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Considerable economic loss to the camel industry is caused by infection with pathogenic *Escherichia coli* in young dromedary camels. Rombol (1942) described enzootic *E. coli* (*Bacterium coli*) infection and severe diarrhea in newborn dromedaries whereas Chauhan et al. (1986) in India reported colibacillosis in two newborn dromedaries presenting with yellowish diarrhea, fever, discomfort, and anorexia, and isolated *E. coli* serotype 083 from fecal samples of the affected calves. In East Africa, Schwartz and Dioli (1992) reported colibacillosis with a morbidity rate of 30% among neonatal dromedary calves suffering from dysentery, abdominal pain, anorexia, and dehydration; they associated the disease with poor sanitary conditions, contaminated water sources, inadequate intake of colostrum, and inclement weather. The authors also stated that in the absence of immediate veterinary intervention, all of the affected animals could die within few days. Alamedjir et al. (1992) also reported diarrheic episodes associated with colibacillosis in young camels in Niger. Mohamed et al. (1998) isolated pathogenic *E. coli* from 17 (40.5%) out of 42 fecal samples of 1–3 months old dromedary calves in the Sudan. Using colony blot DNA hybridization for pathotyping of eight randomly selected isolates, they identified five isolates as EIEC, two isolates as EPEC, and one isolate as VT2 pathotypes. In studies of bacterial causes of diarrhea in camel calves in the Butana region of the Eastern Sudan, Salih and co-workers (Salih et al., 1997, 1998a, 1998b) isolated enteropathogenic *E. coli* from 69 (66%) out of 106 diarrheic camel calves. They examined some of these isolates for virulence antigens and reported two adhesion factors, K88 and F41, in addition to two heat-stable enterotoxins (StaP and STb), one heat-labile (LT), and one Shiga-like toxin 1 (SLT-1). In Mauritania, *E. coli* was detected as a major pathogen accounting for more than 60% of diarrhea cases in camel calves aged between 1 and 3 months (Dia et al., 2000).

Ibrahim et al. (1998) reported edema disease (bowl edema) and enterotoxemia, with isolation of a hemolytic *E. coli* serotype 0139, from the intestines and abdominal fluid of female dromedary camels in Bahrain. The affected animals exhibited severe swelling and distension of the abdomen, with accumulation of 100–150 L of

fluid in the abdominal cavity; as well as edema of the face, ears, and throat and in some cases neurological manifestations. The disease was slowly progressive and highly fatal, with an overall incidence exceeding 50% and a mortality of about 90%.

Bornstein et al. (2000) described a septicemic form of *E. coli* infection (coli septicemia) in four out of ten camel calves in a breeding herd in northern Kenya. The affected calves showed anorexia, diarrhea, and general weakness before dying. Typical lesions of septicemia were noted during necropsy of the dead animals, and *E. coli* was isolated in pure cultures from lymph nodes, tonsils, spleen, lungs, bone marrow, heart blood, and pericardial fluid. Furthermore, pure growth of *E. coli* was obtained in anaerobic culture of the ileocecal lymph node while cultures of the kidney and intestinal contents produced a clearly predominant growth of *E. coli* intermixed with few clostridial colonies.

Wernery and Kaaden (2002) stated that *E. coli* infection characterized by watery diarrhea, dehydration, and sunken eye appearance occurred regularly in dromedary calves, particularly those aged 2–4 weeks, resulting in severe losses in some camel breeding herds in the UAE. According to these authors, the infection in camel calves might have been associated with initial consumption of solid food and sand, and isolation of hemolytic *E. coli* from the gastrointestinal tract and other parts of the body.

Abubaker et al. (2006) isolated *E. coli* from 52 (27.3%) out of 190 diarrheic calf camels in Saudi Arabia while Agab (2006) stated that camel calf diarrhea was one of the commonest diseases in suckling dromedary calves in that country, leading to a high mortality rate, particularly in intensively reared herds. Similar conclusions were made by Al-Ruwaili et al. (2012) who reported high incidence of diarrhea and deaths in newborn camel calves in northern Saudi Arabia, which was ascribed to different pathogenic bacteria and viruses, including *Salmonella* spp., *Enterococcus* spp., group A rotaviruses, *Cryptosporidia*, and others. In addition, they isolated *E. coli* from 99 (58.2%) out of 170 samples of diarrheic calf camels. The affected animals harbored enterotoxigenic *E. coli* (ET *E. coli*), indicating a strong correlation between camel calf diarrhea and the detection of enterotoxigenic *E. coli*. Al-Harbi (2013) investigated scours in 1200 newborn camel calves, aged 1–14 days, in Taif, Western Saudi Arabia. Out of these, 240 (20%) calves developed scours and more than half of them (54.4%) died, the most predominant isolate from them being *E. coli*. The organism was also incriminated as one of the causes of diarrhea in juvenile camels in Riyadh region of Central Saudi Arabia (El Wathig & Faye, 2016).

16.1 Etiology

Escherichia coli is a facultatively anaerobic, motile, gram-negative bacillus belonging to the family Enterobacteriaceae. Most strains of *E. coli* are harmless commensal of the intestinal flora, especially the lower intestines, of warm-blooded animals. However, some varieties are pathogenic due to the fact that they possess virulence genes which enable them to produce toxins and other virulence factors and hence invade and damage different body tissues.

E. coli is excreted in the feces of infected animals and is transmitted between animals primarily via the fecal-oral route. Its pathogenic varieties cause several diseases of considerable economic importance in farm animals, especially in young stock. These diseases include: colibacillosis and coli septicemia in less than 1-week-old bovine and ovine newborns, and 2–4 weeks old camel calves, joint ill in bovine calves and mastitis in dairy cattle, sheep, and camels (Wernery & Kaaden, 2002). They also cause wound infection and retarded wound healing. Colibacillosis in young animals is mostly associated with inadequate colostrum intake and other husbandry errors and is frequently associated with other types of infection.

There are different varieties of pathogenic *E. coli*, all of which possess plasmid-encoded virulence factors, undergo specific interactions with the intestinal mucosa, and produce toxins. These varieties include: Enterotoxigenic *E. coli* (ETEC) which causes most cases of neonatal colibacillosis; Enteropathogenic *E. coli* (EPEC); Entero-invasive *E. coli* (EIEC); Attaching and Effacing *E. coli* (AEEC) and Enterohemorrhagic *E. coli* (EHEC) (Wernery & Kaaden, 2002). *E. coli* varieties possess different antigens which can be used for serotyping.

16.2 Clinical Picture and Pathology

Colibacillosis in camels is typically characterized by profuse yellowish or whitish diarrhea, abdominal pain, anorexia, weakness, sunken eye appearance, and fever. The affected camels are dehydrated, and their hindquarters and tails are soiled with feces. Death often follows in 2–3 days. At necropsy there is pallor of the carcass and congestion of the small intestine with catarrhal enteritis while the gut contents are gray to yellowish and the mesenteric lymph nodes are edematous (Bornstein et al., 2000; Chauhan et al., 1986; Schwartz & Dioli, 1992; Wernery & Kaaden, 2002).

Coli septicemia often develops in conjunction with enteric colibacillosis but may also occur independently. It is characterized by generalized congestion, petechiation of serous membranes, and edema of the meninges. In addition, necropsy reveals marked pallor of the entire cadaver, inflammation of the intestinal mucosa, and grayish and foul-smelling intestinal contents. In severe cases, a fibrin exudate covers the abdominal organs. A detailed description of post-mortem lesions in Kenyan camel calves that died of coli septicemia was given by Bornstein and co-workers (2000). According to these authors, the lesions included accumulation of fibrinous fluid in the pericardium, petechial hemorrhages in the epicardium, endocardium, and renal pelvis, and generalized swelling and hyperemia of the body lymph nodes. In addition, the liver was pale and hard, the rectum contained pasty whitish feces and the intestinal mucosa, particularly that of the colon, was hyperemic and thickened while the meninges were slightly hyperemic.

16.3 Diagnosis

The clinical signs of colibacillosis are not distinguishable from those of other enteric infections in young camels. Therefore, the diagnosis depends on microbiological examinations of fecal samples and specimens from the intestinal tract, lymph nodes, and different organs collected soon after death. Selective media are employed to differentiate *E. coli* from other Enterobacteriaceae while different techniques are used in serotyping of cultured *E. coli* strains isolated from sick camel calves.

16.4 Zoonotic Potentiality

Few studies have been reported on the possible role of camels as a source of pathogenic *E. coli* infection in humans. Fadlelmula et al. (2016) identified Saudi Arabian dromedary camels as potential reservoirs of extended release β -lactamase producing *E. coli* infecting humans, while Baschera et al. (2019) isolated Shiga-toxin producing *E. coli* (STEC), with virulence markers associated with human disease, from camel fecal samples in Kenya. These authors cautioned that camels could be a potential threat particularly for people in close contact with these animals, as well as consumers of camel-derived foodstuffs such as raw camel milk. On the other hand, Rhuoma et al. (2018) reported that mobilized colistin resistance genes (*mcr-1* and *mcr-2*) were lacking in *E. coli* isolates from fecal samples of diarrheic and non-diarrheic camels in Tunisia, suggesting that camels do not constitute a major source of *mcr* genes contamination for the local population and tourists.

16.5 Treatment and Control

Dehydration resulting from severe diarrhea is the most important cause of mortality associated with outbreaks of colibacillosis in camel calves. It is, therefore, essential to administer oral or parenteral electrolytes to the affected animals in order to restore fluid balance. Furthermore, *E. coli* isolates often exhibit multiple antibiotic resistance; therefore, it is important to carry out antibiotic resistance tests on the isolated *E. coli* strain causing the outbreak. Several injectable antimicrobials such as trimethoprim/sulfonamide, neomycin, kanamycin, and colistin have been used in the treatment of coli septicemia (Manfield & Tinson, 1996).

For prevention and control, appropriate husbandry methods, especially housing, nutrition, clean water supply, and protection from extreme weather conditions, should be implemented, in addition to observing good hygienic measures and ensuring adequate intake of colostrum by the newborn. Maternal vaccination is also considered useful for increasing the resistance of newborn calves. A marked reduction in losses among newborn calves was reported by Strauss (1991) as a result of vaccination of all pregnant camels with Colivac at about 8 and then 4 weeks prior to the expected date of parturition.

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