Phage Therapy from Bench to Bedside: Collaborative Approaches to Personalized Treatment

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Antimicrobial resistance (AMR) is a growing global threat that causes millions of deaths each year. This crisis has renewed interest in alternative therapeutic strategies, including bacteriophage (phage) therapy (1-3). Phage therapy is not a new concept; it emerged more than a century ago following the discovery of bacteriophages by Twort and d'Hérelle and was used clinically prior to the advent of antibiotics. Although its use declined in Western medicine after the widespread adoption of antibiotics, phage therapy continued to develop in Eastern Europe, particularly in specialized centers such as the Eliava Institute in Georgia. In recent years, the rise of AMR has reignited global interest, leading to the establishment of dedicated phage therapy programs and clinical services in Europe, North America, and Australia, often within compassionate-use or experimental treatment frameworks.

Bacteriophages are highly specific viruses that infect and lyse bacteria, allowing targeted treatment of multidrug-resistant (MDR) pathogens with minimal disruption to the normal microbiota (4,5). The feasibility of phage therapy has been demonstrated in observational studies and multicenter case series. In a multinational retrospective study involving 100 patients who received personalized phage-based treatments — frequently in combination with antibiotics — clinical improvement was observed in the majority of cases (6). Importantly, phage therapy has generally exhibited a favorable safety profile, with adverse events reported as uncommon and mostly mild. Serious toxicity directly attributable to phages is rare, even among vulnerable patient populations, further supporting their potential clinical application (7).

A high degree of specificity represents both a major strength and a fundamental challenge. While it enables precise bacterial targeting and limits collateral damage to the microbiome, it also necessitates accurate identification of the causative pathogen and careful selection of effective phages. Consequently, phage therapy inherently shifts clinical decision-making toward individualized, patient- and pathogen-specific treatment strategies. Clinical experience accumulated through compassionate-use programs and specialized centers indicates that phage therapy may provide a meaningful therapeutic option for patients with few or no remaining alternatives, particularly those with chronic or refractory infections (5,8). Current applications have primarily focused on difficult-to-treat infections, including chronic osteomyelitis, prosthetic joint and device-related infections, diabetic foot infections, burn wound infections, cystic fibrosis-associated respiratory infections, and other biofilm-associated infections (6,7).

Despite these encouraging outcomes, several scientific and regulatory challenges continue to limit broader clinical adoption. Key issues — including optimal dosing regimens, pharmacokinetics, immune interactions, and the emergence of phage resistance — require further systematic investigation (5,9). In parallel, regulatory uncertainty remains a major obstacle, as phage preparations, which are often tailored to individual patients, do not fit easily within conventional medicinal product frameworks. Although regulatory authorities in different regions have begun to develop adaptive approaches, an internationally harmonized regulatory pathway for phage therapy has not yet been established (9,10).

The clinical implementation of phage therapy is inherently multidisciplinary, spanning a wide range of specialties from the laboratory to the bedside. The process typically begins with microbiological diagnosis and isolation of the causative bacterial pathogen, followed by phage screening and selection based on in vitro susceptibility testing. This phase requires close collaboration among basic scientists, pharmaceutical scientists, and infectious disease specialists. Subsequent steps — including genomic safety assessment, formulation development, quality control, and compliance with Good Manufacturing Practice (GMP) standards — necessitate coordinated input from disciplines such as pharmaceutical biotechnology and clinical pharmacy. The availability of well-organized phage biobanks containing well-characterized phages suitable for clinical use can substantially reduce the time from pathogen identification to therapeutic intervention, particularly in hospitalized patients with urgent clinical needs (11).

At the clinical level, physicians play a central role in determining patient eligibility, integrating phage therapy into comprehensive treatment plans, and interpreting clinical responses. Pharmacists contribute by optimizing

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phage preparation and administration, assessing drug–phage compatibility, and monitoring therapeutic outcomes. Continuous clinical follow-up and systematic evaluation of efficacy and safety complete this process, reinforcing the individualized nature of phage-based interventions.

In conclusion, phage therapy has progressed from a historically marginalized approach to a clinically relevant option in the era of escalating AMR. Its successful integration into healthcare systems depends on structured interdisciplinary collaboration across basic sciences, pharmaceutical disciplines, and clinical medicine. Continued research, regulatory innovation, and coordinated clinical practice are essential to clearly define the role of pharmaceutical care in phage therapy. As experience and infrastructure continue to expand, phage therapy is likely to become an increasingly important component of individualized treatment strategies for resistant bacterial infections.

Conflict of Interest

The author has no conflict of interest to declare.

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