

# ESKAPE Bacteria in the Dog

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ESKAPE bacteria (i.e., *Enterococcus faecium*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and *Enterobacter* species) are a group of common opportunistic pathogens associated mainly with nosocomial infections.

Keywords: animal-assisted interventions ; animal-assisted therapy ; animal-assisted activity ; zoonoses ; dogs ; one health ; ESKAPE ; patients

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## 1. Introduction

The acronym ESKAPE was used for the first time in 2008 by Rice<sup>[1]</sup> and was coined to reflect these microorganism's ability to escape killing by antibiotics by developing antimicrobial resistance, and challenge eradication by conventional therapies. The bacteria of the ESKAPE group cause significant morbidity and mortality and increased resource utilization in healthcare facilities<sup>[2][3]</sup>. Moreover, the World Health Organization (WHO) has recently listed most ESKAPE bacteria in the list of 12 microorganisms against which new antibiotics are urgently needed<sup>[4]</sup>.

## 2. A Potential Zoonotic Risk in Animal-Assisted Therapies, and In Animal-Assisted Activities in the Health Context

Animal-assisted interventions (AAIs) are widespread in different contexts worldwide and bring several benefits to users but can also expose them to the risk of infection with potentially zoonotic agents. The dog is the main animal species involved in these interventions, particularly, in animal-assisted therapies and animal-assisted activities implemented in hospitals, rehabilitation centers, and other health facilities. Our work aimed to systematically review (PRISMA) data on the presence of pathogens bacteria ESKAPE in dogs, within the period of 2000 to 2019, focusing on the presence, percentage estimates, type of samples such as swabs and biological samples (i.e., feces, urines), dog category, and geographic distribution of the study (country and continent). The type of sample performed from the dog was highlighted to assess not only the variety of tropism of these bacteria but also to make a prediction of the body regions (of the dog) at risk of contamination and with which the patients/users involved make contact directly or indirectly; in our opinion, it was also noteworthy to consider the category of belonging of the dog (owned and non-owned) since the dogs that are involved in the AAIs, and in particular, in the AAT, are owned dogs.

*Enterococcus faecium* is a commensal microorganism of the normal gastrointestinal flora in humans and animals. *E. faecium* can be transmitted to humans via direct contact with livestock as well as companion animals<sup>[5]</sup>. Recently, the results of some studies highlighted the potential for zoonotic transmission of ampicillin- and vancomycin-resistant *E. faecium* from the dog<sup>[5][6][7][8]</sup>.

*Staphylococcus aureus* is part of the cutaneous microbiome of animals and humans and is one of the leading causes of fatal nosocomial infection in humans<sup>[9]</sup>. It can cause a range of infections, such as mild-to severe skin and soft tissue infections, endocarditis, osteomyelitis, and fatal pneumonia<sup>[10]</sup>. According to the sensitivity to antibiotic drugs, *S. aureus* can be divided into methicillin-sensitive *Staphylococcus aureus* (MSSA) and methicillin-resistant *Staphylococcus aureus* (MRSA). MRSA is one of the most significant bacteria causing both hospital and community-acquired infections in humans<sup>[11]</sup>.

*K.pneumoniae* is a Gram-negative member of the Enterobacteriaceae, considered one of the common opportunistic agents causing respiratory and urinary tract infections in humans and dogs<sup>[12][13][14][15][16]</sup>. *K. pneumoniae* strains have a significant ability to acquire resistance to antibiotics, and as such, it is of a public health concern<sup>[17]</sup>. Marques et al.<sup>[18]</sup> reported the fecal colonization and sharing of *K. pneumoniae* clonal lineages between healthy humans and dogs living in close contact, suggesting the role of dogs as reservoirs of this bacterium.

*A. baumannii* is the most clinically significant pathogen implicated in human nosocomial infections<sup>[18]</sup>. In humans, *baumannii* infections involve mainly the respiratory tract, but meningitis and urinary tract infections may also occur<sup>[19][20][21]</sup>. Animals represent a potential reservoir of *A. baumannii*, and the risk of transmission could increase in companion animals which are in direct contact or closer vicinity to humans<sup>[22]</sup>.

*P.aeruginosa* is increasingly recognized as an opportunistic pathogen causing chronic and recurrent infections in both humans and animals<sup>[23]</sup>. In humans, it causes nosocomial and healthcare-associated infections in immunocompromised patients<sup>[24][25]</sup>. Fernandes et al. <sup>[26]</sup> demonstrated a zoo-anthropoic transmission (human-to-dog) of VIM-2-producing *P. aeruginosa* in the household following a person's hospital discharge.

*Enterobacter* spp., particularly *E. aerogenes* and *E. cloacae*, have been associated with nosocomial foci and are considered opportunistic pathogens<sup>[27]</sup>. *Enterobacter* spp. can cause numerous types of infections, including brain abscess, pneumonia, meningitis, septicemia, urinary tract (especially catheter-related) infections, and intestinal infections<sup>[28]</sup>. Transmission occurs through direct or indirect contact of the mucosal surfaces with the host organism<sup>[29]</sup>.

Although the numerous investigations carried out both in the medical and veterinary fields on the risk by these nosocomial opportunistic bacteria, the studies concerning the dog involved in AAT and AAA in health context are very limited. The lack of standardized control programs to ESKAPE bacteria in the dogs involved in AAT at the international level and in worldwide introduces a knowledge gap in this field and makes it difficult to estimate related risk level for humans and thoroughly investigate potential transmission dynamics of these pathogens.

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