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ORIGINAL ARTICLE

Hospital-adapted inhaled phage therapy for ventilator-associated pneumonia caused by multidrug-resistant *Klebsiella pneumoniae*

Gorodnichev R et al., Critical Care. 2026;30(1):64.

1 Introduction

Ventilator-Associated Pneumonia (VAP) caused by multidrug-resistant *Klebsiella pneumoniae* (MDR-Kp) remains a major challenge in ICUs with high mortality and limited treatment options. This prospective pilot study evaluated a hospital-adapted inhaled bacteriophage cocktail in ICU patients and demonstrated fast, effective bacterial eradication with favorable safety.

AT A GLANCE

21 ICU Patients	MDR <i>Klebsiella pneumoniae</i> VAP	Nebulized Twice Daily for 14 Days	Targeted Phage Cocktail + Standard Antibiotics	Well Tolerated No therapy-related adverse events	Superior Microbial Eradication 86% vs 57%

FIVE EMERGING TRENDS IN PHAGE THERAPY

01 	02 	03 	04 	05
Hospital-Adapted Cocktails Designed according to local bacterial epidemiology	Precision Phage Therapy Matches phages to dominant MDR strains	Inhaled Delivery Direct lung administration via nebulization	Combination Therapy Works synergistically with antibiotics	AI & Genomics Predicts optimal phage selection and resistance patterns

2 Methodology

Study Design

Single-center, open-label, non-randomized interventional pilot study (n = 21 ICU patients).

Participants

Patients: Adult MDR-K. pneumoniae VAP (n = 21)

Groups (n = 7 each):

- Targeted phage (PT)
- Non-targeted phage (NTPC)
- Control - No phage (CON)

Intervention

- Phage cocktail administered via nebulization twice daily for 14 days.
- All patients received standard antibiotic therapy as per culture sensitivity.

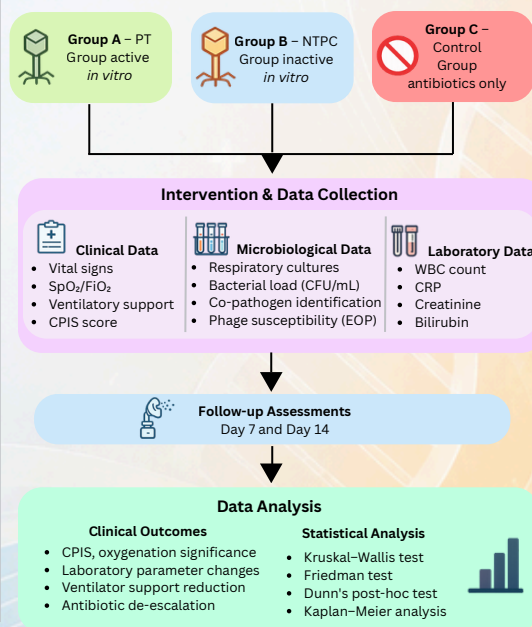
Primary Endpoint

Microbial eradication of *K. pneumoniae* at day 14.

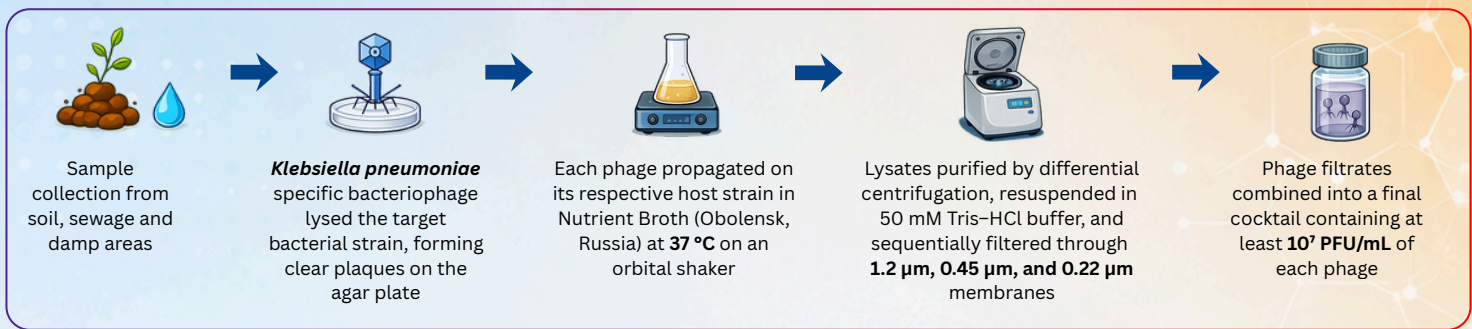
Secondary Endpoint

Assess Safety and Efficacy of Phage Cocktail

3 Flow of Study Design



4 Phage Preparation & Characterization



5 Study Criteria

INCLUSION CRITERIA	EXCLUSION CRITERIA
Adults aged ≥18 years	Prior organ transplantation
Chronic critically ill patients following severe brain injury	Absence of <i>K.pneumoniae</i> on microbiological testing
Tracheostomized patients requiring prolonged mechanical ventilation	Non-Invasive Mechanical Ventilation
VAP diagnosed according to ATS/IDSA 2016 guidelines	Terminal illness with an expected survival <72 hours

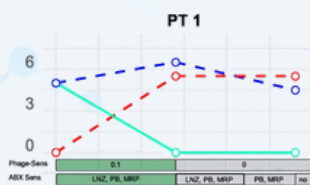
6 Administration

- **Route:** Inhaled via nebulization
- **Frequency:** Twice daily
- **Duration:** 14 days
- **Nebulizer connection:** Connected to the inspiratory limb of the ventilator circuit
- **Dose:** 10 mL phage cocktail per session (≥10⁷ PFU/mL of each phage)
- **Assessment:** Clinical, microbiological, and laboratory evaluations on Days 0, 7, and 14
- **Treatment:** Standard antibiotics administered to all patients according to group allocation



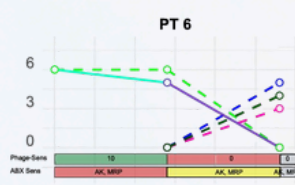
7 RESULTS - Five Major Trends Observed in this study

A Eradication without Strain Replacement



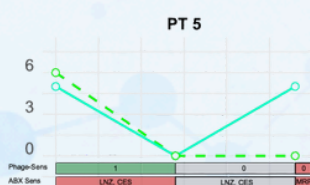
- 7 patients achieved sustained *K. pneumoniae* eradication without KL type switching
- PT1, PT2, and CON5: Pathogen cleared by Day 7
- PT3: Phage susceptibility increased (EOP 10⁻⁶ → 1), with eradication by Day 11
- CON3 and CON7: Eradication despite antibiotic resistance

B Eradication with Strain Replacement



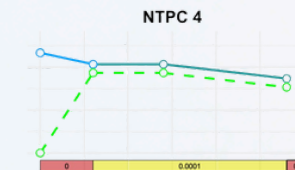
- PT4, PT6, and PT7: Original *K. pneumoniae* strain replaced between Days 1–7, with eradication by Day 14
- Replacement strains showed altered KL/ST types and changed
- PT4: More phage-susceptible, antibiotic-resistant
- PT6 & PT7: More antibiotic-susceptible, phage-resistant

C Transient Clearance



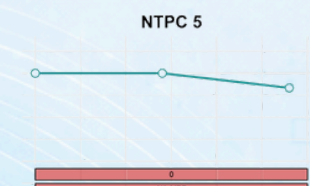
- PT5 and NTPC1: *K. pneumoniae* became undetectable but reappeared by Day 14
- Re-emerged strains retained the same KL type and sequence type (ST)
- PT5: Re-emerged strain developed increased phage resistance while remaining antibiotic-susceptible

D Strain Replacement without Eradication



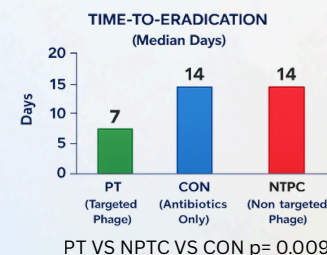
- NTPC2, NTPC3, and NTPC4: Original strains were replaced between Days 3–7
- Replacement strains had different KL types and sequence types (ST)
- New isolates showed low-level phage susceptibility but remained susceptible to antibiotics

E Persistent Colonization by the Original Strain

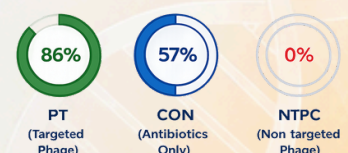


- NTPC5, NTPC6, NTPC7, CON2, CON4, and CON6: Persistent *K. pneumoniae* with unchanged KL type, ST, and antimicrobial susceptibility
- NTPC7, CON2, and CON4 remained antibiotic-susceptible; the remaining patients showed persistent resistance
- No microbiological eradication was achieved during the study period

8 DISCUSSION



MICROBIOLOGICAL ERADICATION (Day 14)



9 CONCLUSION

Hospital-adapted inhaled phage therapy demonstrated superior microbiological eradication and faster clinical improvement in ICU patients with MDR-Kp VAP without safety concerns.

ARTICLE INFORMATION

- **Journal** : Critical Care
- **Publisher** : Springer Nature (BMC)
- **Impact Factor** : 22.0
- **Quartile** : Q1
- **DOI** : 10.1186/s13054-026-05839-8



Successful Bacteriophage Treatment of a Recalcitrant Intra-Abdominal Infection Caused by Multidrug-Resistant *Pseudomonas aeruginosa* in a 2-Year-Old Child

Malhotra S, et al., The Journal of Pediatrics. 2026; 291:115005.



1 Executive Summary

Antimicrobial resistance (AMR) poses an emergency threat to pediatric solid-organ transplant recipients who undergo repeated antimicrobial prophylaxis and treatment. This report details the clinical course of a 2-year-old multiorgan transplant recipient with an extensively drug-resistant (MDR) *Pseudomonas aeruginosa* intra-abdominal infection. Following total failure of conventional antibiotic regimens, personalized emergency bacteriophage therapy achieved complete infection resolution and sustained microbiological cure.



POD 0
Multivisceral
transplant
performed



POD 18
MDR *P. aerug.*
isolated



POD 88
Phage search
initiated



POD 133
FDA emergency
investigational
authorization approved



POD 153
21-day IV phage
infusion



POD 153-174
IV bacteriophage
therapy (21 days)



+6 Months
Infection-free &
off antibiotics

*POD: Postoperative day

2 Patient Summary



Age / Gender
2 years /
Female



History
Multiorgan transplant for
biliary atresia



Infection
MDR *P. aeruginosa* intra-
abdominal infection



Previous Therapy
Multiple antibiotics with
persistent infection



Intervention
Personalized bacteriophage
therapy (2-phage cocktail)
IV administration for 21 days



Outcome
Clinical improvement with no
antibiotics for 6 months

3 Laboratory Monitoring

PARAMETER	CLINICAL RESPONSE & OBSERVATION
Clinical Cure	Marked stabilization by Day 15 of phage therapy; complete resolution of fevers, normalization of CRP, and successful weaning to room air.
Antibiotic Cessation	All systemic antimicrobials were successfully tapered and discontinued. Patient remained antibiotic-free for >6 months.
Neutralization Dynamics	Serum neutralization assays showed marked loss of phage titers by Day 14 (due to anti-phage antibodies), yet clinical cure was fully maintained.
Safety Profile	No phage-related systemic adverse events. Transient high lactate (169 mg/dL) resolved completely upon discontinuation of linezolid.

5 Why Phage Therapy



Targets only
specific
bacteria



Effective against
multidrug-resistant
organisms



Dynamic & self-
amplifying mechanism



Well tolerated with
minimal adverse effects



A promising option for
MDR in ICU patients

6 Key Takeaways

- Bacteriophage therapy can be a life-saving alternative in MDR infections when all other options fail.
- Early consideration and individualized phage selection are crucial.
- Monitoring phage-neutralizing antibodies is important for guiding therapy.
- This case supports further clinical research and structured protocols for phage therapy in children.



4 Antimicrobial Resistance Trajectory



Beta-lactams:
Rapid transition to full
resistance against Cefepime,
Ceftazidime, Ceftazidime/
Avibactam, and Piperacillin/
Tazobactam.



Novel Agents:
Loss of susceptibility to
Ceftolozane/ Tazobactam
(MIC >32) and emerging
resistance to Cefiderocol.



**Aminoglycosides &
Carbapenems:**
Full baseline/acquired
resistance to Meropenem,
Imipenem, and Tobramycin.

ARTICLE INFORMATION

- Journal** : The Journal of Pediatrics
- Publisher** : Elsevier
- Impact Factor** : 4.4
- Quartile** : Q1
- DOI** : 10.1016/j.jpeds.2026.115005



7 Future Implications



Need for robust clinical
trials in pediatric
populations



Regulatory pathways
for phage therapy
must advance



Establish standardized
phage banks & quality
control



Interdisciplinary
collaboration for
optimal implementation



Idvynso

(Doravirine / Islatravir)

100 mg/0.25mg

A complete Regimen for virologically suppressed adults with HIV - 1 infection



FDA Approval

June 18, 2025



Therapeutic class

NNRTI + NRTTI
Fixed Dose
combination



Indication

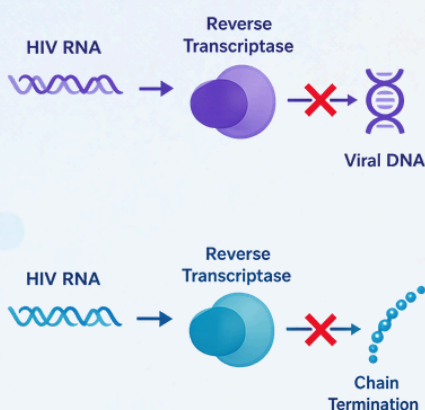
HIV-1 infection in virologically suppressed adults (HIV-1 RNA <50 copies/mL) on a stable antiretroviral regimen



Regimen Type

Complete regimen
(Co-administration with other antiretrovirals not recommended)

1 Mechanism of action



2 Approved Indication



Idvynso is indicated as a complete regimen for the treatment of HIV-1 infection in adults to replace the current antiretroviral regimen in those who are virologically suppressed (HIV-1 RNA <50 copies/mL) on a stable antiretroviral regimen with no history of treatment failure and no known substitutions associated with resistance to Doravirine

3 Dosage & Administration



- Tablet:** Fixed-dose combination of 100 mg Doravirine / 0.25 mg Islatravir
- Recommended Dose:** One tablet taken orally once daily with or without food in adult patients
- Complete Regimen:** Idvynso is a complete regimen; co-administration with other antiretrovirals for HIV-1 treatment is not recommended
- Rifabutin Co-administration:** If co-administered with Rifabutin, take one Idvynso tablet once daily, followed by one tablet of Doravirine (Pifeltro) 100 mg approximately 12 hours later for the duration of Rifabutin co-administration

PATIENT POPULATION	RECOMMENDED DOSE	FREQUENCY
Virologically Suppressed Adults	1 Tablet (100mg / 0.25mg)	Once Daily
Patients Co-administered Rifabutin	1 Tablet + 100mg Doravirine	Dose 12 hrs apart

4 Safety Profile



Contraindications

- Co-administered with strong **CYP3A enzyme inducers** (e.g., Carbamazepine, Oxcarbazepine, Phenobarbital, Phenytoin, Rifampin) may significantly decrease the Doravirine concentration
- Co-administered with **Lamivudine (3TC)** or **Emtricitabine (FTC)** cause intracellular competition which may decrease active Islatravir-triphosphate levels



Warnings & Precautions

- Severe skin & hypersensitivity reactions** (SJS, TEN) and DRESS have been reported. Discontinue immediately if progressive or severe rash occurs
- Risk of adverse reactions or loss of virologic response:** Concomitant use with specific medications may alter drug exposure, leading to treatment failure or adverse events



Adverse Drug Reactions

- Gastrointestinal Disorders:** Diarrhea, abdominal distention, nausea
- Nervous System Disorders:** Dizziness, headache
- General Disorders:** Fatigue
- Metabolism & Nutrition:** Minimal weight changes observed from baseline

5 Patient Counselling

How to Take



Take 1 tablet once daily, with or without food, at the same time each day

Missed Dose



Skip the missed dose and continue regular schedule. Do not take two doses at the same time

Do Not Stop



Do not stop treatment or change the dose without consulting healthcare provider.

Drug Interactions



Inform doctor about all prescription, OTC medicines, herbal products

Watch for Symptoms



Seek immediate medical attention if develop fever, facial swelling, or difficulty breathing

Monitoring



Keep regular follow-up appointments for monitoring HIV viral load

DRUG INFORMATION

Scan to see
Full Drug
Profile



FDA (Drugs@FDA): Idvynso FDA Approval / NDA 216964

भारतीय भेषज संहिता आयोग

स्वास्थ्य एवं परिवार कल्याण मंत्रालय, भारत सरकार
सेक्टर - २३, राज नगर,
गाजियाबाद - २०१ ००२, उत्तर प्रदेश, भारत



INDIAN PHARMACOPOEIA COMMISSION

Ministry of Health & Family Welfare, Government of India
Sector - 23, Raj Nagar
Ghaziabad- 201 002 (U.P.), INDIA

File No. P.17019/03/2025-DSA

Dated: February 20, 2026

Drug Safety Alerts

The analysis of Adverse Drug Reactions (ADRs) from the PvPI database revealed the following;

S. No.	Suspected Drugs	Indication(s)	Adverse Drug Reactions
1	Dacarbazine	Chemotherapy of malignant melanoma, Hodgkin's lymphoma and soft tissue sarcomas.	Transient reversible blurred vision
2	Dolutegravir	In combination with other antiretroviral agents for the treatment of Human Immunodeficiency Virus Type 1 (HIV 1) infection.	Sexual dysfunction

भारतीय भेषज संहिता आयोग

स्वास्थ्य एवं परिवार कल्याण मंत्रालय, भारत सरकार
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INDIAN PHARMACOPOEIA COMMISSION

Ministry of Health & Family Welfare, Government of India
Sector - 23, Raj Nagar
Ghaziabad- 201 002 (U.P.), INDIA

File No. P.17019/03/2026-DSA

Dated: March 30, 2026

Drug Safety Alerts

The analysis of Adverse Drug Reactions (ADRs) from the PvPI database revealed the following;

S. No.	Suspected Drugs	Indication(s)	Adverse Drug Reactions
1	Polymyxin B	Urinary tract infections caused by P. Aeruginosa and E. Coli, bloodstream infections caused by P. Aeruginosa, E. Aerogenes and K. Pneumoniae, Meningeal infections caused by P. Aeruginosa.	Hypokalemia
2	Clomipramine	Antidepressant- Obsessive Compulsive Disorders, phobic states and depression (when sedation is required).	Akathisia
3	Famotidine	Indicated in the treatment of duodenal & peptic ulcer, Zollinger-Ellison syndrome.	Fixed Drug Eruption



A report on Insights and Overview of Clinical Data Management: Present and Future Prospects

Coordinator: Dr. Deepalakshmi M
Associate Professor

Date: 28.02.2026

The main aim of this program was to help Pharm D students understand real-world applications of their studies by interacting with experts from industry and research fields. The first lecture was delivered by Jadesh Yaligar, who served as a Principal Investigator at the Institute for Human Development and Potential, under the Agency for Science, Technology and Research (A*STAR), Singapore. His talk was titled "Pre-Clinical and Translational Metabolic Imaging for Bio-Medical Applications." He explained how advanced imaging techniques are used in biomedical research to study diseases and evaluate drug effects. He also discussed how research findings can be translated into clinical applications to improve patient care. The second lecture was delivered by M. Satish, Manager in Clinical Data Management at Tata Consultancy Services. His lecture was titled "Insights and Overview of Clinical Data Management: Present and Future Prospects." He explained the role of clinical data management in clinical trials and how accurate data helps in developing safe and effective medicines. He also discussed the growing career opportunities for pharmacy graduates in areas such as clinical research, data management, pharmacovigilance, and regulatory affairs. The session helped students understand the skills needed to work in the pharmaceutical industry. The program was attended by 90 students and 5 faculty members, who actively participated in the discussion sessions with the speakers. The lectures provided students with valuable knowledge about current trends in clinical research and biomedical science.



Linking Pharm D Students with Real-World Experts - A Report

Coordinator: Dr. Deepalakshmi M
Associate Professor

Date: 30.03.2026

A guest lecture series titled "Linking Pharm D Students with Real-World Experts" was organized at JSS College of Pharmacy, Ooty. The main aim of this program was to help Pharm D students understand real-world applications of their studies by interacting with experts from industry and research fields. The program was inaugurated by Dr. K. P. Arun, Vice Principal, and Dr. S. Ponnusankar HOD of Pharmacy Practice department. They encouraged students to take advantage of such programs to learn about career opportunities and new developments in healthcare and research. The first lecture was delivered by Dr. K. Tamilarasu, MD., DNB., FACC (Cardiology), Prof & Head of Cardiology, PSG IMS&R, Coimbatore. His talk was titled "Heart failure management-four pillars- clinical pharmacist point of view". He explained the definition, Universal classification and Role of Clinical Pharmacists in Heart Failure. This session was highly interactive and explained the content with a case study. The second lecture was delivered by Dr Poorani Devi, an Associate Professor in OBGYN PSG Hospitals. Her lecture was titled "Role of the clinical pharmacist in Obstetric practice. She explained the right drug, right dose, right duration, right Patient- now with two individuals (mother & fetus). The program was attended by 90 students and 5 faculty members, who actively participated in the discussion sessions with the speakers. The lectures provided students with valuable knowledge about current trends in clinical research and biomedical science.



**ACPE, USA peer team visit to Faculty of Pharmacy, JSS Colleges of Pharmacy, Ooty & Mysuru
(09 Feb 2026 - 12 Feb 2026)**



Faculty of Pharmacy Practice, JSS Academy of Higher Education & Research, Mysuru was the first institution in the Asia-Pacific region to receive accreditation from the Accreditation Council for Pharmacy Education (ACPE), USA, for its Pharm.D programme in 2014. The colleges has consistently upheld the highest standards of pharmacy education, successfully achieving reaccreditation in every accreditation cycle. Continuing this legacy of excellence, the third-cycle ACPE reaccreditation evaluation was conducted from 9th to 12th February 2026 by a team of four peer evaluators appointed by ACPE, USA. The evaluation comprehensively assessed the institution's adherence to international standards in pharmacy education, including academic infrastructure, teaching-learning methodologies, student quality, experiential and clinical training, faculty development, assessment practices, and overall institutional quality assurance. The peer evaluators highly appreciated the institution's state-of-the-art infrastructure, innovative teaching and learning practices, competent faculty, high-quality students, and strong clinical pharmacy practice and experiential education. The evaluation reflected the institution's unwavering commitment to academic excellence and continuous quality improvement. The department is optimistic about receiving ACPE reaccreditation for the next six-year accreditation cycle, further reinforcing its position as a leader in global pharmacy education.

