to proliferation of fibrous tissues and lymphocytic infiltration.

Viral caused pneumonia is characterised histologically by acute interstitial pneumonia (Table 4). There is thickening of the interstitial tissues, capillary walls and alveolar septum due to mononuclear cell, red blood cells and fibroblast cell infiltration. Areas of atelectatic alveoli are present in the adjacent tissues (Ahmed *et al*, 2015; Gafer *et al*, 2015). Chronic interstitial pneumonia is marked by proliferation, hyperplasia, bronchiolitis and bronchopneumonia with accumulation of mononuclear and macrophages cell inside bronchioles (Ahmed *et al*, 2015; Gafer *et al*, 2015).

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