Transmission Routes and Prevention Strategies of Multidrug-Resistant Organism Infections in Hospitals

Bo Wen[1], Fangliang Lei [2*]

[1]Department of Critical Care Medicine, Shanxi Provincial People's Hospital, Xi'an, 710068, China
[2]Office of Hospital Infection Management, Shanxi Provincial People's Hospital, Xi'an, 710068, China
[*]Corresponding author:leifangliang.phd@qq.com

Abstract: *With the spread of multidrug-resistant organisms (MDROs) in hospitals, infection control faces significant challenges. MDROs refer to microorganisms resistant to three or more antimicrobial agents, commonly including methicillin-resistant Staphylococcus aureus (MRSA), vancomycin-resistant enterococci (VRE), and extended-spectrum β-lactamase-producing bacteria (ESBL). These resistant organisms primarily transmit through direct contact, indirect contact, and airborne routes within hospitals. Effective prevention and control of these infections require a comprehensive approach, including strict hand hygiene and personal protection, implementation of infection control standards, environmental cleaning and disinfection, management of medical device sterilization, and rational use of antimicrobial agents along with resistance monitoring. This paper summarizes the transmission routes and prevention strategies for MDRO infections, providing references for hospital management and clinical practice. Future research should focus on optimizing prevention measures and resistance monitoring to address the changing patterns of resistant organisms and enhance infection control effectiveness.*

Keywords: *multidrug-resistant organisms, hospital infections, transmission routes, prevention strategies, resistance monitoring*

Introduction

The emergence of multidrug-resistant organisms is closely related to the widespread use of antimicrobial agents, especially in hospital settings, where the issue of resistant organism transmission is becoming increasingly serious. Infection control in hospitals faces challenges from multidrug-resistant organisms, as these strains exhibit significant resistance to commonly used antibiotics, complicating and increasing the difficulty of treatment. Studying the transmission routes of multidrug-resistant organisms and effective prevention strategies is crucial for enhancing hospital infection management and ensuring patient safety. Understanding their transmission routes can help formulate targeted preventive measures and optimize infection control processes, thereby reducing the spread of resistant organisms and the incidence of related infections.

1. Overview of Multidrug-Resistant Organism Infections

1.1 Definition and Classification of Multidrug-Resistant Organisms

1.1.1 Basic Concept of Multidrug-Resistant Organisms

Multidrug-resistant organisms (MDROs) are microorganisms that exhibit resistance to three or more different classes of antimicrobial agents. Clinically, these bacteria often show resistance to commonly used antibiotics, making the treatment of infections more complex and challenging. Multidrug resistance can be acquired through various mechanisms, including genetic mutations, horizontal gene transfer (such as plasmid transmission), and alterations in cell wall structure. These resistance mechanisms enable MDROs to survive and reproduce under adverse environmental conditions, leading to persistent problems with hospital-acquired infections.

1.1.2 Common Classification of Multidrug-Resistant Organisms

In the hospital environment, common classifications of MDROs include methicillin-resistant Staphylococcus aureus (MRSA), vancomycin-resistant enterococci (VRE), and extended-spectrum

β-lactamase-producing bacteria (ESBL-Producing Bacteria). MRSA is a strain of Staphylococcus aureus that is highly resistant to β-lactam antibiotics, including penicillin and methicillin. MRSA infections primarily manifest as skin and soft tissue infections but can lead to more severe invasive diseases, such as sepsis and pneumonia, especially in immunocompromised patients.

VRE exhibits significant resistance to vancomycin, a key antimicrobial agent. Enterococci are typically part of the normal gut flora; however, when they develop into VRE, they can cause a range of clinical infections, including urinary tract infections, abdominal infections, and endocarditis. On the other hand, ESBL-producing bacteria can produce enzymes that break down various β-lactam antibiotics, such as cephalosporins and penicillins. This group mainly includes Escherichia coli and Klebsiella species, with infections often presenting as urinary tract infections, peritonitis, and pneumonia, posing substantial challenges to conventional antimicrobial treatment. The presence and spread of these MDROs in hospital settings present serious challenges to infection control.[1]

1.2 Clinical Manifestations of Multidrug-Resistant Organism Infections

1.2.1 Skin and Soft Tissue Infections

MDRO infections in the skin and soft tissues manifest as abscesses, cellulitis, and sepsis. MRSA is a primary pathogen responsible for hospital-acquired skin and soft tissue infections, particularly in patients with chronic illnesses and compromised immune systems. Infections typically exhibit classic signs of inflammation, including redness, swelling, heat, and pain, and may be accompanied by fever and systemic symptoms.

1.2.2 Respiratory Infections

MDROs can cause respiratory infections, including community-acquired pneumonia and hospital-acquired pneumonia. Pneumonia caused by MRSA and ESBL-producing bacteria often progresses acutely, accompanied by severe cough, hemoptysis, and dyspnea. Severe cases may lead to septic shock and acute respiratory distress syndrome (ARDS).

1.2.3 Urinary Tract Infections

When MDROs cause urinary tract infections, they typically present as acute cystitis, pyelonephritis, and complicated urinary tract infections. ESBL-producing bacteria are particularly common in urinary tract infections, with clinical symptoms including frequent urination, urgency, dysuria, and flank pain. Complicated infections may result in severe kidney damage and sepsis.

1.3 Epidemiological Characteristics of Multidrug-Resistant Organisms

1.3.1 Incidence and Trends

In recent years, the incidence of MDRO infections has significantly increased, especially in hospital settings. This trend is partly attributed to the widespread and inappropriate use of antimicrobial agents. Epidemiological studies indicate that the trends of MDRO infections exhibit regional variations, affecting both developed and developing countries, with higher incidence rates observed in developing nations. The prevalence of MDROs in hospitals shows distinct temporal and spatial patterns, with notable periodic fluctuations.[2]

1.3.2 High-Risk Populations and Patterns of Nosocomial Infections

High-risk populations include patients who are hospitalized for extended periods, immunosuppressed individuals, patients in intensive care units (ICUs), and those using invasive medical devices. These groups are particularly vulnerable to the acquisition and spread of MDROs, underscoring the need for targeted infection control measures in these settings.

2. Transmission Routes of Multidrug-Resistant Organisms in Hospitals

2.1 Direct Contact Transmission

2.1.1 Direct Contact Between Healthcare Workers and Patients

Direct contact between healthcare workers and patients is a primary route for the transmission of multidrug-resistant organisms (MDROs). When healthcare workers fail to perform proper hand hygiene

or use personal protective equipment, resistant bacteria may be transmitted to patients via hands, clothing, or other directly contacted items. During examinations, nursing procedures, or handling bodily fluids (e.g., changing dressings or cleaning wounds), MDROs are more likely to transfer from healthcare workers' hands or clothing to patients' skin. If a patient has compromised skin or mucous membranes, MDROs can enter the body and cause infections. For instance, if a healthcare worker's hands are not disinfected during dressing changes, MDROs may spread through wounds, exacerbating the infection.

2.1.2 Cross-Contamination Among Patients

Cross-contamination between patients is another significant transmission route for resistant bacteria. In hospitals, patients often share rooms and medical equipment, facilitating the spread of MDROs. The risk of infection is particularly high among immunocompromised patients or those with open wounds. Resistant organisms can be transmitted through direct contact, fluid exchange, or shared medical devices. For example, bed linens, hospital furnishings, or undisinfected medical equipment (such as glucose monitors and ECG machines) may serve as transmission vectors. If these devices are not thoroughly disinfected between patient uses, MDROs can spread to other patients.

2.1.3 Contamination of Healthcare Workers' Hands and Clothing

The presence of resistant bacteria on healthcare workers' hands and clothing is a crucial factor in direct contact transmission. If healthcare workers do not adhere to hand hygiene protocols during medical procedures, MDROs can accumulate on their hands and clothing. This is particularly true when handling bodily fluids, wounds, or conducting procedures that may release bacteria. If healthcare workers do not perform hand hygiene or change their clothing when switching patients, MDROs may spread to other patients through hand contact or clothing friction. Medical attire, such as lab coats and gloves, that is not changed or cleaned promptly can also serve as reservoirs for resistant organisms, increasing the risk of cross-infection.

2.2 Indirect Contact Transmission

2.2.1 Contaminated Surfaces in the Hospital Environment

Surfaces, furniture, and equipment in hospitals—such as bed rails, doorknobs, and examination tables—can serve as reservoirs for MDROs. If these surfaces are not properly disinfected, they may accumulate significant amounts of resistant bacteria. For instance, bed rails and doorknobs are frequently touched by both healthcare workers and patients; if they are not regularly cleaned and disinfected, they become potential sources of MDRO transmission. Resistant organisms can be transferred to patients through contaminated surfaces via healthcare workers’ hands or other objects, leading to hospital-acquired infections. Studies have shown that bacteria on these surfaces can survive for extended periods, particularly in humid environments, enhancing their survival and transmission potential.[3]

2.2.2 Contamination of Medical Devices and Supplies

Contamination of medical devices and supplies is another important route for indirect transmission. Disposable medical devices, such as catheters and ventilator tubing, can become vectors for resistant bacteria if not properly disposed of after use. Reusable equipment, such as endoscopes and surgical instruments, increases the risk of MDRO transmission if there are lapses in disinfection and sterilization processes. In particular, if the cleaning and disinfection of endoscopic devices are insufficient, residual MDROs can directly spread to other patients, resulting in cross-infections. Therefore, hospitals must strictly adhere to disinfection and sterilization protocols to ensure that every medical device is effectively processed before use.

2.2.3 Airborne Transmission in the Hospital Environment

Airborne transmission of MDROs in hospital environments is also significant. In high-risk areas, such as wards and intensive care units, airborne particles may carry resistant bacteria that can become suspended in the air and enter patients' respiratory tracts. Research indicates that these bacterial particles can remain airborne for extended periods and spread to other areas through air currents. For instance, in densely populated wards, the risk of airborne transmission of MDROs is heightened, particularly in poorly ventilated conditions, where these particles can linger longer.[4]

3. Prevention and Control Strategies for Multidrug-Resistant Bacterial Infections in Hospitals

3.1 Preventive Measures

3.1.1 Hand Hygiene and Personal Protection

Hand hygiene is one of the fundamental measures for preventing multidrug-resistant bacterial infections. Healthcare workers must adhere to strict hand hygiene protocols, including thorough handwashing with alcohol-based hand sanitizers or soap and water before and after each patient contact and after handling bodily fluids or secretions. The execution of hand hygiene should involve systematic training and continuous supervision to ensure the correctness and compliance of the technique. Additionally, the proper use of personal protective equipment (PPE) is crucial in preventing the spread of multidrug-resistant bacteria. Based on an assessment of infection risk, healthcare workers should wear appropriate gloves, masks, goggles, and protective clothing. Gloves should be changed after each patient contact or handling of infectious materials, while masks and protective clothing must be used during specific procedures or when interacting with high-risk patients. The selection and use of PPE should comply with infection control standards and be replaced and disposed of timely according to the actual situation.

3.1.2 Implementation of Standard Operating Procedures (SOPs) for Infection Control

Infection control SOPs are central to the systematic prevention of multidrug-resistant bacterial infections. Hospitals should develop detailed SOPs covering isolation measures, environmental cleaning, equipment disinfection, and personnel management. Isolation measures should be established based on the type of infection and characteristics of the resistant bacteria, ensuring that healthcare workers and other patients do not have direct contact with patients harboring resistant bacteria. The SOPs for environmental cleaning should specify the frequency, methods, and types of disinfectants used. Furthermore, the SOPs for medical procedures must include strict operational processes and disinfection requirements to minimize infection risks. Regular evaluation and updates of SOP implementation are necessary to ensure their effectiveness, alongside training and assessment of healthcare workers to enhance the standardization and consistency of operations.[5]

3.2 Environmental Control and Hygiene Management

3.2.1 Cleaning and Disinfection of Hospital Environments

Environmental control is a crucial component in preventing multidrug-resistant bacteria. Regular cleaning and disinfection of hospital environments should be conducted to reduce the survival and transmission risks of resistant bacteria. All surfaces within the hospital, including floors, walls, beds, door handles, and other high-contact surfaces, should be cleaned with effective disinfectants. Particularly in high-risk infection areas, such as intensive care units and emergency rooms, cleaning and disinfection need to be more frequent and thorough. Employing suitable cleaning methods, such as high-pressure steam disinfection and chemical disinfectant treatments, can effectively remove resistant bacteria from surfaces. Additionally, an environmental monitoring plan should be implemented to regularly test for the presence of resistant bacteria in the hospital environment to ensure the effectiveness of cleaning measures.

3.2.2 Disinfection Management of Medical Instruments and Equipment

The disinfection management of medical instruments and equipment is vital for preventing multidrug-resistant bacterial infections. All medical instruments, whether single-use or reusable, must be processed according to strict disinfection and sterilization standards. Single-use instruments should be disposed of safely after use, while reusable instruments require high-level disinfection and sterilization. For the disinfection of equipment, appropriate disinfectants and sterilization methods should be selected in accordance with national and international standards, such as ethylene oxide sterilization, gas sterilization, or high-temperature and pressure sterilization. Furthermore, hospitals should establish a comprehensive instrument management system that includes usage records, monitoring of disinfection processes, and quality control to ensure the safety and effectiveness of instruments. Regular maintenance and inspection of disinfection equipment and procedures are also key measures to ensure disinfection efficacy.

3.3 Antimicrobial Drug Management and Use

3.3.1 Rational Use and Management of Antimicrobial Drugs

Rational use of antimicrobial drugs is one of the core measures to control the spread of multidrug-resistant bacteria. Hospitals should formulate and implement antimicrobial management policies to ensure that the use of these drugs complies with standards. These policies should include guidelines for antimicrobial prescriptions, indications for use, dosages, and treatment durations to avoid unnecessary use and abuse of antibiotics. By establishing an antimicrobial management committee, the use of these drugs can be monitored and audited effectively, thereby reducing their overuse. Additionally, healthcare personnel should receive training on the rational use of antimicrobial drugs to enhance the scientific selection and application of these medications.[6]

3.3.2 Antimicrobial Resistance Monitoring and Management Strategies

Monitoring antimicrobial resistance is a key strategy for effectively controlling multidrug-resistant bacterial infections. Hospitals should establish a comprehensive antimicrobial resistance monitoring system to regularly collect and analyze epidemiological data on resistant bacteria, including resistance patterns, prevalence trends, and sources of infection. Through continuous monitoring, mutations in resistant bacteria and emerging resistance can be detected promptly, allowing for adjustments in infection control strategies and antimicrobial usage policies. Furthermore, monitoring results should be communicated to clinicians to assist them in formulating and optimizing treatment plans based on the latest resistance profiles. Combining the analysis of resistance data with antimicrobial resistance prevention measures both inside and outside the hospital helps develop a systematic management strategy to reduce the transmission and incidence of resistant infections.

Conclusion

The transmission routes of multidrug-resistant bacteria are complex and diverse, including direct contact, indirect contact, and airborne transmission, necessitating comprehensive prevention and control measures. Hospitals should strengthen hand hygiene and personal protection, formulate and implement infection control standard operating procedures, rigorously conduct environmental cleaning and disinfection, manage the disinfection of medical instruments effectively, and use antimicrobial drugs rationally. Additionally, establishing a monitoring and data feedback mechanism for antimicrobial resistance is crucial for understanding the prevalence trends of resistant bacteria in real time and adjusting prevention strategies accordingly. Future research should focus on optimizing these prevention and control measures and exploring strategies to combat emerging resistant bacteria, in order to adapt to changing resistance patterns and enhance the overall effectiveness of hospital infection control.

Fund Project

Supported by Science and Technology Development Incubation Fundation of Shaanxi Provincial People's Hospital (Grant Number: 2023YJY-47)

References

[1] Peng, H., Yang, Y.J., Yang, L., et al. "Analysis of the Characteristics and Prognostic Factors of Multidrug-Resistant Bacterial Infections in ICU Patients." Chinese Medical Herald, 2024, 21(19): 18-22.
[2] Zeng, X.T., Zhang, Q.Y., Pang, N., et al. "Distribution and Influencing Factors of Multidrug-Resistant Bacterial Infections in Intensive Care Units." Chinese Medical Science, 2024, 14(11): 186-190.
[3] Sun, W.G., Wang, W.W., Guo, D.L., et al. "Strengthening Terminal Disinfection to Reduce Multidrug-Resistant Bacterial Infections in Intensive Care Units." Chinese Journal of Disinfection, 2024, 41(05): 371-374.
[4] Liu, F. "Application Observation of Nursing in the Prevention and Control of Multidrug-Resistant Bacterial Infections under Behavioral Change Theory." Chinese Medical Guide, 2024, 22(09): 177-179.
[5] Feng, L. "Causes and Preventive Measures of Multidrug Resistance." Health and Wellness Report,

April 22, 2024 (004).
[6] Tao, C.A. "Research Progress on the Resistance of Disinfectants against Multidrug-Resistant Bacteria in Hospitals and Their Disinfection and Isolation Control." Chinese Health Standards Management, 2024, 15(03): 151-155.