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Common Bacterial Causes of Septicaemia in Animals and Birds Detected in Heart Blood Samples of Referred Cases of Mortality in Northern India

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1. Abstract

Many animals and birds die of septicaemic infections but specific bacteria associated with such infections are not precisely known in the current veterinary setting in India. This retrospective analytical study on 276 cases of bloodstream infections in animals and birds investigated bacterial causes of bacteraemia in animals and birds. The study revealed that from 276 samples of blood from animals and birds died or moribund from pet, domestic, zoo and wildlife sanctuaries a total of 1948 bacterial isolates belonging to 129 species of 52 genera were isolated and identified as cause of bloodstream infection. In 152 (55.07%) samples more than one type of bacterium was detected as the cause of infection. In 124 (44.93%) blood samples bacteria were present as single pure culture and isolates belonged to 42 species of 22 genera the most common was *Escherichia coli* (52 cases), *Bacillus anthracis* (5), *Aeromonas bestiarum (4), Proteus mirabilis (4), Staphylococcus epidermidis (4), Paenibacillus haemolyticus (3), Pantoea agglomerans (3), Pasteurella canis (3), Pseudomonas aeruginosa (3), Salmonella enterica* , ssp. *enterica* serovar Typhimurium *(3), Acinetobacter calcoaceticus-baumannii* complex *(2), Alcaligenes denitrificans (2), A. faecalis (2), Escherichia vulneris (2), Gallibacterium anatis* biovar Anatis *(2), Staphylococcus aureus (2), Streptococcus milleri (2), Streptococcus pneumoniae (2),* and *Aeromonas hydrophila, Aeromonas jandaei, Aeromonas salmonicida, Aeromonas schubertii, Aeromonas trota, Avibacterium avium, Avibacterium gallinarum, Bacillus cereus, Bacillus marcerans, Bacillus mycoides, Falvobacterium aquatile, Klebsiella pneumoniae* ssp. *pneumoniae, Lysinibacillus sphaericus,Micrococcus luteus, Moraxella ovis, Pasteurella dagmatis, Pasteurella multocida, Serratia rubidaea, Staphylococcus capitis ssp. urealyticus, Staphylococcus delphini, Staphylococcus haemolyticus, Staphylococcus intermedius, Streptococcus porcinus* and *Vribrio alginolyticus* were isolated from one case each. Considering all isolations, again *E. coli* (48.19%) were the most common followed by *Proteus mirabilis* (8.70%), *Pantoea agglomerans* (7.61%), *Pseudomonas aeruginosa* (7.25%), *Staphylococcus aureus* (6.52%), *Streptococcus milleri* (6.16%), *Enterococcus faecalis* (5.80%), *Klebsiella pneumoniae* ssp. *pneumoniae* (5.80%), *Aeromonas bestiarum* (5.07%), and *Staphylococcus epidermidis* (4.35%). The antimicrobial susceptibility analysis of the bacterial isolates from heart blood samples of animals and birds revealed a high level of drug resistance. Tigecycline inhibited 94.44% of the bacterial isolates followed by linezolid (93.72%), chloramphenicol (84.78%), piperacillin + tazobactam (83.45%), vancomycin (80.43%), ampicillin (76.57%), imipenem (79.33%), meropenem (70.00), nitrofurantoin (69.81%), cefotaxime (66.91%), cefepime (66.18%), cefoxitin (65.70%), cotrimoxazole (65.70%), piperacillin (65.12%), amoxyicillin+ clavulanic acid (64.98%), moxalactam (64.98%), ciprofloxacin (63.04%), tetracycline(61.84%), ceftriaxone (64.11%), doxycycline (64.11%), penicillin (60.87%), gentamicin (55.07%), azithromycin (54.74%) and the least effective erythromycin (53.68%). The study indicated high levels of an-

timicrobial resistance in bacteria causing infections in animals and even against those antibiotics not used in animals.

2. Introductions

Bacteria are the most cause of septicaemia or bloodstream infection in humans but sometimes virus and fungal infections may also be cause of septicaemia. In the United States, every year at least 1.7 million adults develop sepsis and 350,000 die during their hospitalization [1]. In the treatment of sepsis, the major hurdle is emerging antimicrobial resistance (AMR) in bacteria, in the US alone 35,000 people die annually due to infection with AMR strains [2]. Septicaemia may be associated with a spectrum of illnesses, from short-term pyrexia and mild symptoms of discomfort and ill health to organ dysfunction, and septic shock leading to multiple organ failure and death, making it stand among the top 10 causes of death [3]. Staphylococci, streptococci, *Listeria*, *Salmonella*, *Klebsiella pneumoniae, Escherichia coli*, *Clostridium perfringens,* and *Enterococcus faecium* are among the top bacterial causes of septicaemia in humans but Group B streptococci, *E. coli* and *Staphylococcus aureus* are often the most common cause [4, 5]. Estimates revealed that in 2017 globally there were 48.9 million cases and 11 million sepsis-related deaths worldwide accounting for about 20% of all global deaths [6], and in 2019, five leading pathogens—*Staphylococcus aureus, Escherichia coli, Streptococcus pneumoniae, Klebsiella pneumoniae,* and *Pseudomonas aeruginosa* were responsible for 54·9% (52·9–56·9) of deaths [7].

In animals, especially wild animals, major natural causes of death infections are mostly viral infections such as rabies, foot and mouth disease, pseudorabies, classical swine fever, African swine fever, haemorrhagic fevers, Hendra, Nipah and Ebola virus infections, in wild birds' flues are the considered as the major cause of mass mortality [8]. Besides viral infections, bacteria of *Pasteurella* and *Brucella* species and a few fungal infections are also attributed as causes of death in wildlife [8]. In zoos, >70% of animals die from infectious diseases [9]. However, in a study on African Zebu cattle bacterial infections were not recognized as the major cause of mortality [10]. In a study on dairy animals in the US, most of the deaths are associated with one or more of the infections and among specific pathogens *E. coli* was identified as the most common cause [11]. In dogs, infections are one of the top causes of death after neoplasia and cardiac disorders [12]. In farm animals, common bacterial causes of sudden deaths included *Clostridium* species, *Bacillus anthracis*, *Leptospira interrogans*, Methicillin-Resistant *Staphylococcus aureus* (MRSA) and *Streptococcus equi, Mycobacterium paratuberculosis Pasteurella multocida, E. coli, Klebsiella pneumoniae, Salmonella* Typhimurium and *Yersinia species* [13, 14, 15]. *Aeromonas and Pseudomonas* spp. are the most frequently isolated bacteria from cases of septicemic deaths in reptiles but several other bacteria including *Serratia, Salmonella, Micrococcus, Erysipelothrix, Citrobacter freundii, Morganella morganii, Proteus, Staphylococcus, Streptococcus, Escherichia coli, Klebsiella, and Dermatophilus* species may also be the cause of septicaemia in reptile [16].

In India, in domestic animals and birds some important bacterial diseases considered endemic and economically important and causing septicemic infections are regularly monitored including pasteurellosis especially haemorrhagic septicemia (HS) in cattle, buffalo and birds (*Pasteurella multocida*), black quarter in cattle and buffalo (*Clostridium chauvoei*), brucellosis in cattle, buffalo, sheep and goats (*Brucella abortus, B. melitensis, B. suis*), enterotoxemia in sheep (*Clostridium perfringens*), and contagious caprine pleuropneumonia in goats (CCPP, *Mycoplasma capricolum* ssp. *capripneumoniae*), salmonellosis (*Salmonella enterica* ssp. *enterica*) in poultry, horses and other animals, chronic respiratory disease (CRD) in poultry birds (*Mycoplasma gallisepticum*), mastitis in dairy animals (a multi etiologic disease mainly caused by *Staphylococcus, Streptocococcus* species and *E. coli*) and glanders (*Burkholderia mallei)* in equids [17]. Besides, several other bacterial diseases associated with heavy mortality in animals and birds in India but not monitored regularly include klebsiellosis (*K. pneumoniae, K. oxytoca, K. aerogenes*), raoultellosis (*Raoultella terrigena*) in animals and birds [18], gallibacteriosis (*Gallibacterium anatis*) in birds 19, 20], *Pantoea agglomerans* and *Aeromonas* infections in animals [21, 22], colibacillosis in neonates and colisepticaemia in animals and birds caused by *E. coli* [23], *Edwardsiella tarda, Lelliotia amnigenus, Yersinia enterocolitica*, and *Y. kristensenii* [24] and many other embers of Enterobacteriaceae [25]. In wild animals, a battery of bacteria has been reported to cause septicemic infections leading to abortion and mortality in India including *Aerococcus spp., Acinetobacter calcoaceticus, Alcaligenes faecalis, A. denitrificans, Bordetella bronchiseptica, P. agglomerans, Enterococcus faecalis, Enterococcus malodoratus, E. coli, Falvobacterium aquatile, Klebsiella pneumoniae ssp. pneumoniae, Pasteurella canis, Streptococcus milleri* [26, 27], *Pseudomonas aeruginosa, Staphylococcus epidermidis, S. intermedius, Streptococcus pneumoniae* [27], *Stenotrophomonas maltophilia* [28]. Looking at the diversity of the bacterial causes of septicaemia and death in animals and birds in different parts of the world, this retrospective analysis of cases investigated at the Division of Epidemiology was done to determine the frequency of different bacteria in animals and birds isolated from bloodstream infection. Although this study talks of the occurrence of different bacteria as minor or major causes of bacteraemia in animals and birds, it cannot be considered an epidemiological study as it pertains to only those cases referred for diagnosis of the cause, mostly under instances where the local veterinarians and laboratories failed to identify or assign the cause of disease.

3. Materials and Methods

For the present retrospective study investigation data on isolation and identification of bacteria in heart blood samples of 276 referred cases of septicaemia and septicaemic deaths in animals and birds collected by caretaker veterinarians was retrieved from the Division of Epidemiology Data resources for the last five years (2018-2023). The repository data on bacterial isolates included those strains which were isolated and identified through conventional methods and confirmed either through specific polymerase reaction, gene sequencing and or MALDITOF-MS or both. Besides, for all isolates antimicrobial susceptibility testing (AST) data using disc diffusion assay and concluded as per CLSI guidelines [29]. All the isolates of a single species having similar antibiogram (AST pattern) were considered as single strains.

3.1. Statistical Analysis

Data of AST for all strains along with their source of isolation was entered in an Excel sheet and analyzed using Chi-square statistics to understand the significance of the different associations. For analysis, only those sets were compared where strain numbers or cases were ≥ 10.

4. Results

From 276 samples of blood from animals and birds died or moribund from pet, domestic, zoo and wildlife sanctuaries a total of 1948 bacterial isolates belonging to 129 species of 52 genera were isolated and identified as the cause of bloodstream infection (Table 1). The bacterial isolation and identification data revealed that in 152 (55.07%) of the cases more than one type of bacterium was detected as the cause of infection. In 124 (44.93%) of blood samples single types of bacteria were detected. Bacteria belonging to 42 species of 22 genera were isolated as pure culture from 124 blood samples and may be the most probable cause of septicemic deaths. The most common pure culture isolates were of *E. coli* isolated from 52 cases, distantly followed by *Bacillus anthracis* (5), *Aeromonas bestiarum (4), Proteus mirabilis (4), Staphylococcus epidermidis (4), Paenibacillus haemolyticus (3), Pantoea agglomerans (3), Pasteurella canis (3), Pseudomonas aeruginosa (3), Salmonella enterica* , ssp. *enterica* Serovar *Typhimurium (3), Acinetobacter calcoaceticus-baumannii* complex *(2), Alcaligenes denitrificans (2), A. faecalis (2), Escherichia vulneris (2), Gallibacterium anatis* biovar Anatis *(2), Staphylococcus aureus (2), Streptococcus milleri (2), Streptococcus pneumoniae (2),* and bacteria isolated in pure culture from one case each were *Aeromonas hydrophila, Aeromonas jandaei, Aeromonas salmonicida, Aeromonas schubertii, Aeromonas trota, Avibacterium avium, Avibacterium gallinarum, Bacillus cereus, Bacillus marcerans, Bacillus mycoides, Falvobacterium aquatile, Klebsiella pneumoniae* ssp. *pneumoniae, Lysinibacillus sphaericus,Micrococcus luteus, Moraxella ovis, Pasteurella dagmatis, Pasteurella multocida, Serratia rubidaea, Staphylococcus capitis ssp. urealyticus, Staphylococcus delphini, Staphylococcus haemolyticus, Staphylococcus intermedius, Streptococcus porcinus* and *Vribrio alginolyticus.*

Overall, most commonly isolated bacteria from 276 blood samples of septicemic cases in animals and bird included *E. coli* (48.19%), *Proteus mirabilis* (8.70%), *Pantoea agglomerans* (7.61%), *Pseudomonas aeruginosa* (7.25%), *Staphylococcus aureus* (6.52%), *Streptococcus milleri* (6.16%), *Enterococcus faecalis* (5.80%), *Klebsiella pneumoniae* ssp. *pneumoniae* (5.80%), *Aeromonas bestiarum* (5.07%), and *Staphylococcus epidermidis* (4.35%). There were four more species of bacteria isolated from a significant number of blood samples from lethal bacteremic infections in animals and birds *Enterococcus faecium, Alcaligenes faecalis, Bacillus anthracis,* and *Pasteurella canis* isolated from 11 (3.99%), 10 (3.62%), 10 (3.62%), and 10 (3.62%) samples, respectively. Other bacteria were isolated from less than 10 cases. Of the bacterial strains of 52 genera, isolates belonging to 20 genera were detected only from one sample each while isolates of 5, 2, 2, 3, 3, 3, 1 and 1 genera were isolated from 2, 3, 4, 5, 6, 7, 8 and 13 samples each, respectively (Table 1).

Among the isolates of different genera of bacteria isolated in pure culture, the most common were *Escherichia* (54), *Staphylococcus* (10), *Aeromonas* (9), *Bacillus* (8), *Pasteurella* (5), and *Streptococcus* (5). Isolates of the other 16 genera were detected in pure culture in ≤4 cases. However, among all groups of animals and birds *E. coli* and *Staphylococcus* species strains were the two most commonly isolated groups of bacteria from samples of bloodstream infections. Other bacteria belonging to *Aeromonas, Proteus, Streptococcus, Enterococcus, Pseudomonas, Pantoea, Bacillus, Klebsiella, Alcaligenes* and *Acinetobacter* species were detected in 14.23%, 11.31%, 10.95%, 10.22%, 8.76%, 8.39%, 7.66%, 7.30%, 6.20% and 5.47% of blood samples of animals and birds, respectively, and frequency of their isolation varied among different group of animals and birds (Table 2).

Antimicrobial susceptibility test (AST) results (Table 3) revealed that G+ve bacteria were significantly (p, <0.05) less often resistant than G-ve bacteria for penicillin, ampicillin, tetracycline, doxycycline, nitrofurantoin, cotrimoxazole, erythromycin, cefoxitin, piperacillin and piperacillin + tazobactam but significantly (p, <0.05) more often resistant to cefepime, ceftraxone, carbapenems, and gentamicin than G-ve bacteria. Bacterial isolates from wildlife sanctuary and zoo animals were significantly (p, <0.05) less often resistant than those isolated from domestic and pet animals for penicillin, ampicillin, tetracycline, doxycycline, ciprofloxacin, carbapenems, cotrimoxazole, erythromycin, colistin, tigecycline, and piperacillin. However, isolates from wildlife sanctuary and zoo animals were significantly (p, <0.05) more often resistant to gentamicin and nitrofurantoin than those isolated from domestic and pet animals.

The AST results revealed that on G+ve bacteria tigecycline was the most effective antibiotic inhibiting 94.44% of the bacterial isolates (Table 3) followed by linezolid (93.72%), chloramphenicol (84.78%), piperacillin + tazobactam (83.45%), vancomycin (80.43%), ampicillin (76.57%), imipenem (79.33%), meropenem (70.00), nitrofurantoin (69.81%), cefotaxime (66.91%), cefepime

(66.18%), cefoxitin (65.70%), cotrimoxazole (65.70%), piperacillin (65.12%), amoxyicillin+ clavulanic acid (64.98%), moxalactam (64.98%), ciprofloxacin (63.04%), tetracycline(61.84%), ceftriaxone (64.11%), doxycycline (64.11%), penicillin (60.87%), gentamicin (55.07%), azithromycin (54.74%) and the least effective erythromycin (53.68%). On G+ve bacteria too, tigecycline was the most effective antibiotic inhibiting 92.11% of the isolates closely followed by imipenem and meropenem inhibiting 90.73% and 81.79% of the isolates, then followed by chloramphenicol (80.38%), gentamicin (74.64%), aztreonam (72.88%), ceftriaxone (72.16%), cefotaxime (71.97%), cefepime (71.71%), moxalactam (67.41%), piperacillin + tazobactam (67.07%), amoxycillin+ clavulanic acid (61.54%), colistin (60.5%), ciprofloxacin (58.8%), nitrofurantoin (58.54%), cotrimoxazole (57.43%), cefoxitin (56.78%), azithromycin (55.72%), and ampicillin, piperacillin, doxycycline, tetracycline, penicillin, amoxicillin, erythromycin inhibited less than 50% of the isolates (Table 3).

Comparative AST analysis for G+ve bacteria (Table 4) revealed that *B. anthracis* strains were the most susceptible and *E. faecium* isolates were the most resistant ones for most of the antimicrobials. Among G-ve bacteria *P. aeruginosa* strains were the most often resistant to most of the antibiotics except a few exceptions viz., *A. bestiarum* to cefapime, *E. coli, K. pneumoniae, P. canis* and *P. mirabilis* to ciprofloxacin, *P. canis*, and *P. mirabilis* to colistin, A. *bestiarum, E. coli*, and *K. pneumoniae* to piperacillin, and *E. coli* and *K. pneumoniae* to piperacillin+ tazobactam were more often (p, <0.05) resistant than *P. aeruginosa* strains. On the other hand, *P. canis* strains were more susceptible to most of the antibiotics than any of the other G-ve bacteria (p, <0.05).

Table 1: Bacteria isolated from heart blood of different animals and birds died of septicaemia

Bacterial species	No. of cases	Bacteria isolated from heart bloods or blood of
Achromobacter xyloxidans	2	Rabbit 1, Lion 1
Acinetobacter calcoaceticus-baumannii complex	5	Cattle 1, Crane 1, Poultry 1, Tiger 1, Horse 1
Acinetobacter bereziniae	1	Ostrich 1
Acinetobacter haemolyticus	2	Ostrich 1, Turtle 1
Acinetobacter lwoffii	3	Cattle 1, Goat 1, Lion 1
Acinetobacter schindleri	2	Lion 1, Spotted dear 1
Acinetobacter ursingii	1	Cattle 1
Actinomyces bovis	1	Cattle 1
Aerococcus sanguinicola	6	Cattle 1, Leopard 1, Sambhar deer 1, Poultry 1, Rabbit 1, Tiger 1
Aeromonas bestiarum	14	Bear 1, Bison 1, Cattle 4, Hippopotamus 1, Leopard 1, Lion 2, Pseasant 1, Poultry 2, Tiger 1
Aeromonas caviae	1	Gherial 1
Aeromonas eucranophila	1	Gherial 1
Aeromonas hydrophila	4	Leopard 2, Pig 1, Tutrtle 1
Aeromonas jandaei	3	Buffalo 1, Poultry 2
Aeromonas media	2	Bear 2
Aeromonas popoffii	1	Black buck 1
Aeromonas salmonicida	6	Goat 2, Lion 1, Spotted deer 1, Tiger 2
Aeromonas schubertii	3	Buffalo 1, Gherial 1, Peacock 1
Aeromonas sobria	1	Bear 1
Aeromonas trota	5	Gherial 1, Leopard 2, Poultry 2
Agrobacterium yellow group	1	Yellow Anaconda 1
Alcaligenes denitrificans	7	Cattle 1, Lion 1, Tiger 4, Turtle 1
Alcaligenes faecalis	10	Black buck deer 1, Buffalo 1, Cattle 1, Elephant 1, Lion 1, Panda 1, Poultry 1, Tiger 3
Arsenophonus nasoniae	1	Hyena 1
Avibacterium avium	2	Pigeon 1, Poultry 1
Avibacterium gallinarum	1	Poultry 1
Bacillus anthracis	10	Buffalo 2, Cattle 2, Dog 1, Goat 1, Lion 1, Peacock 1, Poultry 1, Spotted deer 1
Bacillus cereus	5	Cattle 1, Lion 1, Poultry 2, Spotted deer 1
Bacillus coaglulans	1	Lion 1
Bacillus marcerans	1	Tiger 1

Bacillus mycoides	2	Leopard 1, Poultry 1
Bacillus subtilis	3	Peasant 1, Panda 1, Tiger 1
Bordetella avium	5	Poultry 5
Brevibacillus brevis	1	Poultry 1
Budvicia aquatica	1	Poultry 1
Burkholderia cepacia	2	Crocodile 1, Yellow Anaconda 1
Chryseobacterium rhizoplanae	1	Ostrich 1
Citrobacter freundii	4	Buffalo 1, Peacock 1, Tiger 1, Yellow Anaconda 1
Edwardsiella tarda	1	Monitor lizard 1
Enterobacter cloacae	1	Lion 1
Enterococcus casseliflavus	1	Lion 1
Enterococcus durans	1	Gibbon 1
Enterococcus faecalis	16	Bear 2, Duck 1, Elephant 2, Leopard 2, Peacock 2, Poultry 4, Tiger 3
Enterococcus faecium	11	Barking deer 1, Cattle 1, Elephant 1, Leopard 1, Lion 1, Peacock 1, Poultry 2, Tiger 3
Enterococcus gallinarum	1	Buffalo 1
Enterococcus malodoratus	1	Gherial 1
Enterococcus pseudoavium	1	Poultry 1
Erwinia amylovora	1	Poultry 1
Erwinia mallotivora	1	Chinkara deer 1
Erwinia nigrifluens	2	Lion 1, Poultry 1
Erwinia psidii	1	Bear 1
Escherichia coli	133	Barking deer 1, Bear 1, Black buck deer 2, Buffalo 2, Buffalo 4, Cat 1, Cattle 17, Chinkara deer 1, Crocodile 1, Crane 1, Duck 2, Emu 1, Falcon 1, Gherial 2, Goat 3, Hippopotamus 1, Horse 5, Leopard 3, Lion 2, Lorikeet 1, Mithun 1, Peacock 2, Pheasant 1, Pig 2, Pig 1, Pigeon 3, Poultry 53, Rat 1, Rhino 1, Spotted deer 3, Tiger 12, Turkey 1
Escherichia fergusonii	3	Cattle 1, Poultry 2
Escherichia vulneris	5	Gaur antelope 1, Poultry 4
Falvobacterium aquatile	1	Tiger 1
Gallibacterium anatis biovar anatis	2	Duck 2
Gallibacterium anatis biovar haemolytica	5	Pigeon 1, Poultry 4
Hafnia alvei	7	Duck 1, Gibbon 1, Lion 1, Mithun 1, Ostrich 1, Poultry 1, Spotted deer 1
Klebsielal aerogenes	1	Poultry 1
Klebsiella oxytoca	1	Lion 1
Klebsiella pneumoniae ssp. pneumoniae	18	Bear 1, Duck 1, Elephant 1, Golden finch 1, Leopard 3, Lion 1, Lorikeet 1, Peacock 1, Pheasant 1, Poultry 2, Snow leopard 1, Spotted deer 2, Tiger 1, Turtle 1
Kluyvera cryocrescens	1	Spotted deer 1
Kocuria rosea	1	Poultry 1
Laclercia adecarboxylata	1	Goat 1
Leminorella ghrimontii	1	Turtle 1
Lysinibacillus odysseyi	1	Buffalo 1
Lysinibacillus sphaericus	2	Elephant 1, Sambhar deer 1
Mammilicoccus sciuri	2	Poultry 1, Spotted dear 1
Micrococcus luteus	7	Cattle 1, Duck 1, Poultry 2, Leopard 1, Lion 1, Tiger 1
Moellerella wisconsensis	1	Cattle 1
Psychrobacter phenylpyruvicus (*Moraxella phenylpyrivica*)	1	Elephant 1
Moraxella ovis	1	Black buck deer 1
Moraxella lacunata	1	Leopard 1

Paenibacillus amyloliquifaciens	2	Elephant 1, Golden finch 1
Paenibacillus haemolyticus	3	Black buck 3
Pantoea agglomerans	23	Black buck 1, Cattle 5, Elephant 2, Golden finch 1, Leopard 3, Lion 1, Peacock 2, Poultry 5, Spotted deer 1, Tiger 2
Pasteurella multocida	4	Buffalo 1, Gaur antelope 1, Sheep 1, Spotted deer 1
Pasteurella aerogenes	1	Duck 1
Pasteurella canis	10	Dog 1, Spotted deer 9
Pasteurella dagmatis	1	Duck 1
Pectobacterium carotovorm	1	Elephant 1
Pectobacterium chrysanthemi	1	Monitor lizard 1
Pluralibacter gregoviae	2	Ostrich 1, Poultry 1
Photobacter luminescens	1	Spotted dear 1
Pragia fontium	1	Leopard 1
Proteus mirabilis	27	Black buck 1, Cattle 3, Crocodile 1, Dog 1, Duck 1, Elephant 1, Leopard 1, Pig 1, Poultry 11, Spotted deer 1, Tiger 5
Proteus penneri	1	Elephant 1
Proteus vulgaris	5	Cattle 1, Lion 1, Tiger 2, Turtle 1
Providencia alcalifaciens	1	Turtle 1
Pseudomonas aeruginosa	20	Black buck 1, Cattle 2, Crane 1, Elephant 1, Goat 2, Leopard 1, Pig 1 Poultry 10, Tiger 1
Pseudomonas paucimobilis	1	Duck 1
Pseudomonas pseudoalcaligenes	1	Turtle 1
Pseudomonas testosteronii	1	Buffalo 1
Pseudomonas vesicularis	1	Dog 1
Raoultella terrigena	6	Cattle 1, Elephant 1, Goat 1, Golden finch 1, Poultry 1, Rat 1
Salmonella enterica ssp. enterica ser Typhimurium	5	Pig 1, Poultry 4
Salmonella enterica ssp. enterica ser Gallinarum	1	Poultry 1
Serratia ficaria	1	Duck 1
Serratia marcescens	2	Poultry 2
Serratia odorifera	2	Cattle 1, Spotted deer 1
Serratia plymuthica	2	Horse 1, Ostrich 1
Serratia rubidaea	1	Horse 1
Shewanella putrefaciens	1	Turtle 1
Staphylococcus arlettae	3	Leopard 1, Lion 1, Turkey 1
Staphylococcus aureus	18	Buffalo 1, Cattle 3, Dog 1, Golden finch 1, Hog deer 1, Lion 1, Peacock 1, Pigeon 1, Poultry 3, Spotted deer 2, Tiger 3
Staphylococcus auricularis	1	Lion 1
Staphylococcus capitis	5	Horse 1, Lion 1, Poultry 2, Rat 1
Staphylococcus chromogenes	3	Cattle 1, Leopard 1, Tiger 1
Staphylococcus cohnii ssp. *cohnii*	3	Buffalo 2, Horse 1
Staphylococcus delphini	2	Black buck 1, Ostrich 1
Staphylococcus epidermidis	12	Chinkara deer 1, Dog 1, Elephant 2, Goat 1, Golden finch 1, Leopard 1, Lion 1, Poultry 3, Turtle 1
Staphylococcus gallinarum	1	Poultry 1
Staphylococcus haemolyticus	6	Buffalo 2, Dog 1, Leopard 1, Peacock 1, Tiger 1
Staphylococcus hominis	2	Poultry 1, Spotted dear 1
Staphylococcus hicus	1	Poultry 1
Staphylococcus intermedius	5	Cattle 1, Leopard 1, Pigeon 1, Poultry 2
Staphylococcus lentus	5	Buffalo 1, Cattle 1, Elephant 1, Tiger 2
Staphylococcus sacchrolyticus	1	Horse 1
Staphylococcus schleiferi ssp. *coagulans*	2	Buffalo 1, Chinkara deer 1

Staphylococcus xylosus	1	Poultry 1
Stenotrophomonas maltophilia	1	Leopard 1
Streptococcus agalactiae	1	Chinkara deer 1
Streptococcus canis	1	Hyena 1
Streptococcus gallinarum	1	Poultry 1
Streptococcus milleri	17	Buffalo 1, Cattle 3, Dog 2, Lion 1, Lorikeet 1, Tiger 3, Poultry 6
Streptococcus pneumoniae	3	Lion 1, Poultry 2
Streptococcus porcinus	6	Chinkara deer 1, Horse 2, Lorikeet 1, Poultry 2
Streptococcus pyogenes	5	Barking deer 1, Hyena 1, Lion 1, Peacock 1, Tiger 1
Vribrio alginolyticus	1	Poultry 1

Table 2: The most common bacteria isolated from blood stream infections in animals and birds

Pets and domestic animals (n=164)						**Wildlife (n=112)**						**All cases (n=276)**	
Herbivores (n=66)		Carnivores (n=7)		Birds(n=91)		*Herbivores* (n=36)		Carnivores(n=59)		Birds (n=17)			
Escherichia species	40	*Pantoea agglomerans*	5	*Escherichia* species	53	*Escherichia* species	13	*Escherichia* species	22	*Escherichia* species	10	*Escherichia* species	139
Staphylococcus species	13	*Staphylococcus* species	2	*Staphylococcus* species	13	*Staphylococcus* species	13	*Aeromonas* species	16	*Staphylococcus* species	5	*Staphylococcus* species	59
Aeromonas species	10	*Streptococcus* species	2	*Proteus mirabilis*	12	*Pasteurella* species	8	*Staphylococcus* species	13	*Klebsielal* species	4	*Aeromonas* species	39
Bacillus species	6	*Enterococcus* species	2	*Streptococcus* species	11	*Proteus mirabilis*	5	*Enterococcus* species	11	*Enterococcus* species	3	*Proteus mirabilis*	31
Pseudomonas species	6	*Escherichia* species	1	*Pseudomonas* species	11	*Enterococcus* species	5	*Proteus mirabilis*	9	*Streptococcus* species	3	*Streptococcus* species	30
Acinetobacter species	5	*Bacillus* species	1	*Enterococcus* species	7	*Aeromonas* species	5	*Alcaligenes* species	9	*Pantoea agglomerans*	3	*Enterococcus* species	28
Streptococcus species	5	*Pseudomonas* species	1	*Aeromonas* species	6	*Pantoea agglomerans*	4	*Klebsielal* species	8	*Aeromonas* species	2	*Pseudomonas* species	24
Proteus mirabilis	4	*Proteus mirabilis*	1	*Gallibacterium anatis*	6	*Klebsielal* species	4	*Streptococcus* species	7	*Bacillus* species	2	*Pantoea agglomerans*	23
Alcaligenes species	3	*Pasteurella* species	1	*Pantoea agglomerans*	5	*Alcaligenes* species	4	*Pantoea agglomerans*	6	*Acinetobacter* species	2	*Bacillus* species	21
Raoultella terrigena	3			*Salmonella enterica ssp. Enterica*	5	*Pseudomonas* species	3	*Bacillus* species	6	Strains of 9 more genera isolated from one sample each		*Klebsielal* species	20
Serratia species	3			*Bordetella avium*	5	*Streptococcus* species	2	*Acinetobacter* species	5			*Alcaligenes* species	17
Aerococcus sanguinicola	2			*Bacillus* species	4	*Bacillus* species	2	*Paenibacillus* species	4			*Acinetobacter* species	15
Pasteurella species	2			*Klebsielal* species	4	*Hafnia alvei*	2	*Micrococcus luteus*	3			*Pasteurella* species	13
Strains of 10 more genera isolated from one sample each				*Serratia* species	3	*Acinetobacter* species	2	*Pseudomonas* species	2			*Serratia* species	8
				Micrococcus luteus	3	*Lysinibacillus* species	2	*Erwinia* species	2			*Hafnia alvei*	7
				Avibacterium species	3	*Moraxella* species	2	*Aerococcus sanguinicola*	2			*Gallibacterium anatis*	7
				Pasteurella species	2	Strains of 11 more genera isolated from one sample each		*Citrobacter freundii*	2			*Micrococcus luteus*	7
				Hafnia alvei	2			*Burkholderia cepacia*	2			*Raoultella terrigena*	6
				Erwinia species	2			Strains of 11 more genera isolated from one sample each				*Aerococcus sanguinicola*	6
				Strains of 10 more genera isolated from one sample each								*Salmonella enterica ssp. Enterica*	6
												Paenibacillus species	5
												Erwinia species	5
												Bordetella avium	5
												Citrobacter freundii	4
												Moraxella species	4
												Lysinibacillus species	3
												Avibacterium species	3
												Pluralibacter gregoviae	2
												Burkholderia cepacia	2
												Pectobacterium species	2
												Achromobacter xyloxidans	2
												Mammilicoccus sciuri	2
												Strains of 20 more genera isolated from one sample each	

Table 3: Antimicrobial-resistance profile of important bacteria isolated from heart blood samples from 582 cases of death in animals and birds died of septicaemia

Antimicrobials tested	Percent of resistant isolates of bacteria isolated from death cases (number of isolates tested)																Source		All cases
	EC	PM	PA	PS	SA	SM	EF	KP	AB	SE	EFc	AF	BA	PC	G+	G-	WS	PD	
	133 (693)	24 (71)	21 (71)	20 (44)	18 (25)	17 (35)	16 (61)	16 (67)	14 (62)	12 (23)	11 (24)	10 (13)	10 (36)	10 (19)	188 (414)	394 (1534)	165 (811)	417 (1137)	276 (1948)
Amoxicillin+ clavulanic acid	36.08	29.58	36.62	72.73	32	37.14	32.79	50.75	43.55	24.24	66.67	53.85	44.44	26.32	35.02	38.46	39.46	40.21	37.73
Amoxycillin	65.95	52.11	56.34	86.36	40	57.14	47.54	85.07	85.48	36.36	79.17	61.54	50	31.58	44.93	62.19	61.41	58.19	58.52
Ampicillin	54.83	53.52	54.93	77.27	16	28.57	22.95	100	100	15.15	33.33	53.85	30.56	10.53	23.43	51.83	37.85	56.58	45.79
Azithromycin	46.7	68.18	40	58.33	33.33	46.67	60.87	80	30.43	25	72.22	22.22	26.32	22.22	45.26	44.28	44.98	43.22	44.52
Aztreonam	27.99	26.76	28.17	25	NT	NT	NT	29.85	27.42	NT	NT	38.46	NT	10.53	NT	27.12	30.04	27.1	24.1
Carbapenems	15.58	25.35	12.68	38.64	16	42.86	37.7	10.45	32.26	9.09	58.33	46.15	2.78	57.89	25.12	18.97	28.36	20.28	20.28
Cefepime	29.15	33.8	28.17	18.18	12	40	47.54	23.88	32.26	18.18	62.5	23.08	50	10.53	33.82	28.29	32.55	36.12	29.47
Cefotaxime	29.15	22.54	23.94	31.82	20	51.43	34.43	37.31	38.71	30.3	50	46.15	44.44	5.26	33.09	28.03	35.39	31.67	29.11
Cefoxitin	41.99	38.03	39.44	61.36	32	40	50.82	50.75	70.97	27.27	54.17	15.38	27.78	26.32	34.3	43.22	44.39	41.46	41.32
Ceftriaxone	29.73	21.13	25.35	38.64	32	54.29	45.9	28.36	37.1	21.21	58.33	53.85	44.44	21.05	38.89	27.84	37.73	32.74	30.18
Chloramphenicol	19.19	28.17	16.9	77.27	12	22.86	18.03	25.37	9.68	6.06	33.33	30.77	11.11	5.26	15.22	19.62	20.59	19.93	18.69
Ciprofloxacin	51.8	49.3	33.8	20.45	28	40	50.82	38.81	35.48	39.39	62.5	38.46	8.33	57.89	36.96	41.2	35.14	42.88	40.3
Colistin	37.23	84.51	43.66	29.55	NT	NT	NT	47.76	32.26	NT	NT	46.15	NT	63.16	NT	39.5	42.18	36.01	39.5
Cotrimoxazole	49.21	47.89	39.44	75	8	37.14	32.79	38.81	32.26	30.3	50	38.46	36.11	5.26	34.3	42.57	35.27	46.26	40.81
Doxycycline	66.67	78.87	54.93	65.91	32	57.14	65.57	52.24	48.39	33.33	66.67	69.23	11.11	26.32	38.89	56.52	46.86	59.61	52.77
Erythromycin	88.93	96.36	70	86.11	55.56	46.67	54.9	100	69.23	32.14	64.71	80	30	21.05	46.32	77.99	64.83	76.72	70.86
Gentamicin	30.74	32.39	16.9	20.45	24	68.57	67.21	29.85	24.19	36.36	70.83	15.38	8.33	21.05	42.51	25.36	32.92	25.8	29
Linezolid	NT	NT	NT	NT	12	2.86	6.56	NT	NT	6.06	0	NT	8.33	NT	6.28	NT	8.63	3.96	6.28
Moxalactam	31.31	28.17	36.62	38.64	28	45.71	34.43	40.3	45.16	30.3	50	15.38	41.67	10.53	35.02	32.59	37.85	34.34	33.11
Nitrofurantoin	38.67	88.73	38.03	93.18	28	31.43	36.07	70.15	20.97	21.21	50	53.85	13.89	5.26	30.19	41.46	44.76	31.14	39.07
Penicillin	64.5	47.89	64.79	52.27	36	60	49.18	100	100	36.36	58.33	46.15	41.67	10.53	39.13	60.1	52.16	64.06	55.65
Piperacillin	66.99	38.33	46.3	27.03	10	28	42.59	73.91	70.49	18.52	66.67	58.33	31.82	27.78	34.88	56.2	55.04	59.94	51.74
Piperacillin Tazobactam	39.66	29.73	34.29	20	0	20	30	62.07	36.36	5.88	60	40	6.67	33.33	16.55	32.93	35.8	45.49	30.11
Tetracycline	67.1	73.24	56.34	59.09	32	45.71	57.38	55.22	53.23	30.3	79.17	69.23	5.56	21.05	38.16	56.84	50.31	57.83	52.87
Tigecycline	4.62	19.72	11.27	50	0	20	3.28	14.93	6.45	6.06	0	15.38	0	5.26	5.56	7.89	4.69	11.57	7.39
Vancomycin	NT	NT	NT	NT	16	28.57	22.95	NT	NT	30.3	12.5	NT	27.78	NT	19.57	NT	16.75	14.85	19.57

EC, *Escherichia coli;* PM, *Proteus mirabilis;* PA, *Pantoea agglomerans;* PS, *Pseudomonas aeruginosa;* SA, *Staphylococcus aureus;* SM, *Streptococcus milleri;* EF, *Enterococcus faecalis*; KP, *Klebsiella pneumoniae* ssp. *pneumoniae;* AB, *Aeromonas bestiarum;* SE, *Staphylococcus epidermidis;* EFc, *Enterococcus faecium;* AF, *Alcaligenes faecalis;* BA, *Bacillus anthracis;* PC, *Pasteurella canis;* G+, G-positiveve bacteria, G-, G-negative bacteria;WS,Cases from wildlife sanctuaries; PD, cases from pet and domestic animals

Table 4: Comparative antimicrobial susceptibility of major Gram-positive bacteria associated with blood stream infections in animals and birds (all differences were considered significant if p= <0.05).

Antimicrobials	*Bacillus anthracis*		*Enterococcus faecalis*		*Enterococcus faecium*		*Staphylococcus aureus*		*Staphylococcus epidermidis*		*Streptococcus milleri*	
	Less resistant than	More resistant than	Less resistant than	More resistant than	Less resistant than	More resistant than	Less resistant than	More resistant than	Less resistant than	More resistant than	Less resistant than	More resistant than
Amoxy-cillin	*A. bestiarum, E. coli, E. faecium, K. pneumoniae, P. aeruginosa*	*0*	*A. bestiarum, E. coli, E. faecium, K. pneumoniae, P.a eruginosa*	*0*	*0*	*B. anthracis, E. faecalis, P. agglomerans, P. canis, P. mirabilis, S. aureus, S. epidermidis*	*A. bestiarum, E. coli, E. faecium, K. pneumoniae, P. aeruginosa*	*0*	*A. bestiarum, E. coli, E. faecium, K. pneumoniae, P. aeruginosa*	*0*	*A. bestiarum, K. pneumoniae, P. aeruginosa*	*0*
Amoxy-cillin+cla-vulanic acid	*P. aeruginosa*	*0*	*E. faecium, K. pneumoniae, P. aeruginosa*	*0*	*0*	*A. bestiarum, B. anthracis, E. coli, K. pneumoniae, P. agglomerans, P. canis, P. mirabilis, S. aureus, S. epidermidis, S. milleri*	*E. faecium, P. aeruginosa*	*0*	*A. faecalis, E. faecium, K. pneumoniae, P. aeruginosa*	*0*	*E. faecium, P. aeruginosa*	*0*
Ampi-cillin	*E. coli, P. aeruginosa, P. agglomerans, P. mirabilis*	*0*	*A. faecalis, E. coli, P. aeruginosa, P. agglomerans, P. mirabilis*	*0*	*E. coli, P. aeruginosa*	*0*	*A. faecalis, E. coli, P. aeruginosa, P. agglomerans, P. mirabilis*	*0*	*A. faecalis, E. coli, P. aeruginosa, P. agglomerans, P. mirabilis*	*0*	*E. coli, P. aeruginosa, P. agglomerans, P. mirabilis*	*0*
Azithro-mycin	*E. faecalis, E. faecium, K. pneumoniae, P. aeruginosa, P. mirabilis*	*0*	*0*	*A. bestiarum, B. anthracis, E. faecalis, P. agglomerans, P. acnis, S. aureus, S. epidermidis*	*0*	*A. bestiarum, A. faecalis, B. anthracis, E. coli, P. canis, S. aureus, S. epidermidis*	*E. faecalis, E. faecium, K. pneumoniae, P. mirabilis,*	*0*	*A. faecalis, E. faecalis, K. pneumoniae, P. aeruginosa, P. mirabilis*	*0*	*K. pneumoniae*	*0*
Carba-penems	*A. bestiarum, A. faecalis, E. coli, E. faecalis, E. faecium, . canis, P. mirabilis, S. milleri*	*0*	*0*	*B. anthracis, E. coli, K. pneumoniae, P. agglomerans, S. aureus, S. epidermidis*	*0*	*A. bestiarum, B. anthracis, E. coli, K. pneumoniae, P. agglomerans, P. mirabilis, S. aureus, S. epidermidis,*	*A. faecalis, E. faecalis, E. faecium, P. aeruginosa, P. canis, S. milleri*	*0*	*A. bestiarum, A. faecalis, E. faecalis, E. faecium, P. aeruginosa, P. canis, P. mirabilis, S. milleri*	*0*	*0*	*B. anthracis, E. coli, K. pneumoniae, P. agglomerans, S. aureus, S. epidermidis*
Cefepime	*0*	*E. coli, K. pneumoniae, P. aeruginosa, P. agglomerans, P. canis, S. aureus, S. epidermidis*	*0*	*E. coli, K. pneumoniae, P. aeruginosa, P. agglomerans, P. canis, S. aureus, S. epidermidis*	*0*	*A. bestiarum, A. faecalis, B. anthracis, E. coli, K. pneumoniae, P. aeruginosa, P. canis, P. mirabilis, S. aureus, S. epidermidis*	*A. bestiarum, B. anthracis, E. faecalis, E. faecium, P. mirabilis, S. milleri*	*0*	*B. anthracis, E. faecalis, E. faecium, S. milleri*	*0*	*0*	*P. aeruginosa, P. canis, S. aureus, S. epidermidis*
Cefo-taxime	*0*	*E. coli, P. canis, P. mirabilis, P. agglomerans, S. aureus*	*0*	*P. canis*	*0*	*E. coli, P. canis, P. mirabilis, P. agglomerans, S. aureus*	*B. anthracis, E. faecium, S. milleri*	*0*	*0*	*P. canis*	*0*	*E. coli, P. agglomerans, P. canis, P. mirabilis, S. aureus*
Cefoxitin	*A. bestiarum, E. faecalis, E. faecium, . pneumoniae, P. aeruginosa,*	*0*	*A. bestiarum*	*A. faecalis, B. anthracis, S. epidermidis*	*0*	*A. faecalis, B. anthracis, S. epidermidis*	*A. bestiarum, P. aeruginosa*	*0*	*A. bestarum, E. faecalis, E. faecium, K. pneumoniae, P. aeruginosa*	*0*	*A. bestiarum*	*0*
Ceftri-axone	*0*	*P. agglomerans, P. mirabilis, S. epidermidis*	*0*	*E. coli, K. pneumoniae, P. agglomerans, P. canis, P, mirabilis, S. epidermidis*	*0*	*E. coli, K. pneumoniae, P. canis, P. mirabilis, P. agglomerans, S. aureus, S. epidermidis*	*0*	*0*	*A. faecalis, B. anthracis, E. faecalis, E. faecium, S. milleri*	*0*	*0*	*E. coli, K. pneumoniae, P. agglomerans, P. canis, P. mirabilis, S. epidermidis*
Chloram-phenicol	*E. faecium, P. mirabilis, P. aeruginosa*	*0*	*P. aeruiginosa*	*0*	*P. aeruiginosa*	*A. bestiarum, B. anthracis, P. canis, S. epidermidis*	*P. aeruginosa*	*0*	*A. faecalis, E. faecium, K. pneumoniae, P. aeruginosa, P. mirabilis, S. milleri*	*0*	*P. aeruginosa*	*S. epidermidis*
Cipro-floxacin	*A. bestiarum, A. faecalis, E. coli, E. faecalis, E. faecium, K. pneumoniae, P. agglomerans, P. canis, P. mirabilis, S. epidermidis, S. milleri*	*0*	*0*	*B. athracis, P. aeruginosa, P. agglomerans, S. aureus*	*0*	*A. bestiarum, B. anthracis, K. pneumoniae, P. aeruginosa, P. agglomerans, S. aureus*	*B. anthracis, E. coli, E. faecalis, E. faecium, P. canis*	*0*	*0*	*B. anthracis*	*0*	*B. anthracis*
Cotri-moxazole	*A. bestiarum, A. faecalis, P. aeruginosa, S. aureus*	*P. canis*	*E. coli, P. aeruginosa*	*P. canis, S. aureus*	*P. aeruginosa*	*P. canis, S. aureus*	*A. bestiarum, A. faecalis, B. anthracis, E. coli, E. faecalis, E. faecium, K. pneumoniae, P. aeruginosa, P. agglomerans, P. mirabilis, S. epidermidis, S. milleri*	*0*	*E. coli, P. aeruginosa*	*P. canis, S. aureus*	*P. aeruginosa*	*P. canis, S. aureus*
Doxy-cycline	*A. bestiarum, A. faecalis, E. coli, E. faecalis, E. faecium, K. pneumoniae, P. aeruginosa, P. agglomerans, P. mirabilis, S. aureus, S. epidermidis, S. milleri*	*0*	*0*	*A. bestiarum, B. anthracis, P. canis, S. aureus, S. epidermidis*	*0*	*B. anthracis, P. canis, S. epidermidis*	*A. faecalis, E. coli, E. faecalis, E. faecium, P. aeruginosa, P. agglomerans, P. mirabilis, S. milleri*	*B. anthracis*	*A. faecalis, E. coli, E. faecalis, E. faecium, P. aeruginosa, P. agglomerans, P. mirabilis, S. milleri*	*B. anthracis*	*S. aureus*	*B. anthracis, P. canis, P. mirabilis, S. epidermidis*

Erythro-mycin	*A. bestiarum, A. faecalis, E. coli, E. faecium, K. pneumoniae, P. mirabilis*	*0*	*E. coli, K. pneumoniae, P. aeruginosa, P. mirabilis*	*P. canis, S. epidermidis*	*E. coli, K. pneumoniae, P. mirabilis*	*B. anthracis, P. canis, S. epidermidis*	*E. coli, K. pneumoniae, P. aeruginosa, P. mirabilis,*	*P. canis*	*A. bestiarum, A. faecalis, E. coli, E. faecalis, E. faecium, K. neumoniae, P. aeruginosa, P. agglomerans, P. mirabilis*	*0*	*E. coli, K. pneumoniae, P. aeruginosa, P. agglomerans, P. canis, P. mirabilis*	*0*
Genta-micin	*A. bestiarum, E. coli, E. faecalis, E. faecium, K. pneumoniae, P. mirabilis, S. epidermidis, S. milleri*	*0*	*0*	*A. bestiarum, A. faecalis, B. anthracis, E. coli, K. pneumoniae, P. agglomerans, P. aeruginosa, P. canis, P. mirabilis, S. aureus, S. epidermidis*	*0*	*A. bestiarum, A. faecalis, B. anthracis, E. coli, K. pneumoniae, P. aeruginosa, P. agglomerans, P. canis, P. mirabilis, S. aureus, S. epidermidis*	*E. faecalis, E. faecium, S. milleri*	*0*	*E. faecalis, E. faecium, S. milleri*	*B. anthracis, P. agglomerans*	*0*	*A. bestiarum, A. faecalis, B. anthracis, E. coli, K. pneumoniae, P. aeruginosa, P. agglomerans, P. canis, P. mirabilis. S. aureus, S. epidermidis*
Moxa-lactam	*0*	*P. canis*	*0*	*P. canis*	*0*	*A. faecalis, E. coli, P. canis, P. mirabilis*	*0*	*0*	*0*	*0*	*0*	*A. faecalis, P. canis*
Nitro-furantoin	*A. faecalis, E. coli, E. faecalis, E. faecium, K. pneumoniae, P. aeruginosa, P. agglomerans, P. mirabilis*	*0*	*K. pneumoniae, P. aeruginosa, P. mirabilis*	*B. anthracis, P. canis*	*P. aeriginosa, P. mirabilis*	*A. bestiarum, B. anthracis, P. canis, S. epidermidis*	*K. pneumoniae, P. aeruginosa, P. mirabilis, S. milleri*	*P. canis*	*A. faecalis, E. coli, E. faecium, K. pneumoniae, P. aeruginosa, P. mirabilis*	*0*	*K. pneumonia, P. aerugionosa, P. mirabilis*	*P. canis*
Penicillin	*E. coli, P. agglomerans*	*P. canis*	*E. coli*	*P. canis*	*0*	*P. canis*	*E. coli, P. agglomerans*	*P. canis*	*E. coli, P. agglomerans, S. milleri*	*P. canis*	*0*	*P. canis, S. epidermidis*
Pipera-cillin	*A. bestiarum, E. coli, E. faecium, K. pneumoniae*	*0*	*A. bestiarum, E. coli, K. pneumoniae*	*S. aureus, S. epidermidis*	*0*	*B. anthracis, P. aeruginosa, P. canis, P. mirabilis, S. aureus, S. epidermidis, S. milleri*	*A. bestiarum, A. faecalis,E. coli, E. faecalis, E. faecium, K. pneumoniae, P. agglomerans, P. mirabilis*	*0*	*A. bestiarum, A. faecalis, E. coli, E. faecalis, E. faecium, K. pneumoniae*	*0*	*A. bestiarum, E. coli, E. faecium, K. pneumoniae*	*0*
Pipera-cillin +Tazo-bactam	*A. bestiarum, E. coli, E. faecium, K. pneumoniae, P. agglomerans*	*0*	*0*	*S. aureus*	*0*	*B. anthracis, P. canis, S. aureus, S. epidermidis*	*A. bestiarum, A. faecalis, E. coli, E. faecalis, E. faecium, K. pneumoniae, P. agglomerans, P. canis, P. mirabilis,*	*0*	*A. bestiarum, A. faecalis, E. coli, E. faecium, K. pneumoniae, P. agglomerans, P. mirabilis*	*0*	*K. pneumoniae*	*0*
Tetra-cycline	*A. bestiarum, A. faecalis, E. coli, E. faecalis, E. faecium, K. pneumoniae, P. aeruginosa, P. agglomerans, P. mirabilis, S. aureus, S. epidermidis, S. milleri*	*0*	*0*	*B. anthracis, P. canis, S. aureus, S. epidermidis*	*0*	*A. bestiarum, B. anthracis, K. pneumoniae, P. agglomerans, P. canis, S. aureus, S. epidermidis, S. milleri*	*A. faecalis, E. coli, E. faecalis, E. faecium, K. pneumoniae, P. aeruginosa, P. agglomerans, P. mirabilis*	*B. anthracis*	*A. bestiarum, A. faecalis, E. coli, E. faecalis, E. faecium, K. pneumoniae, P. aeruginosa, P. agglomerans, P. mirabilis*	*B. anthracis*	*E. coli, E. faecium, P. mirabilis*	*B. anthracis*
Tige-cycline	*A. faecalis, K. pneumoniae, P. aeruginosa, P. agglomerans, P. mirabilis, S. milleri*	*0*	*K. pneumoniae, P. aeruginosa, P. mirabilis, S. milleri*	*0*	*A. faecalis, K. pneumoniae, P. agglomerans, P. mirabilis, S. milleri*	*0*	*A. faecalis, K. pneumoniae, P. aeruginosa, P. mirabilis, S. milleri*	*0*	*P. aeruginosa*	*0*	*P. aeruginosa*	*A. bestiarum, B. anthracis, E. coli, E. faecalis, E. faecium, S. milleri*

5. Discussion

This analytical study revealed that *E. coli* and strains of *Staphylococcus* species were the most commonly isolated ones from the heart blood of animals and birds that died of septicaemia. The observations are in concurrence with earlier reports mentioning there are two groups of bacteria as major causes of bloodstream infections not only in animals and birds [13, 14, 15] but also in humans [3, 4, 5]. Other common groups of bacteria identified from blood samples of animals and birds in the study belonged to *Aeromonas*, *Bacillus*, *Pasteurella*, and *Streptococcus* species. Among these, *Streptococcus* strains are also a common cause of septicaemia in humans [7] and animals [16], while *Pasteurella* strains are commonly reported in animals and birds in India [17] and abroad [3, 4, 5, 16]. Strains of *B. anthracis* were detected in blood samples of nine animals and a bird is of concern as anthrax, a disease caused by *B. anthracis*, is endemic in Southern India and is comparatively uncommon in Northern India in domestic animals [17]. Of the other bacteria detected in pure culture from blood samples *Klebsiella pneumoniae, Salmonella* Typhimurium, *Yersinia* species [13, 14, 15], *Aeromonas* and *Pseudomonas* spp. *Serratia*, *Salmonella*, and *Proteus* species strains [16] have been reported earlier too as causes of septicemic infections and deaths in animals. Though pasteurellosis in the form of haemorrhagic septicaemia (HS), caused by *P. multocida*, is endemic in India [17], deaths due to *P. canis* have rarely been reported in India [30]. Another *Pasterurella* (*P. dagmatis*) identified as a cause of septicemic death in a duck unit is still more rare cause of septicaemia but dogs are known to spread this through their bite causing wound infection and local sepsis [31] and rarely fatal septicaemia [32]. Though *Pasteurella* strains were associated with several deaths in the study, 80% of the isolates were susceptible to tetracycline, one of the most recommended antibiotics for the treatment of pasteurellosis in animals and birds [14, 15]. However, the presence of carbapenem resistance (CR) in many of the *Pasteurella* strains is of concern and is rare even in *Pasteurella* strains of human origin [33].

There is no surprise in finding *E. coli* as the most common cause of septicaemic infections in animals and birds but carbapenem drug-resistance in 22.88% of the *E. coli* isolates from heart blood samples of affected animals and birds is of public health concern [34]. The reason for the acquisition of carbapenem-resistant *E. coli* (CRE) in animals and birds may not be the use of carbapenems in animals and birds but the consumption of contaminated food and water. Water bodies in Northern India have been reported to harbour not only CRE but other CR bacteria too [35]. Besides CRE, carbapenem resistance was detected in 26.80% of the isolates of other bacteria and is of very serious public health concern as this high level of carbapenem resistance is rarely reported in pathogens in other parts of the world [34], however, about a quarter of water bodies in Bareilly regions have been reported to harbour carbapenem-resistant bacteria [35].

Though *S. aureus* is considered to be the major staphylococci associated with septicemic infections in animals [13-15], the present study indicated the emergence of other species of *Staphylococcus* as major cause of septicemia which were isolated from 41 cases while *S. aureus* strains were detected in 18 cases. If we consider isolation in pure culture even then S. aureus was much behind than other species of Staphylococcus, as it was isolated from only two blood samples in pure culture, and *S. epidermidis* from four blood samples. Methicillin-resistant *S. aureus* (MRSA) are often considered the nastiest ones due to the associated health risk [34], in the present study 22.22% of the *S. aureus* isolates could be classified as MRSA, 52.63% had MDR and 21.05 % were resistant even to meropenem. More of the staphylococci other than *S. aureus* were found to be methicillin-resistant (24%), carbapenem-resistant (29.79%) and 65.96% had MDR. Therefore, the detection of other staphylococci in many more cases than *S. aureus* indicated the emergence of non-*S. aureus* staphylococci loaded with more drug resistance potential may be the bigger threat to animal health [36].

Acinetobacter calcoaceticus-baumannii complex strains isolated from five cases of those it was present as a single bacterium in two cases is of concern as this bacterium considered a cause of nosocomial infections in humans are rarely reported as a cause of death or septicaemia in animals and is considered as one of the neglected pathogens in the veterinary field [37]. *Acinetobacter* is often considered important due to their high levels of antimicrobial drug resistance (AMR), in the present study 88.89% of the *Acinetobacter* isolates had multiple drug resistance (MDR) and 33.33% had CR, these figures are quite in the occurrence of MDR and CR reported in Acinetobacter isolates present in water bodies of the study region [35]. The high levels of drug resistance in *Acinetobacter* killing animals and birds indicate the grim future of health in the region.

Alcaligenes denitrificans and *A. faecalis* were not only isolated from heart blood samples but as pure culture from four cases indicating the importance of this emerging pathogen of veterinary health significance. *Alcaligenes* strains are rarely reported cause of septicemia in animals and in humans [38]. In the study, 64.29% and 35.71% of the *Alcaligenes* isolates were MDR and CR type, respectively and these values are comparatively lower than those reported earlier *Alcaligenes* isolates from water bodies (84.62% MDR and 83.33% CR strains) in Bareilly [35].

Gallibacterium anatis isolates were detected in the blood of nine isolated cases of death birds have been reported as an emerging pathogen in Northern India [19, 20]. In the present study, four of the 7 isolates had MDR and quinolone resistance. The emergence of drug resistance in *G. anatis* strains in India [19] and abroad has been reported earlier too [39].

Though many aeromonads have been reported to be associated with bloodstream infection in reptiles and wild animals [16, 21], *A. bestiarum* was detected in 14 blood samples and four cases as a single bacterium in pure culture from two cases of deaths in poultry birds and one sample each from cattle and bison is of concern. Though *A. bestirum* isolates have been identified as a cause of abortion and death in wild cats [26, 27], they have rarely been reported as a cause of death in domestic animals and birds in India. In the study, 82.86% and 34.29% of the *Aeromonas* isolates had MDR and CR, respectively. The emergence of drug resistance in Aeromonads too is an emerging problem similar to other pathogens, and water bodies in the Bareilly region have been reported recently full of MDR and CR strains of Aeromonas species [35].

Detection of *Falvobacterium aquatile*, a pathogen of aquatic animals and fish [40], in pure culture from the heart blood of a tiger that died in a wildlife sanctuary, is rare, and the animal might have got the infection from water or fish in wild. The observation indicated a widening of the host range of this rare pathogen of terrestrial animals. The isolate of *F. aquatile* causing the death of the tiger was resistant to tetracycline, the drug which is often recommended as the drug of choice for Flavobacterium infection [40]. Therefore, AST should be recommended before the institution of antimicrobial therapy.

In the present study strains of *Lysinibacillus sphaericus* and *L. odysseyi* detected in two and three cases of herbivores, respectively, and *L. sphaericus* was the sole isolate in pure culture from the heart blood of an elephant that died of septicaemia is of importance as this ubiquitous bacterium have rarely been reported to cause septicaemia in animals, but is reported to cause sepsis in humans [41]. The presence of MDR specifically against commonly used antilikes (ampicillin, tetracycline, chloramphenicol and cephalosporins) in the strains of *L. sphaericus* associated with the death of elephants is of public health concern.

Micrococcus luteus was detected in seven heart blood samples and could be attributed as the cause of death at least in one case where it was isolated in pure culture from the heart blood of a dead poultry bird. Though M. *luteus* is not considered a pathogen it is reported to cause pneumonia, localized cutaneous infections, and catheter-related infections [42]. Most of the micrococci isolates had resistance to azithromycin, a drug of choice for infections caused by G+ve bacteria [14, 15], is of concern but their susceptibility to other antibiotics like chloramphenicol and ciprofloxacin keeps the hope for management of infections with micrococci.

Strains of Moraxella ovis, M. lacunita and *M. phenylpyruvica* (now known as *Psychrobacter phenylpyruvicus*) were detected in three blood samples one each of black buck, leopard and elephant, respectively. Though *M. lacunita* and *M. phenylpyruvica* were not isolated as the sole pathogen, *M. ovis* was isolated in pure culture from the heart blood of a black buck deer that died of septicaemia. Although *M. ovis* strains are known to cause conjunctivitis, polyarthritis and metritis in sheep and goats; they rarely cause infections in other animals, that too, lethal for septicaemia [43, 44]. *Moraxella lacunata* is a commensal flora of the upper respiratory tract and rarely causes conjunctivitis, keratitis, endophthalmitis, endocarditis, septic arthritis and kidney infections [45]. Isolates of *Psychrobacter phenylpyruvicus* are reported to be associated with urinary tract infection, pleuritis, endocardititis and upper respiratory tract infection but rarely cause fatal septicaemia [46, 47]. Susceptibility of all three strains of *Moraxella* to antibiotics including ampicillin is an indication Indian *Moraxella* strains might be lacking the R-factors in Moraxella from other countries [48].

Though *Serratia* strains belonging to four species (*S. maecescens, S. odorifera, S. plymuthica* and *S. rubidaea*) were detected in eight blood samples, only *S. rubidaea* was detected as a sole bacterium in pure culture from heart blood of a horse died of infection. *Serratia* strains are known to cause lethal infections in animals, and birds [16] and invasive infections and bacteraemia in humans leading to fatal outbreaks [49, 50]. Thus, the isolation of *S. rubidaea* as the single cause of bacteremia in a pet horse may be alarming. More than 85% of isolates in the study produced extended spectrum-β-lactamases (ESBL), and more than 70% had MDR but none was resistant to carbapenems. Though *Serratia* strains are often considered opportunistic pathogens with alarmingly high levels of MDR and CR [51], in an earlier study in Bareilly on *Serratia* strains of water origin CR was not observed [35].

Strains of *Streptococcus* species were detected in 30 blood samples in all types of domestic and wildlife animals and birds, *S. melleri* being the most prominent one but in only one case of death in poultry birds an isolate of *S. porcinus* was detected in pure culture. *Streptococcus milleri,* also known as *S. anginosus*, the most common streptococci identified in heart blood samples has emerged as an important pathogen in humans known to cause head and neck infections and abscesses [52] responsible for almost two-third pyogenic infections of the brain [53]. About two decades ago most of the *S. milleri* strains were considered susceptible to ciprofloxacin [54], cefotaxime and vancomycin [55] but in the present study one-third of the isolates were resistant to ciprofloxacin and almost 50% of the isolates were resistant to vancomycin and cefotaxime indicating the fast emergence of drug resistance in *S. milleri*. The emergence of AMR in *S. milleri* strains sees to be faster as they were more often resistant to vancomycin, cefotaxine, and ciprofloxacin than isolates belonging to other species of streptococci. Streptococci of many different species are one of the most prominent causes of bacteraemia and septicaemia in humans and animals [4, 5, 7, 13-17, 26, 27] but *S. porcinus,* an upper-respirartory tract pathogen of swines often associated with pneumonia, septicaemia, arthritis, metritis and abortion [56, 57] has rarely been reported as a cause of septicaemic death in poultry birds. The observation indicated widening of host range of animal's pathogens, an imminent threat.

Vribrio alginolyticus was isolated from a poultry bird diagnosed died due to salpingitis, oophoritis, egg peritonitis, impacted oviduct and septicaemia is a halotolerant bacterium often present in sea environments and reported to cause wound infections in human [58]. The source of infection in the poultry birds was not known but fishmeal used as a feed ingredient may be a possible source. The isolate was susceptible to most of the antibiotics including tetracycline, often used as a drug of choice in the treatment of *V. alginolyticus* infections.

The study concludes that in animals and birds, *E. coli* and *Staphylococcus* species are the two major causes of bloodstream infection but *P. aeruginosa, P. mirabilis* and *P. agglomerans* are equally important. Among streptococci, S. milleri and aeromonads A. bestiarum have emerged as an important cause of septicaemia in animals and birds. Further, the emergence of AMR in pathogenic bacteria especially towards the reserved antibiotics (carbapenems, tigecycline, linezolid not allowed to be used in animals) indicated that it is not necessary to use antibiotics in therapeutics to have AMR strains in animals and birds.

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