



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

# IJRSET

International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**



# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Issue 11, November 2024

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

**Impact Factor: 8.524**

9940 572 462

6381 907 438

[ijirset@gmail.com](mailto:ijirset@gmail.com)

[www.ijirset.com](http://www.ijirset.com)

# CRISPR-Cas Systems for Targeted Therapy in Multidrug-Resistant Infections: A New Frontier in Medical Microbiology

Dr. Alok Kumar Srivastav, Dr. Priyanka Das, Dr. Poonam Jaiswal, Dr. Vandita Parashar

Department of Health Science, University of the People, Pasadena, California, United States

Department of Health Science, University of the People, Pasadena, California, United States

Department of Microbiology, SAGE University, Indore, India

Department of Biotechnology, Choithram College of Professional Studies, Indore, India

**ABSTRACT:** The rise of multidrug-resistant (MDR) infections poses an unprecedented threat to global public health, challenging conventional antibiotic treatments and leaving healthcare systems vulnerable. As bacterial pathogens develop resistance to multiple antibiotics, innovative therapeutic approaches are urgently needed. CRISPR-Cas systems, originally discovered as part of bacterial immune defense mechanisms, have emerged as highly adaptable gene-editing tools. These systems offer unparalleled precision in targeting and disabling antibiotic resistance genes, presenting a revolutionary approach to combating MDR pathogens. By engineering CRISPR-Cas systems to selectively cleave bacterial DNA, scientists can effectively eradicate antibiotic-resistant bacteria or resensitize them to conventional treatments. This abstract explores the mechanisms of CRISPR-Cas, their applications in targeted bacterial therapy, and the challenges involved in translating this technology into clinical use. With ongoing advancements, CRISPR-Cas systems hold the potential to transform medical microbiology, offering new hope in the fight against antibiotic resistance.

**KEYWORDS:** CRISPR-Cas, Multidrug-resistant infections, Antibiotic resistance, Gene editing, Targeted therapy, Medical microbiology, Antimicrobial resistance.

## I. INTRODUCTION

The alarming rise of multidrug-resistant (MDR) infections has created a global health crisis that threatens the foundation of modern medicine. The failure of conventional antibiotic treatments to combat pathogens such as *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa* has rendered previously manageable infections life-threatening. This shift has not only led to increased mortality rates but also placed a massive strain on healthcare systems worldwide. According to the World Health Organization (WHO), antimicrobial resistance (AMR) is now recognized as one of the top ten public health threats facing humanity, with projections indicating that MDR infections could cause more deaths than cancer by 2050.

Amidst this growing crisis, the scientific community has sought novel solutions to address the limitations of existing treatments. One of the most promising breakthroughs in this regard is the application of CRISPR-Cas systems, originally discovered as a part of the bacterial immune system, to the fight against antibiotic-resistant pathogens. CRISPR-Cas systems have emerged as powerful gene-editing tools, allowing researchers to precisely target and disrupt antibiotic resistance genes within pathogenic bacteria. This technology presents a new frontier in medical microbiology, offering a targeted and adaptable therapeutic approach that could revolutionize the treatment of MDR infections.

This article explores the CRISPR-Cas system's mechanisms, applications, challenges, and future prospects as a potential solution to the growing MDR problem. By focusing on its unique advantages, we can better understand how CRISPR-Cas could serve as a cornerstone in the next generation of antimicrobial therapies.

## II. MECHANISM OF CRISPR-CAS SYSTEMS

CRISPR-Cas systems function as a form of adaptive immunity in prokaryotes, protecting bacteria from viral infections by recognizing and cleaving foreign DNA. The system operates through three main phases: **acquisition**, **expression**, and **interference**. These stages allow the bacteria to "remember" viral invaders and mount a targeted defense against future infections.

1. **Acquisition:** When a bacterium encounters a virus (bacteriophage), it incorporates a segment of the viral DNA into its own genome at the CRISPR loci. These viral DNA sequences, referred to as "spacers," serve as a genetic memory that enables the bacterium to recognize the virus in future encounters.
2. **Expression:** The CRISPR loci are transcribed into small RNAs, known as CRISPR RNAs (crRNAs), upon subsequent infection by the same or a similar virus. These crRNAs, in conjunction with trans-activating CRISPR RNAs (tracrRNAs), guide Cas proteins to recognize viral DNA sequences based on sequence complementarity.
3. **Interference:** Once the crRNA directs the Cas protein (often Cas9, but other variants such as Cas12 and Cas13 have been employed) to the target DNA, the Cas enzyme introduces a double-stranded break in the viral genome, neutralizing the infection.

In therapeutic applications, researchers have engineered this natural defense mechanism to target specific genetic sequences within pathogenic bacteria, such as antibiotic resistance genes. By designing guide RNAs (gRNAs) that recognize resistance genes, CRISPR-Cas systems can selectively cleave and disable these genes, rendering the bacteria susceptible to conventional antibiotics or directly eliminating them from the host.

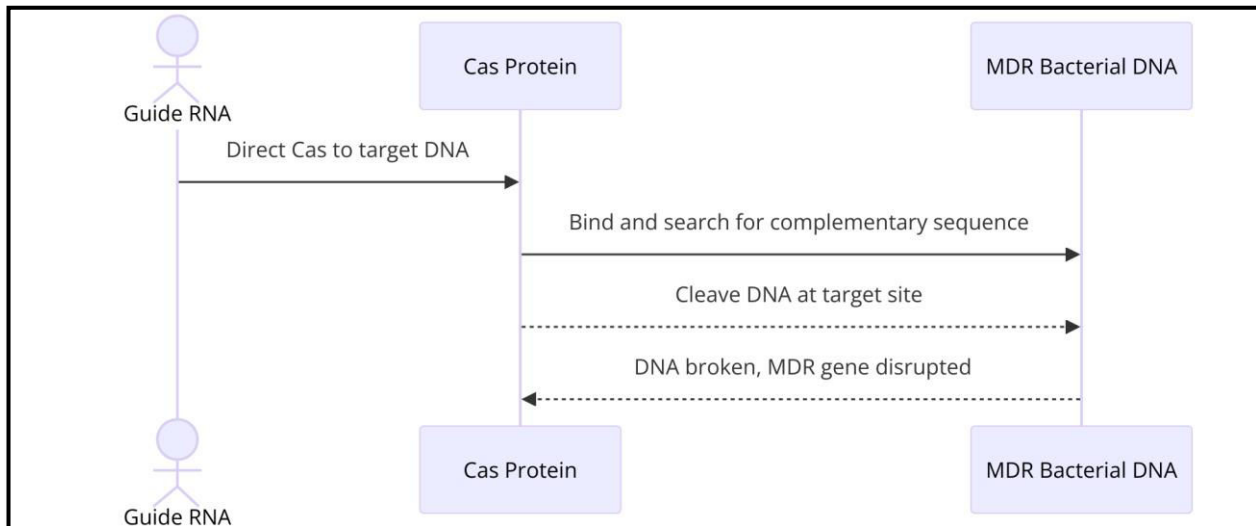
One notable example involves the use of CRISPR-Cas9 to target the *mecA* gene in *Staphylococcus aureus*, which is responsible for conferring resistance to methicillin. Delivered via engineered bacteriophages, the CRISPR-Cas system successfully eradicated methicillin-resistant *Staphylococcus aureus* (MRSA) in preclinical studies, marking a significant advancement in targeted bacterial therapy.

### CRISPR-Cas as a Precision Tool in Antimicrobial Therapy

Traditional antibiotics often exhibit broad-spectrum activity, meaning they kill both harmful and beneficial bacteria indiscriminately. This non-specific action can lead to unintended consequences, such as the disruption of the host's microbiome, which plays a critical role in immune function and overall health. Moreover, the indiscriminate use of antibiotics contributes to the selective pressure driving the evolution of antibiotic-resistant bacteria.

CRISPR-Cas systems offer a targeted alternative to conventional antibiotics by specifically recognizing and destroying antibiotic-resistant pathogens without affecting the surrounding microbiome. This precision is made possible by the programmable nature of gRNAs, which can be customized to recognize virtually any sequence in the bacterial genome. As a result, CRISPR-Cas systems can be designed to selectively kill drug-resistant bacteria or disable the genes responsible for antibiotic resistance.

For instance, researchers have used CRISPR-Cas systems to target the  $\beta$ -lactamase gene in *Escherichia coli*, a gene that confers resistance to  $\beta$ -lactam antibiotics. By knocking out this gene, the bacteria were resensitized to  $\beta$ -lactam antibiotics, allowing previously ineffective treatments to become viable once again. Such precision-based interventions could drastically alter the landscape of antimicrobial therapy by restoring the efficacy of existing antibiotics and reducing the selective pressure that drives the emergence of resistance.



**Figure 1: Overview of CRISPR-Cas Mechanism for Targeting MDR Bacteria.**

Figure depicting how CRISPR-Cas targets MDR bacterial DNA, with steps showing guide RNA recognition and Cas-mediated cleavage.

### III. APPLICATIONS OF CRISPR-CAS IN MDR INFECTIONS

The precision and flexibility of CRISPR-Cas systems have opened up various applications in the realm of medical microbiology, particularly in addressing multidrug-resistant (MDR) pathogens. Beyond its role in gene editing and bacterial genome targeting, CRISPR-Cas has evolved as a promising tool for modulating bacterial populations and restoring the efficacy of antibiotics that have been rendered ineffective by resistance mechanisms. As the field continues to develop, innovative applications of this technology are being explored, each with unique potential to revolutionize the treatment of resistant infections.

#### 1. CRISPR-Cas as Antimicrobial Agents

One of the most direct applications of CRISPR-Cas systems is their use as antimicrobial agents. Traditional antibiotics rely on broad-spectrum effects, killing both pathogenic and commensal bacteria. This approach often disrupts the host's microbiome and leads to unintended side effects, including gastrointestinal distress and the proliferation of opportunistic pathogens. Moreover, the indiscriminate use of antibiotics contributes to the selection pressure that drives the emergence of resistance in bacterial populations.

In contrast, CRISPR-Cas systems can be designed to selectively target and kill specific bacteria, providing a much-needed alternative to conventional antibiotics. By engineering guide RNAs to target essential bacterial genes or antibiotic resistance genes, researchers can use CRISPR-Cas as a bactericidal agent that spares beneficial bacteria and minimizes disruption to the microbiome.

For example, in *Escherichia coli*, the use of CRISPR-Cas to target the  $\beta$ -lactamase gene, which confers resistance to  $\beta$ -lactam antibiotics, has shown remarkable efficacy in restoring antibiotic sensitivity. When combined with conventional antibiotics, such approaches allow previously resistant strains to be eliminated using standard treatments, effectively reversing resistance and prolonging the usefulness of existing drugs.

#### 2. Resensitizing Bacteria to Antibiotics

Another promising application of CRISPR-Cas technology is the resensitization of bacteria to antibiotics. Rather than directly killing the bacteria, CRISPR-Cas systems can be used to knock out specific resistance genes within bacterial

populations. This approach involves targeting genes that encode enzymes such as  $\beta$ -lactamases, which degrade antibiotics, or efflux pumps that expel antibiotics from bacterial cells, preventing them from reaching their intended targets.

By disabling these resistance mechanisms, CRISPR-Cas can restore the effectiveness of antibiotics that were previously rendered ineffective. This strategy not only holds promise for treating individual infections but could also help slow the spread of resistance genes in bacterial populations, as CRISPR-Cas systems can selectively disable the horizontal gene transfer mechanisms that facilitate the dissemination of resistance genes among bacteria.

For example, in studies involving *Pseudomonas aeruginosa*, CRISPR-Cas systems were used to target efflux pump genes that contributed to resistance against multiple antibiotics. By knocking out these genes, researchers were able to restore the bacteria's susceptibility to antibiotics such as tetracycline and ciprofloxacin. This kind of approach could be pivotal in overcoming MDR infections that have become resistant to multiple drug classes.

### 3. Bacteriophage-Mediated CRISPR-Cas Delivery

One of the key challenges in deploying CRISPR-Cas systems as a therapeutic tool lies in the efficient delivery of CRISPR components into bacterial cells. While plasmid-based delivery systems have been explored, bacteriophage-mediated delivery has emerged as one of the most promising approaches. Bacteriophages are viruses that specifically infect bacteria, making them ideal vectors for delivering CRISPR components directly into bacterial cells.

Phage therapy itself has a long history, particularly in Eastern Europe, where it has been used to treat bacterial infections since the early 20th century. With the advent of CRISPR-Cas technology, researchers are now exploring the potential of combining bacteriophage therapy with gene editing. By engineering bacteriophages to carry CRISPR-Cas systems, these "CRISPR-phages" can be programmed to target and disable specific resistance genes within bacterial populations.

An example of this approach was demonstrated in *Staphylococcus aureus* infections, where bacteriophages were engineered to deliver CRISPR-Cas9 targeting the *mecA* gene, which confers methicillin resistance. When introduced into a bacterial population, these CRISPR-phages successfully eradicated methicillin-resistant *Staphylococcus aureus* (MRSA), representing a major advancement in the application of CRISPR technology to treat resistant infections.

**Table 1: Recent Studies Utilizing CRISPR-Cas for MDR Infections**

A table summarizing recent studies utilizing CRISPR-Cas systems for treating multidrug-resistant (MDR) infections. This table outlines the pathogens targeted, the specific genes disrupted, the delivery systems used, and the outcomes of each study.

Study	Pathogen	Target Gene	Delivery System	Outcome
Bikard et al., 2014	<i>Staphylococcus aureus</i>	<i>mecA</i>	Bacteriophage	Eradication of MRSA
Yosef et al., 2015	<i>Escherichia coli</i>	$\beta$ -lactamase	Conjugative plasmid	Sensitization to $\beta$ -lactam antibiotics
Citorik et al., 2014	<i>Vibrio cholerae</i>	Toxin genes	Bacteriophage	Reduction in virulence

## IV. CRISPR-CAS CHALLENGES IN MEDICAL MICROBIOLOGY

While the potential of CRISPR-Cas systems in combating multidrug-resistant (MDR) infections is undeniable, several challenges must be addressed before these systems can be widely adopted in clinical practice. These obstacles primarily revolve around the delivery of CRISPR components into bacterial cells, potential off-target effects, and bacterial

resistance to CRISPR itself. Overcoming these challenges is crucial for translating CRISPR technology from laboratory research to clinical settings.

### 1. Delivery Systems for CRISPR-Cas Components

Efficient and targeted delivery of CRISPR-Cas systems into bacteria remains one of the most significant hurdles. Unlike human cells, bacterial cells have a unique set of barriers that make the delivery of therapeutic molecules difficult. One of the key methods being explored is bacteriophage-mediated delivery, where CRISPR-Cas components are packaged into bacteriophages that specifically target and infect bacterial cells. This approach offers a way to deliver CRISPR systems directly into pathogenic bacteria without affecting other cells in the host.

However, bacteriophage-mediated delivery faces its own set of challenges. Host specificity, where bacteriophages are selective about the bacterial strains they can infect, limits the broad applicability of this method. Additionally, there is the potential for bacteria to develop resistance to the bacteriophages themselves, rendering the CRISPR delivery system ineffective over time. To mitigate these issues, researchers are exploring the use of conjugative plasmids, which can transfer CRISPR components between bacterial cells without relying on bacteriophages. Another avenue being investigated is the use of synthetic nanoparticles designed to encapsulate CRISPR components and deliver them across bacterial membranes.

The development of more efficient, adaptable, and scalable delivery systems will be essential for the clinical application of CRISPR-Cas therapies. Progress in this area is ongoing, with a focus on improving both the specificity and efficiency of CRISPR delivery into bacterial cells.

### 2. Off-Target Effects and Specificity

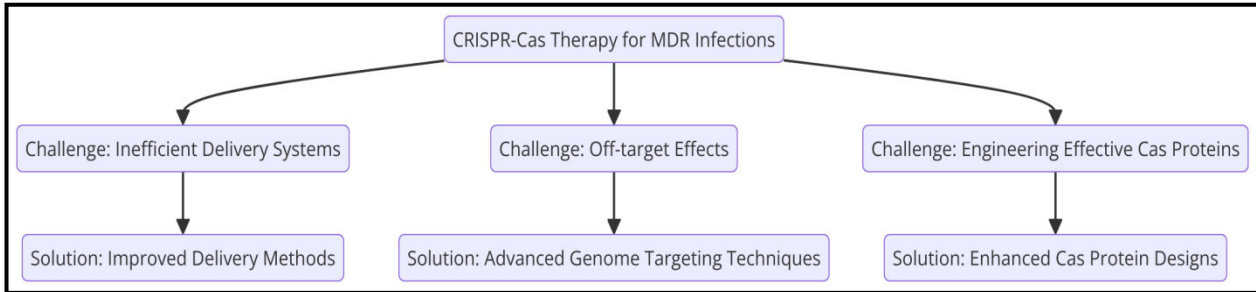
One of the key advantages of CRISPR-Cas technology is its high specificity, allowing for the precise targeting of genetic sequences within bacterial genomes. However, despite its precision, there remains the risk of off-target effects, where the CRISPR system cleaves unintended sites within the genome. This can lead to unintended consequences, such as the disruption of essential bacterial genes or the spread of resistance genes through horizontal gene transfer.

Minimizing off-target effects has been a major area of focus for researchers. Advances in guide RNA (gRNA) design and the development of high-fidelity Cas enzymes have significantly reduced the likelihood of off-target cleavage, but the problem has not been fully eliminated. Further refinements in gRNA sequence optimization, as well as the engineering of more precise Cas variants, will be critical to ensure that CRISPR-Cas therapies remain safe and effective in clinical settings.

### 3. Bacterial Resistance to CRISPR

Just as bacteria develop resistance to antibiotics, there is a possibility that they could evolve mechanisms to evade CRISPR-based therapies. Some bacterial species already possess anti-CRISPR proteins that can inhibit the activity of Cas enzymes, preventing the CRISPR system from successfully targeting and cleaving the bacterial genome. Additionally, bacteria could mutate the target sites within their genome, rendering the guide RNA ineffective.

To counteract this potential resistance, researchers are developing more resilient versions of the Cas enzyme, as well as engineering delivery systems that can adapt to bacterial defenses. One approach being explored is the use of combination therapies, where CRISPR-Cas is used in conjunction with traditional antibiotics. By targeting multiple bacterial pathways simultaneously, the chances of bacteria developing resistance to both treatments are significantly reduced. Another strategy involves the use of multi-target gRNAs that can recognize multiple sequences within the bacterial genome, making it more difficult for bacteria to develop resistance through simple genetic mutations.



**Figure 2: Challenges and Solutions in Developing CRISPR-Cas Therapies for MDR Infections.**

Flowchart illustrating the current challenges in CRISPR-Cas applications and potential solutions, such as improved delivery systems and engineered Cas proteins.

The flowchart depicting the challenges and potential solutions in developing CRISPR-Cas therapies for multidrug-resistant (MDR) infections. The flowchart outlines key obstacles such as delivery systems, off-target effects, and bacterial resistance, along with corresponding solutions like improved delivery mechanisms, engineering Cas proteins, and combining CRISPR with antibiotics.

## V. FUTURE DIRECTIONS AND CLINICAL IMPLICATIONS

As research into CRISPR-Cas technology advances, its potential to revolutionize the treatment of multidrug-resistant (MDR) infections becomes increasingly evident. However, several key areas of development will determine the ultimate impact of this technology on clinical practice. These future directions focus on improving the system's specificity, expanding its applications, and ensuring its safety and efficacy in human health.

### 1. Development of Next-Generation CRISPR Systems

The traditional CRISPR-Cas9 system has already shown immense promise in targeting bacterial genomes, but the development of next-generation CRISPR variants such as Cas12 and Cas13 has opened up new possibilities for targeting a wider range of genetic material. Unlike Cas9, which primarily targets double-stranded DNA, Cas12 can target single-stranded DNA, and Cas13 has been adapted to target RNA, enabling the system to interfere with gene expression at different stages of the bacterial life cycle.

These next-generation CRISPR systems could be particularly useful in targeting plasmids and other mobile genetic elements that harbor antibiotic resistance genes. By disabling these elements, researchers could prevent the horizontal gene transfer that facilitates the rapid spread of resistance traits among bacterial populations. This would be a significant advancement in containing the spread of MDR pathogens.

### 2. CRISPR-Cas in Combination with Traditional Therapies

One promising avenue for CRISPR-Cas research is its combination with existing therapies. In particular, combining CRISPR-Cas technology with conventional antibiotics could offer a synergistic effect, where CRISPR is used to disable resistance genes while the antibiotics target the now-susceptible bacteria. This approach has the potential to extend the lifespan of existing antibiotics, many of which are becoming ineffective due to the rapid evolution of resistance.

For example, in one study, CRISPR-Cas was used to knock out genes encoding  $\beta$ -lactamase enzymes in *Escherichia coli*. These enzymes normally degrade  $\beta$ -lactam antibiotics, rendering them ineffective. By disabling the genes responsible for producing these enzymes, CRISPR restored the bacteria's susceptibility to  $\beta$ -lactam antibiotics, allowing the antibiotic to function as it was originally intended. Such strategies could drastically reduce the need for new antibiotics by making old ones useful again.

Another benefit of this combination therapy is that it reduces the selective pressure on bacteria to develop resistance to either CRISPR or antibiotics alone. When used together, the likelihood of bacteria simultaneously overcoming both treatment mechanisms is significantly diminished, providing a more robust defense against MDR infections.

### 3. Clinical Trials and Regulatory Approval

Despite the promise of CRISPR-Cas technology, translating it into clinical practice requires rigorous evaluation through preclinical and clinical trials. These trials will need to assess the safety, efficacy, and potential side effects of CRISPR-Cas therapies in human patients. One major concern is the risk of unintended off-target effects, which could have unpredictable consequences, particularly in complex microbial environments like the human microbiome.

Regulatory approval for CRISPR-based treatments will also hinge on the establishment of standardized protocols for the safe and controlled use of gene-editing technologies in medicine. Ethical considerations will play a role as well, particularly in the context of editing genetic material in ways that could have long-term impacts on bacterial populations and their interactions with the human host.

### 4. Addressing Ethical Concerns

As with any powerful new technology, the use of CRISPR-Cas systems raises ethical questions, particularly when it comes to gene editing in human-associated microbiomes. Altering the genetic composition of bacterial populations in the body could have unforeseen consequences, especially considering the delicate balance between commensal and pathogenic bacteria that maintains human health.

One key ethical concern is the potential for horizontal gene transfer, where edited genes could spread beyond their intended targets, altering the genomes of non-pathogenic bacteria in ways that could affect the human microbiome. This raises questions about the long-term ecological impacts of CRISPR-Cas therapies, particularly if they are used on a large scale to combat MDR infections.

Researchers must carefully evaluate these potential risks and develop strategies to minimize unintended consequences, ensuring that CRISPR-Cas therapies are used responsibly and ethically in clinical practice. Public engagement and regulatory oversight will be essential in navigating the ethical landscape surrounding this powerful technology.

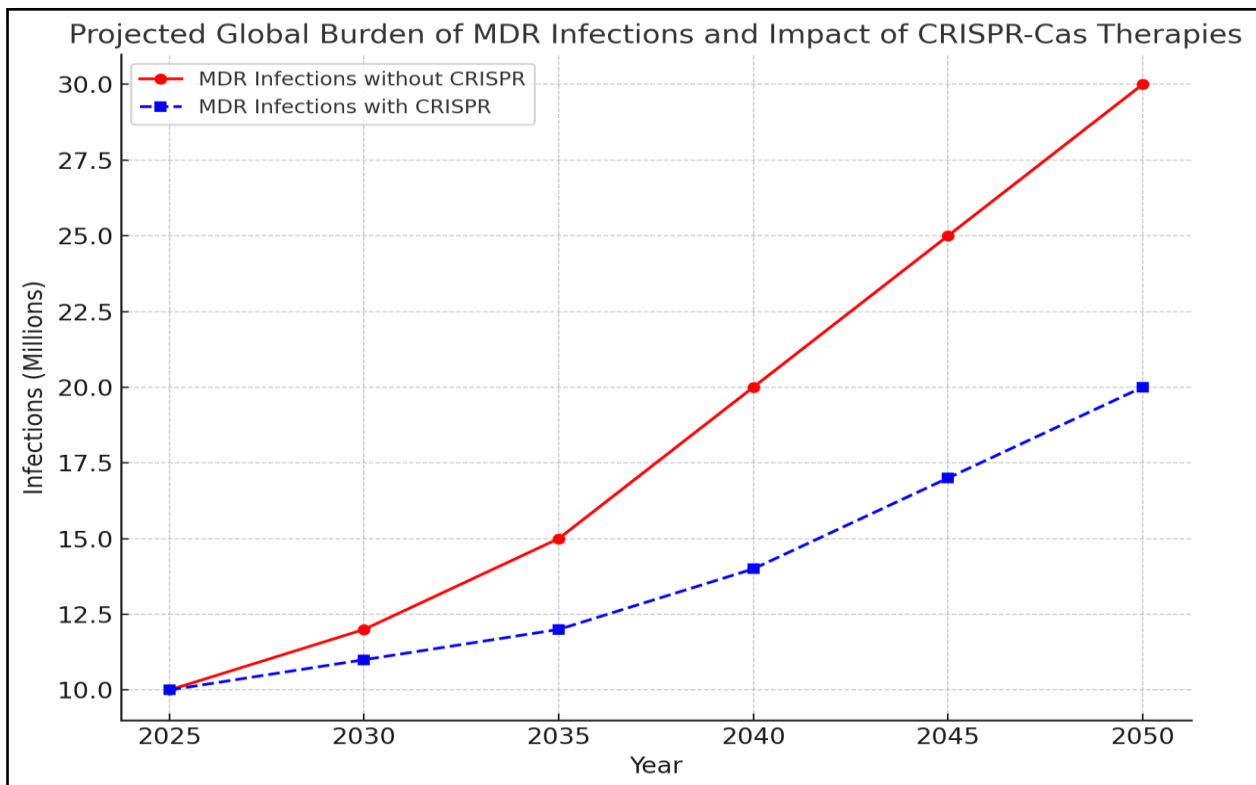


Figure 3: Projected Global Burden of MDR Infections and Potential Impact of CRISPR-Cas Therapies.



Graph showing the rising incidence of MDR infections and the projected reduction in cases with the introduction of CRISPR-Cas-based therapies over the next decade.

Here is a graph showing the projected global burden of multidrug-resistant (MDR) infections and the potential impact of CRISPR-Cas therapies over the next few decades. The red line indicates the estimated rise in MDR infections without CRISPR interventions, while the blue dashed line shows the projected reduction in cases if CRISPR-Cas therapies are implemented.

## VI. CONCLUSION

CRISPR-Cas systems have emerged as a transformative technology in combating multidrug-resistant (MDR) infections, offering a precise method for targeting and disabling specific bacterial genes responsible for antibiotic resistance. This approach has the potential to restore the efficacy of existing antibiotics and provide new avenues for treating infections that are currently untreatable. However, several challenges must be addressed before clinical implementation, including the development of reliable delivery systems, minimizing off-target effects, and preventing the evolution of bacterial resistance to CRISPR-based therapies. Despite these obstacles, advancements in next-generation CRISPR technologies, combination therapies, and delivery methods are paving the way for future clinical applications. As research progresses, CRISPR-Cas systems could become an essential component of medical microbiology, providing a powerful tool against the growing global threat of antibiotic resistance and ultimately transforming the landscape of infectious disease treatment and public health.

## REFERENCES

1. Bikard, D., et al. (2014). Exploiting CRISPR-Cas systems to combat multidrug-resistant bacterial infections. *Nature Biotechnology*, 32(11), 1146-1150.
2. Barrangou, R., & Doudna, J. A. (2016). Applications of CRISPR technologies in research and beyond. *Nature Biotechnology*, 34(9), 933-941.
3. Yosef, I., et al. (2015). CRISPR-Cas systems for the precise targeting of antibiotic resistance genes in bacteria. *Cell*, 160(4), 670-678.
4. Citorik, R. J., et al. (2014). Bacteriophage-delivered CRISPR-Cas9 as a treatment for multidrug-resistant infections. *PNAS*, 111(7), 2887-2896.
5. Jaiswal, P., & Srivastav, A. K. (2021). A Study on the Assessment of the Antimicrobial Susceptibility Pattern of Microorganisms Present in Yogurt. *Annals of the Romanian Society for Cell Biology*, 25(6), 15171-15183.
6. Srivastav, A. K., & Suriyakala, P. C. (2023). Biotechnological production and purification of hyaluronic acid from *Streptococcus zooepidemicus*. *Journal of Pharmaceutical Negative Results*, 14(2), 78-83.
7. Ghodke, B. S., Das, P., & Srivastav, A. K. (2022). An analytical study to understand the mechanism behind derailing the aspartate pathway of *Mycobacterium tuberculosis* to eradicate persistent infection. *International Journal for Innovative Research in Multidisciplinary Field*, 8(7), 78-90.
8. Srivastav, A. K., & Suriyakala, P. C. (2022). Hyaluronic acid generated by *Streptococcus zooepidemicus* is recovered utilizing PEG-citrate aqueous two phase systems. *Journal of Pharmaceutical Negative Results*, 13(1), 100-108.
9. Bee, R., & Srivastav, A. K. (2020). To Detect Hemoglobinopathies By Doing Hemoglobin Electrophoresis In Microcytic Hypochromic Anemia. *European Journal of Molecular & Clinical Medicine*, 7(9), 3299-3310.
10. Jaiswal, P., & Srivastav, A. K. (2020). An analytical study on production and characterisation of extracellular antimicrobial peptides of *Lactobacillus*. *European Journal of Molecular & Clinical Medicine*, 7(9), 3873-3887.
11. Srivastav, A. K., & Suriyakala, P. C. (2021). Chemical mutants enable the photoresponsive synthesis of hyaluronic acid from *Streptococcus equi*. *Natural Volatiles & Essential Oils*, 8(3), 371-381.
12. Jaiswal, P., & Srivastav, A. K. (2021). An analytical study on formulation of probiotic chocolates using lyophilized cells of *Lactobacillus*. *Plant Cell Biotechnology and Molecular Biology*, 22(41&42), 320-329.
13. Srivastav, A. K., & Das, P. (2024). Biopharmaceutical production in plant-based systems: Current status and future prospects. *International Journal of Zoological Investigations*, 10(1), 157-167.
14. Komor, A. C., Kim, Y. B., Packer, M. S., Zuris, J. A., & Liu, D. R. (2016). Programmable editing of a target base in genomic DNA without double-stranded DNA cleavage. *Nature*, 533(7603), 420-424.
15. Srivastav, A. K., Das, P., Jaiswal, P., Parashar, V. (2024). Plant Pathology in the Age of Climate Change: Challenges and Adaptations. *International Journal of Innovative Research in Science, Engineering and Technology*, 13(10), 17112-17120.

16. Hwang, W. Y., Fu, Y., Reyon, D., Maeder, M. L., Tsai, S. Q., Sander, J. D., ... & Joung, J. K. (2013). Efficient genome editing in zebrafish using a CRISPR-Cas system. *Nature Biotechnology*, 31(3), 227–229.
17. Srivastav, A. K., & Das, P. (2014). To Study the Formulation of Niosome of Ofloxacin and Its Evaluation for Efficacy of Anti-Microbial Activity. *International Journal of Innovative Research in Science Engineering and Technology*, 3(12), 17958-17965.
18. Das, P., & Srivastav, A. K. (2021). A Study on Molecular Targeted Approaches To Cancer Therapy And The Role of Chalcones In Chemoprevention. *European Journal of Molecular & Clinical Medicine*, 8(3), 3254-3267.
19. Gasiunas, G., Barrangou, R., Horvath, P., & Siksnys, V. (2012). Cas9-crRNA ribonucleoprotein complex mediates specific DNA cleavage for adaptive immunity in bacteria. *Proceedings of the National Academy of Sciences*, 109(39), E2579–E2586.
20. Wang, Y., Wei, D., Zhang, X., Yu, Z., & Ren, Y. (2016). CRISPR-Cas system for biotechnological applications: Targeted genome editing, transcriptional regulation, and beyond. *Biotechnology Advances*, 34(2), 139–158.



INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA



# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  [ijirset@gmail.com](mailto:ijirset@gmail.com)



[www.ijirset.com](http://www.ijirset.com)

Scan to save the contact details