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Clinical recovery from multidrug-resistant bacterial infection in a suppurative wound of a Royal Bengal Tiger using linezolid

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Abstract

Antimicrobial resistance (AMR) poses a critical threat to both human and animal health, with indiscriminate and excessive antibiotic use in livestock and captive wildlife contributing to its rapid emergence. This case report describes a clinical case of treatment failure due to multidrug-resistant bacteria in a captive tiger (*Panthera tigris*) at Chattogram Zoo, Bangladesh. An adult tiger was injured in a fight, leading to a wound on the shoulder region. Initial treatment with flucloxacillin (10 mg/kg, intramuscularly [IM], for 13 days) failed to yield improvement. Subsequent bacteriological culture and antimicrobial susceptibility (AMS) testing revealed flucloxacillin resistance. The animal was then treated sequentially with cefazolin (20 mg/kg IM, 13 days) and ciprofloxacin (15 mg/kg IM, 10 days), both of which were identified as susceptible in vitro; however, neither resulted in clinical recovery. The administration of linezolid (600 mg orally, every 12 hours for 15 days) led to complete wound healing. This case highlights the clinical challenges posed by AMR in captive wild animals and underscores the necessity of prompt culture-guided therapy and prudent antibiotic use in zoological settings.

Keywords: Antimicrobial susceptibility, captive animal, cefazolin, flucloxacillin, treatment failure, wildlife disease.

Introduction

The tiger (*Panthera tigris*) is the largest cat species, and it is native to Asia (Maharjan *et al.*, 2024). In taxonomical classification, it belongs to the order Carnivora within the family Felidae (Wild Cat Family, 2024). There are nine subspecies of tiger in the world; six of these subspecies are endangered, and the remaining three are extinct (Wilting *et al.*, 2015). The endangered six subspecies are the Bengal (*P. t. tigris*), Indo-Chinese (*P. t. corbetti*), South China (*P. t. amoyensis*), Siberian (*P. t. altaica*), Malayan (P. t. jacksoni), and Sumatran (P. t. sumatrae) tigers. The extinct three subspecies are the Caspian tiger (*P. t. virgata*), the Javan tiger (*P. t. sondaica*), and the Bali tiger (*P. t. balica*) (Liu *et al.*, 2018). The Bengal Tiger is a living subspecies native to Asia, most commonly found in Bangladesh, India, Nepal, and Bhutan (Goodrich *et al.,* 2022). The Bengal tiger is listed as an endangered subspecies according to the IUCN Red List of Threatened Species (IUCN 2021). According to the last census conducted in 2024, the number of Royal Bengal Tigers living in the Sundarbans is 125 (Bangladesh Forest Department 2024), which represents about 5.0%-6.25% of the entire wild Bengal tiger population in the world. Zoos provide conservation support for endangered species, playing a vital role in the conservation of the tiger population (Christie 2010).

Antimicrobial resistance (AMR) has become a major global threat to humans, animals, and plants (WHO 2023). A major driver of antimicrobial resistance (AMR) in animals is the prophylactic use of antimicrobials for disease prevention or growth promotion. Subtherapeutic doses of antimicrobials are also responsible for the emergence of resistant bacterial strains (Van Boeckel *et al.*, 2015). Antibiotic-resistant bacteria (ARB) and antibiotic residues may transfer into wild animals through various routes, such as food/ meat, and the environment. Manure of the food-producing animals used in the land acts as a reservoir of resistant bacteria and antibiotic residues; these spread

into the wild animal population (Libisch *et al.*, 2020). Food-producing animals, especially poultry, may be an important source of antibiotic-resistant bacteria due to the extensive use of antibiotics, including third-generation antibiotics, in industrial farming (Alam *et al.*, 2023; de Been *et al.*, 2014). Thus, chicken meat when supplied as a diet can transfer AMR to the tigers in captive conditions (Shousha *et al.*, 2015). In captive conditions, tigers are fed raw meat diets consisting of broiler meat, beef, whole poultry, or rabbit carcass (Dotterweich & Lacie, 2020). These types of feed ingredients can transfer AMR to tigers in captive conditions. In captivity, tigers remain in close contact with humans, who can transfer AMR bacteria from humans to animals as well (Xue *et al.*, 2016). In Bangladesh, most of the AMR research mainly focused on livestock, poultry, and humans, but there is a limited number of studies on evidence-based treatment of captive wildlife like tiger that are victims of AMR bacteria. This case report aims to analyse therapeutic challenges, AMR patterns and clinical management of a persistent MDR wound infection in a Royal Bengal Tiger.

Materials and Methods

Case history and clinical examination

The Chattogram Zoo, Bangladesh currently houses 19 Royal Bengal tigers in two separate enclosures segregated by sex. The zoo is managed by a team of two on- site veterinarians, and they are responsible for animal health, medical care and nutrition. The tigers are routinely fed raw meat, including chicken and beef, at an allotted amount that is determined by veterinarians. On 8 April 2024, a wound was detected on shoulder of a 3.1-year-old female tiger, which was presumed to have resulted from intraspecific fighting (Figure 1). Notably, this tiger had experienced a similar fighting-related injury the previous year, which had successfully healed following treatment with the antibiotic ceftriaxone. In the current incident, she was treated with flucloxacillin at a dose of 10 mg/kg body weight, administered at 8-hour intervals for 13 consecutive days. However, the tiger did not respond to this therapeutic regimen.

Laboratory Test

- *Sample collection, transportation and preservation*

For the bacteriological culture and antimicrobial susceptibility test (AST), sterile swab samples were collected from the wound of the tiger for three consecutive days following the failure of antibiotic therapy. The first sample was obtained on the 19th day of postinfection, after completing a 13-day course of flucloxacillin. The infection did not subside, so the second sample was collected on the 35th day after the failure of recovery of a 13-day course of cefazolin, and the final sample was collected on the 45th day after finishing a 10-day course of ciprofloxacin. A sterile cotton bud was gently rubbed on the wound area and then dissolved in 3 mL of 0.9% NaCl that was contained in the 10mL falcon tube (Scenesafe, UK). The marked falcon tube was placed in an icebox that maintained a temperature of 4°C and carried to the Udder Health Bangladesh (UHB) lab, where it was maintained at 4°C until the bacterial culture.

Figure 1. Wound present on the shoulder region of the tiger

- *Bacteriological culture and antimicrobial susceptibility*

The collected sample was inoculated on blood agar supplemented with 5% bovine blood, MacConkey agar, and incubated for 24 hours at 37 °C. Presumptive identification of bacteria was done based on cultural characteristics on blood agar, which was identified as gram-positive bacteria and growth on blood agar and MacConkey agar was identified as both gram-negative and gram-positive bacteria, as follows by Singha (Singha *et al.*, 2024). Antimicrobial susceptibility tests were performed using the Kirby–Bauer disc diffusion method according to the Clinical and Laboratory Standards Institute (CLSI) (Humphries *et al.*, 2021). A total of 17 antibiotic discs were used in AMS test including Amoxicillin+Clavulanic Acid (20µg+10µg), Ampicillin (10 µg), Ceftriaxone (30 µg), Ciprofloxacin (5 µg), Clindamycin (2 µg), Cefazolin (30 µg), Gentamicin (10 µg), Cefotaxime (5 µg), Ceftazidime (10 µg), Linezolid (30 µg), Vancomycin (30 µg), Cefoxitin (30 µg), Oxacillin (1 µg), Erythromycin (15 µg), Penicillin (0.6 µg), Sulfamethoxazole + Trimethoprim (23.75 µg+1.25 µg), and Tetracycline (30 µg). The results of the AMS tests were interpreted according to the criteria established by CLSI guidelines (Humphries *et al.*, 2021) as susceptible, intermediate, and resistant (Table 1). Resistant to at least one agent of three or more antimicrobial categories, determined as MDR bacteria.

Treatment Strategy

Following the injury, the tiger was initially treated with flucloxacillin at a dosage of 10 mg/kg body weight, administered intramuscularly at 8-hour intervals for 10 consecutive days (Table 2). However, no clinical improvement was observed. Subsequently, bacteriological isolation and AMS testing were conducted. The AMS test results revealed resistance to clindamycin and ceftriaxone, whereas cefazolin was found to be effective. Based on these findings, the tiger was treated with cefazolin (Inj. Zolibac 1 g®, manufactured by Square Pharmaceuticals PLC, Bangladesh) at 20 mg/kg body weight, administered intramuscularly at 8-hour intervals for 13 consecutive days, but remained ineffective. Further, the AMS test result showed that the sensitive antibiotic was ciprofloxacin. Then the antibiotic ciprofloxacin (Inj. Ciprocin 50 mL®, manufactured by Square Pharmaceuticals PLC, Bangladesh) was provided at 15 mg/kg body weight intramuscularly in 8-hour intervals for 10 days. But when it did not work, another AMS test was conducted. AMS test results indicated that the antibiotics linezolid and vancomycin were sensitive. After these tests, the tiger was treated with the antibiotic linezolid (Tab. Linzolid-600 mg®, manufactured by Incepta Pharmaceuticals Limited, Bangladesh), using one tablet (600 mg) at 12-hour intervals orally for 15 days. After this medication, the tiger fully recovered.

Results and Discussion

The current case report was considered to describe the antibacterials used to treat the injured tiger. The current study identified a multidrug-resistant bacterial infection in the wound of the Royal Bengal Tiger. The result of consecutive culture and AST revealed that the responsible bacteria showed

Table 1. Summary of the antimicrobial susceptibility and resistance profiles of suspected bacteria over time, and key findings reflect the presence of multidrug-resistant (MDR) bacteria.

Date	Tested antibiotics[1]	Sensitive antibiotics [2]	Resistant antibiotics[3]	Suspected Bacterial Type[4]
28/04/24	Cefazolin, Clindamycin, Ceftriaxone Vancomycin	Cefazolin, Vancomycin (intermediate)	Clindamycin, Ceftriaxone	Gram Positive, Gram Negative
15/05/24	Amoxycillin+Clavulanic acid, Ceftriaxone, Ciprofloxacin, Gentamycin,Cefotaxime, Ceftazidime, Ampicillin	Ciprofloxacin	Amoxycillin+Clavulanic acid, Ceftriaxone, Gentamycin, Cefotaxime, Ceftazidime, Ampicillin	Gram Positive
26/05/24	Ampicillin, Cefoxitin, Erythromycin, Ciprofloxacin, Amoxycillin+Clavulanic acid, Penicillin, Gentamycin, Linezolid, Vancomycin	Linezolid, Vancomycin	Ampicillin, Cefoxitin, Erythromycin, Ciprofloxacin, Amoxycillin+Clavulanic acid, Penicillin, Gentamycin	Gram Positive, Gram Negative

[1] AST were performed against these listed antibiotics by following CLSI guidelines
[2]Antibiotics shown efficacy to effectively kill or inhibit microorganism on AST
[3]Antimicrobials to which microorganism shows resistance on AST
[4]The presumptive bacterial identification based on the growth on blood agar and MacConkey agar

resistance to multiple classes of antimicrobials like tetracyclines, penicillins, aminoglycosides, and exhibited susceptibility to the third-generation cephalosporins, fluoroquinolones, and Oxazolidinones. Focused on these findings, the therapeutic regimen was strategically changed at each stage to promote gradual healing of the wound and complete clinical recovery of the tiger. To the best of our knowledge, this is the first documented report of the successful management of a MDR wound infection in a Royal Bengal Tiger with linezolid. The necessity to require a critical last-line antibiotic like linezolid for wound management underscores the growing and serious threat of antimicrobial resistance in captive wild animals and the severe depletion of viable therapeutic options. Linezolid is a well- established antibiotic in human medicine, but its application to large wild felids has not been reported previously.

In this current case, microbiological investigation was limited to phenotypic bacterial isolation and AST, but species-level identification could not be performed due to limitations of advanced diagnostic infrastructure during case management. Advanced molecular diagnostic techniques, including 16s rRNA gene sequencing and MALDI-TOF mass spectrometry, may provide precise species-level identification and should be considered in future investigations of MDR infection cases in wildlife species (Seng *et al.*, 2009; Woo *et al.*, 2008).

Initially, following the injury, the tiger was treated with flucloxacillin. It is a narrow-spectrum, beta-lactamase-resistant penicillin (Kennard *et al.*, 2019). Recently, the use of the antibiotic flucloxacillin has increased for treatment purposes, and this overuse can develop antimicrobial resistance (Francis *et al.*, 2016). After the use of flucloxacillin, the tiger did not recover, possibly in response to the invasion by antimicrobial-resistant bacteria.

When flucloxacillin didn't work, then the AMS test was conducted, and it showed that the Cefazolin was sensitive in-vitro. Cefazolin is a first-generation antibiotic in the group of cephalosporins (Kirby *et al.*, 1973). Then Cefazolin was administered at 20 mg/kg body weight intramuscularly for 13 days, but the wound did not heal. In a study, cefazolin showed less effectiveness against some strains of Staphylococcus aureus (Weis *et al.*, 2019). Methicillin-susceptible Staphylococcus aureus (MSSA) strains can produce type A beta-lactamase; these are responsible for the failure of cefazolin (Nannini *et al.*, 2009). Further in-vitro AMS tests identified Ciprofloxacin as a sensitive antibiotic. Based on the veterinarian's advice, Ciprofloxacin at 15 mg/kg body weight at 8-hour intervals intramuscularly was used for 10 days. Ciprofloxacin is an antibiotic in the group of fluoroquinolones, and it is effective against gram-positive and gram-negative bacteria and also against methicillin-resistant Staphylococcus aureus (MRSA) and Pseudomonas aeruginosa (Terp & Rybak, 1987). However, it remained ineffective. Further AMS tests showed that the antibiotic ciprofloxacin became resistant, but it was sensitive previously. Due to improper use of this antibiotic, it might have developed resistance, which arises when the treatment disturbs the susceptible bacteria and selectively allows adapted or mutated strains to survive, expand, and spread to others (Habboush & Guzman N, 2025).

In the final AMS test, the result indicated the sensitive antibiotic was linezolid. Linezolid is a synthetic antibiotic in the class of oxazolidinones. It is highly effective against gram-positive bacteria and indicated for the treatment of skin infections (Azzouz & Preuss, 2024). It acts by binding to the 23S rRNA component of the 50S ribosomal subunit, thereby blocking formation of the 70S initiation complex essential for bacterial protein synthesis (Shinabarger *et al.*, 1997). This distinct mechanism confers no cross-resistance with other antibiotic classes (Falagas *et al.*, 2008). It is found to be highly sensitive to the methicillin-resistant Staphylococcus aureus or Streptococcus pyogenes that are responsible for the skin infection. It is also effective against vancomycin-resistant enterococci (Hashemian *et al.*, 2018). Then linezolid was prescribed at a dose of 600 mg at 12-hour intervals for 15 days. After this treatment, the tiger recovered (Figure 2). This outcome illustrates a critical, growing problem of multidrug-resistant (MDR) infection in captive wildlife. This case gives strong reasoning for evidence-based treatment decisions and a need for AMR surveillance in the captive wildlife interface.

This study is constrained by some limitations of a single-case nature, the absence of bacterial specification, and the lack of pharmacokinetic data for linezolid in tigers. Future investigation should focus on bacterial specification, increased sample size with collaborations, and pharmacokinetic evaluations to validate therapeutic application in tigers.

Table 2. Chronological therapeutic interventions, adjustment of antimicrobials and other supportive therapies guided by sequential culture and antimicrobial susceptibility test results.

Date	Groups of Drug	Generic name	Trade name	Route	Dosage	Duration
Before CS Test						
8/04/24	Antibacterial	Flucloxacillin Sodium	Inj. Fluclox 500mg	i/m	10 mg/kg (8 hours interval)	13 days
	Anthelmintic	Ivermectin	Inj. A-mectin Vet 5ml	i/m	2 ml	Single dose
Along with that as supple-ment from 10-04-24	Immunostimulant	Pidotimod	Tab. Pidonex 800mg	PO	1tab (SID)	10 days
	Anti-inflammatory	Hydrocortisone Acetate	Cream. Topicort	Topically	SID	10 days
After CS Test						
After 1st test (28-04-24)	Antibacterial	Cefazolin Sodium	Inj Zolibac -1 gm	i/m	1gm (8 hours interval)	13 days
After 2nd test (15-05-24)	Antibacterial	Ciprofloxacin	Inj Ciprocin -50 ml	i/m	15 mg/kg IM (8-hour interval)	10 days
	Proton pump inhibitor	Pantoprazole Sodium	Tab Pantonix 20	PO	1+0+1	10 days
After 3rd test (26-05-24)	Antibacterial	Linezolid	Tab Linzolid-600mg	PO	1+0+1 (12 hours interval)	15 days
	Proton pump inhibitor	Pantoprazole Sodium	Tab Pantonix 20	PO	1+0+1	15 days
	Nutritional supplement	Multivitamin and Multimineral	Syp. Zovia GOLD-100 ml	PO with feed	4 tsp	15 days

Figure 2. The tiger's wound recovered following treatment with the antibiotic linezolid.

Conclusion

This case highlights the emergence of antimicrobial resistance in a captive Bengal tiger, demonstrated by the failure of response to several antibiotic therapies. It emphasises the need for prudent antibiotic use, proper antimicrobial stewardship, and safe feeding practices in zoo animals to reduce the risk of treatment failure and curb the spread of resistant pathogens. This study indicates that evidence-based treatment decisions would be an effective pathway for management of captive wildlife, and surveillance is needed to assess the AMR in the wildlife-human-environment interface to understand the transmission of AMR bacterial strains. To elucidate resistant development and dissemination, further investigation is warranted. This evaluation should include assessing the feed, personnel and environmental samples to identify specific AMR genes and trace their potential transmission pathways.

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CONFLICT OF INTEREST

The authors declare no competing interests.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

AUTHOR CONTRIBUTIONS

Anik Dutta: Investigation, Data curation, Data visualization, Writing- original draft. Tishita Sen Ape: Laboratory analysis, Data visualization, Writing-review and editing. Md. Sarwar Uddin: Investigation, Sample collection. Md. Shahadat Hossain Suvo: Sample collection, Writing-review and editing. Shuvo Singha: Supervision, Writing-review and editing. Md. Mizanur Rahman: Writing- review and editing. All authors read and approved the final manuscript.

ETHICAL APPROVAL

Permit to handle the tiger was issued by the Ethics Committee of Chattogram Veterinary and Animal Sciences University (CVASU) under permit number CVASU/Dir(R&E) EC/2025/952/6.

USE OF GENERATIVE AI

The authors used ChatGPT (OpenAI, GPT-5.5) for grammatical improvement and language editing during the preparation of this manuscript. The authors thoroughly reviewed and edited the content generated and take full responsibility for the content of the publication.

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