Review article
UDK 616.993:615.33.015.8
https://doi.org/10.46784/e-avm.v17i1.361

ZOONOTIC DISEASES AND ANTIMICROBIAL RESISTANCE: A DUAL THREAT AT THE HUMAN-ANIMAL INTERFACE

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Abstract

With over 200 zoonotic diseases and the emergence of antimicrobial-resistant (AMR) microbes, a substantial threat looms over public health. If we are unable to cope with AMR, it suggests a potential of 10 million global fatalities by 2050. The evolving landscape of AMR transcends geographic boundaries and species, necessitating collaborative and multidisciplinary efforts. The interplay between humans, animals, and the environment highlights the profound significance of One Health in addressing these interconnected challenges. The imperative of multidisciplinary efforts to safeguard the health and well-being of our shared world, comprised of humans, animals, and the environment, can pave the way toward success. The role of surveillance, education, and public awareness in combating AMR and fostering responsible antimicrobial use is inevitable in addressing this global concern.

Key words: Antimicrobial resistance, zoonoses, One Health

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ZOONOTSKA OBOLJENJA I ANTIMIKROBNA REZISTENCIJA: DVOSTRUKA PRETNJA U RELACIJI LJUDI-ŽIVOTINJE

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Kratak sadržaj

Preko 200 zoonotskih oboljenja i sve učestalija pojava mikroorganizama rezistentnih na antimikrobne lekove (AMR) predstavljaju ozbiljnu pretnju za javno zdravlje. Ako ne uspemo da se izborimo sa antimikrobnom rezistencijom, to može da znači potencijalnih 10 miliona smrtnih slučajeva na globalnom nivou do 2050. Slika širenja AMR prevazilazi sve geografske granice i vrste, što zahteva kolaborativne i multidisciplinarne pristupe. Povezanost izmedju ljudi, životinja i životne sredine ističe značaj koncepta „Jednog zdravlja" (One Health) u pristupu ovakvim višestruko povezanim izazovima. Ovakve multidisciplinarne aktivnosti za očuvanje zdravlja i dobrobiti našeg zajedničkog sveta sastavljenog od ljudi, životinja i okoline, su svakako imperativ koji može otvoriti put za uspeh. Uloga nadzora, edukacije i razvoja javne svesti je ključna u borbi protiv AMR i afirmisanju odgovorne primene antimikrobnih supstanci u okviru ovog globalnog problema.

Ključne reči: antimikrobna rezistencija, zoonoze, Jedno zdravlje

INTRODUCTION

Antimicrobial resistance (AMR) stands as a formidable challenge in the realm of veterinary medicine and public health, presenting a critical threat to the health and well-being of animals and humans. At its core, AMR refers to the ability of microorganisms to withstand the effects of antimicrobial agents, such as antibiotics, rendering these treatments less effective (Founou et al., 2017). In the context of One Health, this phenomenon strikes at the heart of efforts to maintain animal health, ensure food security, and safeguard public health through the prevention and treatment of infectious diseases (Saleem et al., 2022). With over 200 zoonotic diseases, the development of antibiotic-

resistant bacteria and their dissemination environment and living organisms is causing a huge threat to human beings (Dafale et al., 2020).

The data, showing that approximately 4.95 million deaths were linked to bacterial antimicrobial resistance on a global scale in 2019, underscores the significant benefits of proactive infection prevention (Laxminarayan, 2022). If the current pattern of improper and excessive antibiotic use persists, projections suggest that it could lead to approximately 10 million fatalities globally by the year 2050 (Pulingam et al., 2022). The global landscape is now characterized by an escalating concern over AMR, transcending geographical boundaries and species barriers (Christaki et al., 2020). The localized issue has transformed into a pervasive challenge that spans continents, ecosystems, and sectors. The effective management of AMR is vital because it is overshadowing the remarkable development of medicine in the field of antibiotics (Marston et al., 2016). It has become the need of the hour to reinforce the impeccable mark of antibiotics, which helped save millions of lives for humans and animals.

A comprehensive strategy is imperative to confront the multifaceted challenge posed by AMR. The One Health approach emerges as a powerful paradigm, advocating for collaboration across the realms of human health, animal health, and the environment. Recognizing the intricate connections between these domains, One Health emphasizes the inextricable linkages between the health of animals, humans, and ecosystems (Olaru et al., 2023). By recognizing the interplay between veterinary medicine, medical practice, and environmental factors, the One Health approach deepens our understanding of AMR transmission and paves the way for integrated solutions that transcend disciplinary boundaries (Dafale et al., 2020).

The rise of novel, opportunistic pathogens and the increasing prevalence of drug resistance among existing pathogens represent a global concern of paramount significance (Dafale et al., 2020). Many of these emerging diseases have transcended geographical boundaries, infiltrating diverse environments worldwide. This evolving disease landscape exploits the breeding grounds for pathogenic determinants within ecosystems, utilizing any available biological host. Among these hosts, animals have emerged as a prominent breeding ground for drug-resistant pathogens (Dafale et al., 2020).

Within the intricate ecosystem of the animal gut, a myriad of microbial communities coexists, acting in synergy to benefit their host (Purohit et al., 2018). Introducing drug-resistant pathogens into this microbial landscape disrupts the delicate balance and structure of the community, facilitating the transfer of resistance genes to other pathogens within the gut (Abushaheen et al., 2020). Bacteria have developed various means to ease their transmis-

sion between animals and humans, leading to zoonotic infections with significant implications for public health. One key route for bacterial transmission is direct contact between animals and humans, allowing pathogens to transfer from one species to another. Additionally, some bacteria can spread through insects or contaminated food and water sources to reduce the gap between animal reservoirs and human populations. Once bacteria successfully cross the species barrier, their characteristics play a crucial role in shaping their virulence and pathogenicity. These pathogens may possess virulence factors, such as toxins and adhesion molecules, that enable them to adhere to host tissues, evade immune responses, and cause disease in both animal and human hosts. Furthermore, the ability of bacteria to adapt to different host environments enhances their survival and persistence, further contributing to their pathogenic potential.

The intricate interplay between humans and animals within ecosystems has given rise to a compelling paradigm known as the "One Health" approach. This approach recognizes the interconnections between human, animal, and environmental health, particularly in the context of antimicrobial resistance. It underscores the need for a holistic understanding of how the health of animals and humans are intertwined, emphasizing the importance of collaborative efforts to address the complex challenges posed by emerging pathogens and drug resistance.

ONE HEALTH AND AMR: UNDERSTANDING THE CONNECTION

The intricate web of life intertwines across species and ecosystems, forming a complex tapestry where the health of animals, humans, and the environment is interdependent (Olaru et al., 2023). In the face of global challenges, such as antimicrobial resistance (AMR), the One Health approach emerges as a compelling strategy to address the multifaceted complexities at the human-animal-environment interface (Dafale et al., 2020).

The One Health concept signifies a departure from traditional, compartmentalized approaches to health management. It acknowledges that the health of humans is deeply entwined with the well-being of animals and the environment and that disruptions in one domain can reverberate throughout the interconnected network. This holistic perspective underscores that disease processes do not respect disciplinary boundaries; they transcend species and ecosystems, necessitating collaborative efforts to unravel their complexities. Microorganisms are ubiquitous as they are present in the gut of animals, manure, soil, water bodies, and human beings. As they are interconnected and components of a cycle, drug-resistant pathogens pose a matchless threat. These

pathogens reproduce at an instant rate and also produce resistance in the native gut microbiome of living organisms (Dafale et al., 2020). This is due to the indiscriminate use of antibiotics and the lack of effective policies to restrain its dissemination.

Consequently, it becomes inevitable to entail multidisciplinary teams involving medical specialists, veterinarians, ecologists, and stakeholders to manage this aggravating concern of AMR (Dafale et al., 2020). By embracing the principles of One Health, practitioners, researchers, and policymakers are better equipped to grapple with the challenges posed by emerging diseases, including those fueled by antimicrobial resistance.

The global rise of antimicrobial resistance exemplifies the urgent need for a One Health perspective (Majumder et al., 2020). As pathogens evolve and adapt in response to antimicrobial agents, they threaten both human and animal populations, transcending geographic borders and species barriers. Within this context, the interplay between animal health, human health, and the environment becomes glaringly evident. Zoonotic diseases, which are infections that can be transmitted between animals and humans, serve as poignant examples of how the interconnectedness of these realms can magnify the challenge of AMR. The transmission of resistant pathogens from animals to humans and vice versa not only heightens the potential for treatment failures but also underscores the shared vulnerabilities that traverse species lines.

The One Health approach is a call to recognize the indivisible nature of the health of animals, humans, and the environment. It reminds us that the boundaries between these domains are porous, and the solutions to complex challenges like AMR must be collaborative, multidisciplinary, and holistic 14. As we navigate the intricate web of health interactions, fostering synergies between veterinary medicine, human medicine, and environmental science is imperative. This review article seeks to delve deeper into the nexus between AMR and the One Health framework, shedding light on the ways in which these concepts intersect and offering insights into the transformative potential of collaborative approaches in safeguarding the health of our shared world.

ZOONOTIC DISEASES AND AMR: A DUAL THREAT

In the intricate tapestry of global health, zoonotic diseases emerge as a crucial juncture where the boundaries between animal and human health blur, posing a dual threat that resonates across species lines. Zoonoses, entailing 60% of the infectious ailments that a human being suffers from, are transmissible between animals and humans and have garnered increasing attention due

to their potential to incite not only immediate health crises but also to contribute to a more insidious menace: antimicrobial resistance (AMR) (Rahman et al., 2020). As we navigate this complex landscape, it becomes evident that the convergence of zoonotic diseases and AMR presents a critical nexus that demands comprehensive exploration (Olaru et al., 2023).

Antibiotics are used to cure bacterial infections, increase growth to cover up decreased body weight, and enhance milk production. Their mode of action varies based on what structure of bacteria they attack. Although their use is of matchless importance, the unmetabolized antibiotics are disseminated to the surroundings, such as water bodies, soil, other animals, and human beings. It leads to modification in the sensitivity of microorganisms and they start developing resistance to antibiotics (Dafale et al., 2020). This change in sensitivity has posed a massive threat to the public and animal health (Jin et al., 2022).

Zoonotic diseases, at their core, exemplify the interconnectedness of ecosystems and species. These diseases traverse the interface between animals and humans, often sparking outbreaks that lay bare the vulnerabilities within our intertwined health systems. As agents of transmission leap from animals to humans and vice versa, they amplify the potential for the dissemination of resistant pathogens. Indeed, the movement of zoonotic infections carries with it the lurking specter of AMR—an intricate interplay that renders the treatment of such diseases increasingly challenging.

The misuse of antimicrobials in animal populations, often intended to combat zoonotic infections, has inadvertently fueled the development of resistance (Kasimanickam et al., 2021). These scenarios magnify the delicate balance that must be struck between safeguarding animal health, controlling zoonotic outbreaks, and mitigating the risk of AMR amplification. Amidst the tapestry of zoonotic diseases, specific pathogens stand out for their potential to fan the flames of AMR. These bacteria, like Campylobacter and Salmonella, cause sickness in people, and are found in animals like poultry. Because of this, farmers use medicines to kill bacteria in poultry. However, some bacteria become resistant to these medicines. This shows that we need to work on stopping diseases from spreading and making sure medicines keep working well. Campylobacter is one of the leading causes of bacterial gastroenteritis worldwide. It is commonly transmitted through the consumption of contaminated food, particularly undercooked poultry, unpasteurized milk, and contaminated water. Campylobacteriosis typically manifests as diarrhea (often bloody), abdominal pain, fever, and sometimes vomiting. While most cases of Campylobacter infection are self-limiting, severe cases can occur, especially in vulnerable populations such as the elderly, infants, and immunocompro-

mised individuals. Campylobacteriosis is a significant public health concern, and strategies to prevent contamination of food and water sources are essential for its control. The shared susceptibility of animals and humans to these pathogens necessitates a coordinated, multidisciplinary approach that recognizes the vulnerabilities and potential consequences in both realms.

SURVEILLANCE AND MONITORING EFFORTS

In the relentless pursuit of combating antimicrobial resistance (AMR), surveillance and monitoring stand as sentinel guardians, poised to decipher resistant pathogens' intricate patterns and dynamics. Rooted in the realms of both veterinary and medical practice, these vigilant endeavors play a pivotal role in assessing the extent of AMR, identifying emerging threats, and guiding prudent interventions. Within this pivotal context, the surveillance and monitoring of AMR become linchpins that demand thorough exploration and evaluation.

Genomic surveillance offers the chance to detect genetic markers that signal resistance to antimicrobials or host adaptation, enabling timely intervention and reducing the risk of broader spread (Argimón et al., 2021). Therefore, genomic data is of huge importance to cope with the evolving sensitivity of pathogens to antimicrobials. The cornerstone of effective AMR management lies in comprehensive surveillance programs that cast a discerning eye on the intricate interplay between pathogens, antimicrobials, and the diverse environments they traverse. Conducting regular national surveys to assess the prevalence of antimicrobial resistance (AMR) provides a dependable, firsthand evaluation of AMR rates in countries that lack robust and extensive surveillance networks. This entails the use of a carefully chosen subset of surveillance locations, determined by statistically sound probability sampling techniques, to ensure accurate data that reflects the entire nation (Bertagnolio et al., 2023). These programs serve as a critical conduit for collecting and analyzing data on the prevalence, distribution, and genetic traits of resistant microorganisms. In both veterinary and medical domains, surveillance not only informs clinical decision-making but also guides policy development, enabling evidence-based strategies to tackle the looming specter of AMR. The insights garnered from surveillance initiatives empower healthcare practitioners, policymakers, and researchers with a potent arsenal to counteract the inexorable rise of resistance.

However, the path to establishing and maintaining robust surveillance systems in veterinary practice is beset with challenges. Unlike the controlled environments of clinical laboratories, the multifaceted landscapes of veterinary

settings encompass diverse animal species, production systems, and geographical variations. Coordinating data collection, standardizing methodologies, and ensuring representativeness at the national level and across boundaries poses a formidable task (Anjum et al., 2021). Furthermore, the varying capacities and resources of different regions often hinder the implementation of uniform surveillance strategies. Overcoming these challenges necessitates a harmonized approach that considers the unique contexts of each setting while fostering collaborative efforts. The global stage paints a diverse tableau of AMR surveillance strategies, reflecting the nuanced dynamics of different regions and countries. While some areas have harnessed robust surveillance networks encompassing veterinary clinics, hospitals, and even environmental reservoirs, others struggle to establish the foundational infrastructure for systematic monitoring. Disparities in surveillance capacity, data sharing, and analytical capabilities further complicate the evaluation of global progress. The global stage paints a diverse tableau of AMR surveillance strategies, reflecting the nuanced dynamics of different regions and countries. While some areas have harnessed robust surveillance networks that encompass veterinary clinics, hospitals, and even environmental reservoirs, others struggle to establish the foundational infrastructure needed for systematic monitoring. Disparities in surveillance capacity, data sharing, and analytical capabilities further complicate the evaluation of global progress. The World Health Organization (WHO) has been actively funding and supporting AMR investigations in developing countries, including several African countries. One notable example is the Global Antimicrobial Resistance Surveillance System (GLASS), a collaborative effort led by WHO to collect and analyze data on AMR from around the world, including many developing countries (WHO, 2020). In Africa, the WHO has been working closely with national governments, local health authorities, and research institutions to strengthen surveillance systems for AMR, build laboratory capacity, and develop national action plans to combat AMR effectively. For instance, the WHO Regional Office for Africa has been supporting AMR surveillance initiatives in Nigeria, Kenya, Uganda, and South Africa, among others. These efforts reflect a global recognition of the importance of addressing AMR as a public health priority. By investing in surveillance, research, and capacity-building initiatives in developing countries, the WHO and other international organizations aim to create a more comprehensive understanding of the global AMR threat and develop effective strategies to combat it. Additionally, by supporting these efforts in developing regions, the global community can work towards ensuring equitable access to effective antimicrobial treatments and mitigating the spread of drug-resistant infections worldwide.

EDUCATIONAL INITIATIVES AND PUBLIC AWARENESS

In the ongoing battle against antimicrobial resistance (AMR), knowledge is unequivocally a powerful weapon that holds the potential to reshape behaviors, alter practices, and ultimately drive a transformative shift in how we interact with antimicrobial agents. For instance, vaccines are considered a better option to dodge the spread of AMR and infectious diseases (Micoli et al., 2021). As the challenge of AMR continues to cast a shadow on global health, the imperative to educate and raise awareness among key stakeholders becomes ever more pressing (Ahmed et al., 2020). From veterinarians and medical professionals to farmers and the general public, fostering a nuanced understanding of responsible antimicrobial use resonates as a linchpin in the effort to mitigate AMR's impact.

Central to the educational endeavor is the understanding that antimicrobial stewardship transcends professional boundaries and extends to every facet of society. The study reveals that insufficient training on the optimum use of antibiotics and irrational use of essential antibiotics is escalating this global issue (Saman et al., 2023). For veterinarians and medical practitioners alike, the judicious use of antimicrobials forms an integral component of their practice—forging a bridge between the realms of clinical care and public health. Equipping these professionals with comprehensive knowledge not only enhances the quality of patient care but also aligns with the larger goal of curbing the emergence and spread of resistant pathogens.

The agricultural sector, in particular, occupies a critical position in the AMR narrative. Farmers, who play a pivotal role in food production, are uniquely positioned to drive change through their choices in animal husbandry and antimicrobial use. Educating farmers about the consequences of overreliance on antimicrobials, the emergence of resistance, and the ripple effects on both animal and human health can catalyze the adoption of more sustainable and responsible practices. By forging a connection between knowledge and action, the agricultural landscape can be transformed into a bastion of AMR mitigation (Calvo-Villamañán et al., 2023).

A key conduit for driving awareness and behavioral change lies in the realm of public awareness campaigns and educational programs. These initiatives wield the power to ignite collective consciousness, shaping public perceptions and attitudes toward antimicrobial use. Whether through digital platforms, community outreach, or school curricula, these campaigns have the potential to resonate with diverse audiences, bridging the gap between the complexities of AMR and the everyday lives of individuals. By fostering an understanding

of how individual actions contribute to the larger tapestry of AMR dynamics, these programs can spur a groundswell of support for responsible antimicrobial practices.

CONCLUSION

The interplay between AMR, zoonotic diseases, surveillance efforts, policy interventions, educational initiatives, and emerging research trends underscores the multifaceted nature of this critical concern. As we draw this review article to a close, a tapestry of insights and imperatives emerges-a testament to the collaborative spirit that must underpin our efforts to safeguard the well-being of our shared world. The lines between animal, human, and environmental health are not mere abstractions-they are tangible connections that shape the landscape of infectious disease dynamics, the propagation of resistance, and the efficacy of our interventions. The One Health ethos serves as a beacon, illuminating the path toward a holistic understanding of the intricate interactions that define the AMR landscape. It reminds us that no facet of this challenge can be addressed in isolation; the collective wisdom of veterinary, medical, environmental, and policy domains must converge to enact sustainable change.

As we look toward the horizon, the battle against AMR invites us to recognize that our actions today will echo far beyond the present moment. The strides we make in responsible antimicrobial use, the partnerships we cultivate, the policies we enact, and the knowledge we impart will reverberate through the intricate web of health and well-being that spans across species and ecosystems. The tapestry woven through these pages carries with it a profound call-a call to engage, to learn, to adapt, and to unite in a shared mission to safeguard both animal and human health. The journey to curb antimicrobial resistance is not a solitary pursuit; it is a symphony of collective effort, a tapestry of collaboration, and a testament to the power of our shared commitment to a healthier future.

Author's Contributions

Q.S. conceptualization, first draft, and preparation of the final draft. *K.A.U. supervision, editing*, and preparation of the final draft. *R.A*. providing resources.

Competing interest

The authors declare that there is no conflict of interest associated with the research reported in this article.

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Received: 26.02.2024.
Accepted: 07.05.2024.