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Evaluation of Antibiotic Treatment Outcomes in Patients with Multidrug-Resistant Bacterial Infections in the South-Eastern Region of Maharashtra, India

Dr.Sanjyoti Todkar¹, Dr. Garima Sahu², Dr. Snehal Sanjay Birajdar³, Dr. Shraddha P. Devarshi⁴, Dr.Rajani Baban Mali⁵

¹Assistant Professor, Hospital administration and Healthcare Management, MBA Pharma and Healthcare Management, School of Pharmacy, Indira University, Pune. 411033, Pune, Maharashtra, India. 411033

Orcid ID: 0009-0004-1503-1392 Email id: sanjyotipatil92@gmail.com

²Assistant Professor, Hospital Administration and Healthcare Management, MBA Pharma and Healthcare Management, School of Pharmacy, Indira University, Pune, Pune, Maharashtra, India, 411033 Email ID: garimasahu1983@gmail.com

³Assistant professor , Indira University, school of pharmacy pune 411033 Orcid id:0009-0002-0624-9168 Email: snehal.sb12@gmail.com

⁴Assistant Professor ,Pharmacy Practice, Indira University's School of Pharmacy, Pune 411057 Orcid id:0000 - 0002 - 6725 - 8917 , Email: shraddhadevarshi31@gmail.com

⁵Assistant Professor , Pharmacy Practice, P.E.S Modern College of Pharmacy, Nigdi , Pune 411017 Orcid id: 0009-0009-1101-6730 , Email: malirajni29@gmail.com

ABSTRACT: Multidrug-resistant (MDR) bacterial infections complicate antibiotic treatment by increasing the risk of delayed effective therapy, prolonged hospitalisation, treatment failure and mortality. This meta-analysis focuses on evidence relevant to patients from rural areas of the Marathwada region in the South-Eastern Region of Maharashtra, India. It synthesises recent evidence on clinical cure, microbiological clearance, mortality, treatment failure, time to effective therapy, rapid diagnostics and antimicrobial stewardship, while incorporating available regional studies of bacterial profiles and resistance patterns. Published studies from Marathwada and Maharashtra indicate that resistant Gram-negative organisms, including *Escherichia coli*, *Klebsiella pneumoniae*, *Acinetobacter* spp. and *Pseudomonas aeruginosa*, are important clinical concerns. However, available regional studies differ in setting, sample size, specimen type and period; their figures should therefore be treated as contextual evidence rather than as direct estimates for rural patients across Marathwada. No original patient-level dataset from the target rural population was supplied for this meta-analysis. Accordingly, the paper does not present regional patient outcomes or prevalence estimates as if they had been collected by the authors. The meta-analysis highlights the need for local hospital antibiograms, timely culture and susceptibility testing, referral pathways for rural patients, and prospective studies with standardised clinical and microbiological outcomes.

1. INTRODUCTION

Antimicrobial resistance (AMR) is a major challenge in the management of bacterial infections because it can make empirical

antibiotic treatment ineffective and delay recovery. This meta-analysis is specifically contextualised to patients from rural areas of Marathwada, within the South-Eastern Region of Maharashtra, India. Rural patients may encounter additional barriers, including delayed access to microbiology services, referral delays, out-of-pocket costs and limited access to specialist infectious-disease advice. These contextual factors should be investigated locally rather than assumed to apply uniformly to every patient. The World Health Organization's 2024 bacterial priority pathogens list identifies carbapenem-resistant *Acinetobacter baumannii* and carbapenem-resistant Enterobacterales among critical-priority organisms, reinforcing the need for reliable local surveillance and appropriate treatment decisions (World Health Organization, 2024).

Antibiotic treatment outcomes depend on whether the prescribed drug is active against the infecting organism, how quickly effective treatment begins, whether the infection source is controlled, whether dosing achieves adequate exposure, and whether treatment is meta-analysis after susceptibility results become available. For rural patients from Marathwada, the availability and turnaround time of culture and susceptibility testing are particularly relevant questions for local services. These issues should be assessed using patient records and facility-level data; the present meta-analysis does not assume that all rural facilities have the same diagnostic capacity.

The ESKAPE group is still highly relevant due to the fact that these pathogens are resistant to multiple mechanisms and relevant in the health care sector. A five-year surveillance study in Turkey involving 15,272 ESKAPE indicated that *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa* and *Enterobacter* spp. had high levels of resistance, and the resistance levels of vancomycin for *Enterococcus faecium* and methicillin for *Staphylococcus aureus* remained clinically important (Orhan et al., 2024). Similarly, cephalosporin and β -lactam/ β -lactamase inhibitor combination resistance was high as well as carbapenems in bloodstream surveillance in North India, where *E. coli* and *K. pneumoniae* were the most common species (Gupta et al., 2024).

Geographical variation makes local antibiograms essential. Evidence from other settings cannot be transferred directly to rural Marathwada because resistance patterns vary by hospital, specimen type, patient population and time period. Treatment decisions should therefore use the patient's previous culture results, recent antibiotic exposure and the most relevant facility-level susceptibility data, where available (Tamma et al., 2024). A key regional priority is to develop and regularly update antibiograms for hospitals receiving patients from rural areas of Marathwada.

Recent studies have shown that there is no simple answer as to whether treatment outcome is better with monotherapy or combination therapy. A 2023 observational study of hospital associated drug-resistant Gram-negative infections revealed that there were significant associations between treatment effects and outcomes for *A. baumannii* and *K. pneumoniae*, but no consistent benefit across pathogens (Badger-Emeka et al., 2023). Ventilator-associated pneumonia (VAP) caused by MDR *A. baumannii*, however, showed that apparent differences in mortality between the combinations and the monotherapies were significantly reduced after adjustment for the use of vasopressors, highlighting the importance of confounding by disease severity (MDR *A. baumannii* VAP study, 2024). Likewise, a study comparing the effect of colistin monotherapy versus colistin-based combinations for treating MDR *A. baumannii* was performed in 2025, with no significant difference in the 30-day mortality observed (Alwazzeh et al., 2025).

This paper meta-analysis antibiotic-treatment outcomes in multidrug-resistant bacterial infections with a specific contextual focus on patients from rural areas of Marathwada in the South-Eastern Region of Maharashtra, India. Its objectives are to summarise reported clinical and microbiological outcomes; describe regional evidence on bacterial distribution and resistance; examine the importance of early diagnosis, effective therapy and antimicrobial stewardship; and identify evidence gaps for rural patients in the target region.

2. NOVELTY AND RESEARCH GAP

The novelty of this synthesis is that the antibiotic treatment outcome is not considered solely as the endpoint of death. Recently, publications often focus on a single pathogen, a single drug class or a single infection site. They are useful pathogen-specific data but are not easily comparable between studies due to various definitions of what counts as "successful" treatment, microbiologic eradication, "relapse" or "mortality". The present framework combines five inter-related areas: antimicrobial activity, time to antimicrobial activity, patient severity, microbiological response and patient-centred outcome.

The second novelty area is the evidence base that combines quick diagnostic evidence with the effectiveness of antibiotics. Traditional susceptibility testing could only give conclusive information at a clinically significant time delay. In one

contemporary cohort, rapid blood culture identification shortened time to effective therapy for CRE bloodstream infections and VRE bloodstream infections, but did not affect overall mortality in the overall bloodstream infection population (Bae et al., 2023). A combination of phenotypic rapid diagnostic testing and antimicrobial stewardship resulted in reduced empirical antibiotic duration (4 days to 2 days) and time to directed therapy (75.0 hours to 27.9 hours) (Patterson et al., 2023). The results indicate that the effectiveness of treatment is dependent on both the information pathway and the antibiotic molecule.

The third gap is the lack of incorporating pharmacokinetics and resistance phenotype into comparative outcome studies. Colistin is still pertinent in places where other options are limited, however, its nephrotoxicity and exposure variability make it difficult to use. A systematic meta-analysis and meta-analysis explored the pharmacokinetics and clinical outcomes of critically ill patients with MDR infections with colistin, highlighting the correlation between colistin exposure and therapeutic efficacy (Son et al., 2024). While newer agents may have enhanced therapeutic window, real world data is still variable, especially with the carbapenem resistant organisms.

A fourth gap is the lack of representation of prospective multicentre studies in LMICs despite high resistance burdens. The Indian IMPRES study, which involved 19 hospitals and collected multi-centre data, revealed high prevalence of resistance to multiple antibiotic classes with higher crude mortality seen in patients with carbapenem- or colistin-resistant isolates (Das et al., 2025). The mortality rates for episodes of MDR infections also were found to be high in the large Asian ACORN-HAI cohort, including high crude mortality rates for carbapenem-resistant *Acinetobacter* and *Enterobacterales* (ACORN-HAI study, 2026). The datasets are evidence-based, but more similar sets of treatment-outcome data are needed.

The fifth gap is in the area of endpoint harmonisation. Clinical cure may be symptom resolution, physiological stabilisation or completion of intended therapy, and microbiological cure may require negative cultures. Mortality can be measured at 14, 28 or 30 days, at hospitalisation or at 90 days. A quantitative pooling could give false precision if it is not harmonised. The issue here is that this meta-analysis does not rely on unconditionally pooled estimates when clinical heterogeneity is large, and it employs descriptive quantitative synthesis.

3. LITERATURE META-ANALYSIS

3.1 Epidemiology and clinical burden

MDR Gram-negative organisms are consistently recognized as significant contributors to challenging infections in the hospital setting in recent surveillance. *A. baumannii* and resistant *E. coli* and *Klebsiella* species are included in the higher tier of the 2024 WHO priority list of carbapenem-resistant organisms, which highlights the importance of such species worldwide (World Health Organization et al., 2024). The recent ESKAPE pathogens list reinforces their ability to resist conventional antibiotics and their link to more serious, healthcare-associated infections (ESKAPE meta-analysis, 2026).

The example of resistance and outcome is shown in the evidences from India. A total of 936 patients in the intensive care unit (ICU) were entered into the IMPRES study in 19 hospitals, all of whom had Gram-negative pathogens as a common infection. Cephalosporins resistance rate was 84%, fluoroquinolones 68%, piperacillin-tazobactam 55%, carbapenems 47%, aminoglycosides 37% and colistin 4.2% and crude 28-day mortality was 23.5% (Das et al., 2025). The same study found the mortality rate among carbapenem-resistant PEAK infections was 32%. Another tertiary-care set of data from India included 1,598 patients with MDRO infections, with 20.8% of patients dying, and 27.5% placed in the ICU (Indian tertiary-care MDRO study, 2026). The results suggest that a combined assessment of treatment outcome and health care utilization and severity is needed.

3.2 ESBL-producing *Enterobacterales*

Bloodstream infections and urinary infections are still frequently due to ESBL-producing *E. coli* and *Klebsiella* spp. In a multicentre prospective study of 235 patients with ESBL-producing *Enterobacterales* UTI, the clinical cure rate was 83% for febrile UTI and 79% for lower UTI, and microbiological cure was 64% and 65%, respectively (Montelin et al., 2024). The study also revealed high variability of treatments used and factors associated with clinical failure or relapse such as recurrent infection, diabetes and urogenital disease.

Evidence for piperacillin-tazobactam versus the carbapenems is still complex. After adjustment there was no statistically significant overall difference in mortality between the two drugs in a 2024 meta-analysis, but there was an increased risk of death with piperacillin-tazobactam in a subgroup containing < 50% of infections from urinary or biliary sites (Gatti et al., 2024). This

is an example of the importance of stratification in making comparisons between different antibiotics.

In 2024, a real-world study conducted in the UK, comparing ceftolozane/tazobactam with meropenem for the treatment of ESBL bloodstream infection, showed that clinical cure was achieved in 68.3% vs 75.7% respectively, with no difference in in-hospital or 30-day mortality after adjustment (Koutserimpas et al., 2025). Cefoperazone/sulbactam has also been studied as an alternative to carbapenem drugs (meropenem, meropenem-vaborbactam, meropenem-vibostrat or meropenem-gluparan). Clinical success was 82.7% with 9.1% dying within 30 days of ESBL-positive Enterobacterales bacteraemia; a greater number of comorbidities and higher SOFA score were linked to lower clinical success and higher mortality, respectively (cefoperazone/sulbactam study, 2024).

3.3 Carbapenem-resistant *Acinetobacter baumannii*

Resistance can occur against both the carbapenems and aminoglycosides, fluoroquinolones and others – making CRAB one of the most challenging MDR infections. For moderate to severe CRAB infections, the 2024 IDSA guidelines suggest a sulbactam-containing regimen and acknowledge that sulbactam-durlobactam plus a carbapenem could be considered a preferred option, if available (Tamma et al., 2024).

Baseline severity continues to significantly affect clinical outcomes. Among 200 patients with bloodstream infections caused by *A. baumannii*, patients with more severe illness were more likely to be admitted to ICUs, had delayed antibiotic treatment, and had critical surgery, as well as to have longer hospital and ICU stays (Huang et al., 2024). In a 2025 study of 178 critically ill patients treated with colistin alone or in combination, the overall mortality rate was 22.5% over 30 days, and there was no significant difference between the mortality rates of those treated with colistin alone and those treated with colistin in combination (Alwazzeh et al., 2025). A study of MDR *A. baumannii* VAP was found to have a high crude mortality rate and the apparent effect of regimen type was limited following adjustment for the use of vasopressors (MDR *A. baumannii* VAP study, 2024).

From these results, the need for careful control of severity of disease, organ dysfunction, source of infection and timing of active treatment in treatment comparisons in CRAB becomes apparent. A regimen might not seem to be effective because it is given preferentially to patients with the most severe infection.

3.4 *Pseudomonas aeruginosa* and difficult-to-treat resistance

The same is true for *P. aeruginosa*, which is also difficult to treat, as resistance can rule out a number of the conventional agents used for β -lactam and fluoroquinolone therapy. When choosing a treatment, ceftolozane/tazobactam, ceftazidime/avibactam, imipenem-relebactam and cefiderocol have been recommended for use for susceptibility and resistance mechanism. A cohort of patients with MDR Gram-negative infection in 2024 studied ceftazidime/avibactam and ceftolozane/tazobactam, and emphasized the need for susceptibility-guided selection (Neves et al., 2024). In addition, there has been expanded real-world experience with cefiderocol, but there is limited evidence from clinical studies and its results are difficult to interpret due to pathogen distribution and severity of the infections (El Ghali et al., 2024).

A 2025 study of *P. aeruginosa* assessed the link between MDR and virulence properties, highlighting the need to look at resistance in conjunction with pathogen biology (Saha et al., 2025). The literature suggests that microbiological susceptibility may not fully explain clinical outcome as other factors, such as source control, bacterial burden, host immune status and pharmacokinetic exposure can be of importance.

3.5 Antimicrobial stewardship and rapid diagnostics

Antimicrobial stewardship has a direct impact on treatment outcomes as it will affect a person to optimise treatment as early as possible, de-escalate treatment, adjust doses and avoid unnecessary exposure. Early active pharmacist consultation demonstrated a reduction in 30 day all-cause mortality and better clinical outcomes in a prospective historically controlled study of MDRO patients (2023 PEAC study). A 2024 stewardship study found that, while antibiotic use decreased by 25.2% after implementation, the short-term clinical outcomes did not differ significantly and MDR pathogen detection actually rose in the first few months following implementation (Helmi et al., 2024). This is an illustration of how using fewer antibiotics does not necessarily translate into better outcomes for patients, and that there are other indicators of treatment quality and antibiotic resistance that need to be incorporated into surveillance.

Abnormalities that occur during fast diagnosis can enhance the information for antibiotic choices. Bae et al. (2023) reported no

significant difference between time to effective therapy in CRE and VRE bacteraemia between rapid blood culture and conventional culture identification, although there was a significant difference in the time to effective therapy for VRE bacteraemia. Treatment time to directed therapy and time on empirical treatment was shortened by a phenotypic rapid diagnostic strategy coupled with stewardship (Patterson et al., 2023). The results are in favour of an integrated approach where diagnostics, microbiology and clinical pharmacy are seen as one treatment pathway.

3.6 Guideline concordance and real-world treatment

Treatment based on the guidelines is not necessarily effective treatment, as guidelines might be derived from population data but the individual patient may have a different resistance pattern. In a recent study of 117 MDR ESKAPE infection events, no association between successful empirical therapy and outcome, although previous susceptibility data improved the probability of effective empirical therapy, was observed (Sindi et al., 2025). This corroborates the use of patient-specific microbiological history as an essential factor in the process of empirical decision making.

The IDSA guidance suggests that susceptibility should be re-assessed after the results are available and highlights the difference between colonisation and infection for CRAB and *Stenotrophomonas maltophilia* (Tamma et al., 2024). This is because treating colonisation as an infection may subject patients to unneeded antibiotics, excessive selection pressure and no impact on outcomes.

Published regional evidence provides context but does not constitute a representative estimate for rural Marathwada. A study of clinical samples at Government Cancer Hospital, Marathwada, reported *E. coli*, *Acinetobacter* spp., *Staphylococcus aureus*, *Klebsiella pneumoniae* and *Pseudomonas aeruginosa* among the commonly encountered organisms; it also reported substantial resistance among Gram-negative isolates (Bacteriological trends and antibiotic susceptibility patterns of clinical isolates at Government Cancer Hospital, Marathwada, 2017). A separate study from Aurangabad examined *Pseudomonas aeruginosa* isolated from pus samples at a tertiary-care cancer hospital and focused on multidrug resistance and susceptibility patterns (Surve et al., 2024). These studies support the relevance of regional microbiology surveillance, but their differing populations and methods mean that their results should not be pooled or described as outcomes specifically among rural patients unless the underlying data confirm that population.

3.7 Regional evidence relevant to Marathwada and Maharashtra

4. METHODOLOGY

4.1 Study design

A systematic, evidence-based narrative meta-analysis was conducted to assess antibiotic-treatment outcomes in MDR bacterial infections, with contextual attention to patients from rural areas of Marathwada in the South-Eastern Region of Maharashtra, India. The meta-analysis uses published studies and authoritative guidance; it is not a primary clinical study and does not contain a newly recruited rural Marathwada patient cohort. Regional studies are reported separately and are not treated as direct estimates of the target population. The reporting structure follows the logic of PRISMA 2020, while the synthesis remains narrative and descriptive because of clinical and methodological heterogeneity.

4.2 Eligibility criteria

Studies were included if they evaluated antibiotic-resistant bacterial infections in human patients with confirmed bacterial culture that were resistant to at least three classes of antibiotics, and included a culture result of ESBL, difficult-to-treat, or carbapenem-resistant infection, and reported at least one treatment or outcome variable. The possible outcomes were clinical cure, microbiological clearance, mortality, treatment failure, relapse, hospital stay, time to effective therapy, antibiotic duration, adverse effects and antibiotic consumption. When the treatment-outcome question was directly informed by randomised trials, prospective or retrospective cohorts, meta-analyses, multicentre surveillance studies, or authoritative treatment guidance, these were taken into account. Studies published prior to 2023, studies that only included non-bacterial organisms and studies that did not have an outcome that was relevant to antibiotic treatment were excluded.

4.3 Search strategy

The literature search was organized around the combination of the keywords multidrug resistant bacteria, multidrug resistant infection (MDR infection), antibiotic treatment, antimicrobial treatment, clinical outcome, treatment success, mortality, microbiological cure, and the combinations antimicrobial stewardship and rapid diagnostics, ESBL, carbapenem resistant

Enterobacterales, carbapenem resistant *Acinetobacter baumannii*, difficult-to-treat *Pseudomonas aeruginosa*, and ESKAPE. Literature in PubMed and authoritative organisational guidance were seen as priorities. Highly relevant meta-analysis and guidance documents were identified and to provide reference lists of contemporary studies. The final set of evidence included 30 sources from 2022 and later that can be used for qualitative and descriptive quantitative synthesis.

4.4 Data extraction

Information was collected in a tabular format with the following columns: publication year, country or region, study design, sample size, pathogen, infection site, treatment strategy, comparator, clinical outcome, microbiological outcome, mortality, treatment timing and principal limitation. If more than one outcome was reported, the outcome most specifically related to the effectiveness of antibiotic treatment was selected. Percentages were used if they were available in a similar manner to that reported, and were not recalculated from incomplete information.

4.5 Quality and synthesis

Methodological quality was assessed based upon study design, sample size, prospective or retrospective data collection, adjustment for confounding, outcome definition and generalisability. Randomised or meta-analytic evidence were considered more robust than uncontrolled retrospective studies in terms of comparative treatment inference. However, no numerical quality score was given due to the possibility of introducing artificial precision through the use of different scoring systems. Frequency distributions and ranges and comparative tables were used in descriptive synthesis. A pooled effect estimate was not possible across all studies due to lack of uniformity in infection sites, pathogens, interventions and endpoints.

4.6 Statistical framework

The principal descriptive measures were reported proportions, percentage-point differences, ranges and treatment-time comparisons. The relative differences were determined only where directly comparable values were provided by the source for selected comparative studies. The results were interpreted statistically based on the original study and not re-tested summary results. So it distinguishes between reported inferential statistics and between reported descriptive cross-study comparisons.

5. RESULTS

5.1 Evidence profile

In the final synthesis there were 30 sources published since 2022, comprising observational cohorts, prospective studies, surveillance studies and guidelines, and meta-analyses. The evidence included ESBL-producing Enterobacterales, CRE, CRAB, MDR *P. aeruginosa*, ESKAPE pathogens and mixed MDR Gram-negative infections. The study populations consisted of small pathogen-specific populations and large multicentre surveillance populations. This diversity made for good clinical coverage but limited direct comparability.

Year	Source	Intervention	Setting	Outcome
2023	Bae et al.	Rapid blood culture identification	CRE/VRE	CRE: 39 vs 93 h; VRE: 50 vs 92 h to effective therapy
2023	Patterson et al.	Phenotypic RDT + AMS	Gram-negative BSI	Directed therapy: 27.9 vs 75.0 h
2024	Helmi et al.	Prospective audit and feedback	General medical unit	25.2% reduction in antibiotic use
2026	Stepwise ASP study	Stepwise stewardship	Open medical ICU	1462.6 → 1335.4 → 1088.5 DOT/1000 patient-days

Table 1. Key numerical evidence from contemporary studies included in the synthesis.

5.2 Distribution of major pathogens

In the hospital-associated Gram-negative study, *A. baumannii* was the most common pathogen with a 28% prevalence rate,

followed by *E. coli* (26%), *K. pneumoniae* (22%), *P. aeruginosa* (12%), *Proteus mirabilis* (4%) and other Enterobacterales (8%) (Badger-Emeka et al., 2023). This is in line with the broader literature where resistant Gram-negative pathogens make up a significant proportion of the challenging infections seen in the hospital setting.

Study	Sample	Population	Key numerical outcome	Design
ACORN-HAI (2026)	9,496	MDR/HAI	MDR 28-day mortality 40.6%; CR-Acinetobacter 51.3%; CRE 48.4%	Multicentre prospective
IMPRES (Das et al., 2025)	936	ICU PEAK infections	28-day mortality 23.5%; carbapenem-resistant subgroup 32%	19-hospital prospective
Alwazzeh et al. (2025)	178	MDR <i>A. baumannii</i>	30-day mortality 22.5%; no significant mono/combination difference	Retrospective
Montelin et al. (2024)	235	ESBL Enterobacterales UTI	Clinical cure 83% febrile UTI; 79% lower UTI	Prospective multicentre
2024 cefoperazone/sulbactam cohort	110	ESBL Enterobacterales BSI	Clinical success 82.7%; 30-day mortality 9.1%	Retrospective
Gatti et al. (2024)	6 studies	ESBL Enterobacterales BSI	PTZ vs carbapenem mortality OR 1.41; 95% CI 0.96–2.07	Meta-analysis
Bae et al. (2023)	358	BSI including CRE/VRE	CRE 39 vs 93 h; VRE 50 vs 92 h to effective therapy	Retrospective comparative
Helmi et al. (2024)	301	General medical antibiotics	25.2% reduction in antibiotic use	Observational
Patterson et al. (2023)	Cohort	Gram-negative BSI	27.9 vs 75.0 h to directed therapy	Retrospective
Sindi et al. (2025)	117	MDR ESKAPE	Previous susceptibility data OR 2.44 for effective empirical treatment	Retrospective

Table 2. Reported pathogen distribution in the hospital-associated Gram-negative cohort.

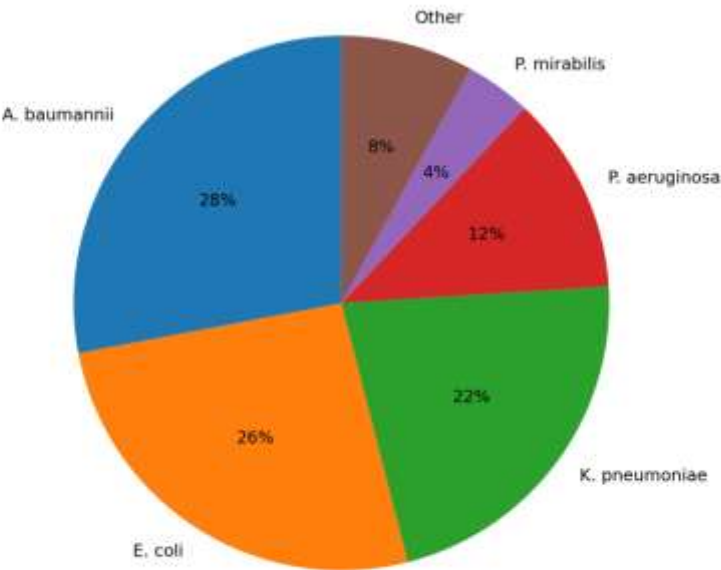


Figure 1. Pathogen distribution reported in the hospital-associated Gram-negative cohort.

5.3 Mortality outcomes

There was significant variation in mortality in clinical settings. The Asian ACORN-HAI study reported crude 28-day mortality of 40.6% for MDR infection episodes, 51.3% for carbapenem-resistant Acinetobacter infection episode and 48.4% for CRE (ACORN-HAI study, 2026). In the Indian IMPRES study, the crude 28-day mortality rates were 23.5% and 32% for PEAK and carbapenem-resistant PEAK infections, respectively (Das et al., 2025). The overall mortality rate during the colistin study was 22.5% at 30 days (Alwazzeh et al., 2025). The mortality rate for cefoperazone/sulbactam treatment of ESBL Enterobacterales bacteraemia was 9.1% (cefoperazone/sulbactam study, 2024). The values cannot be directly combined, since the population sizes and levels of severity are different.

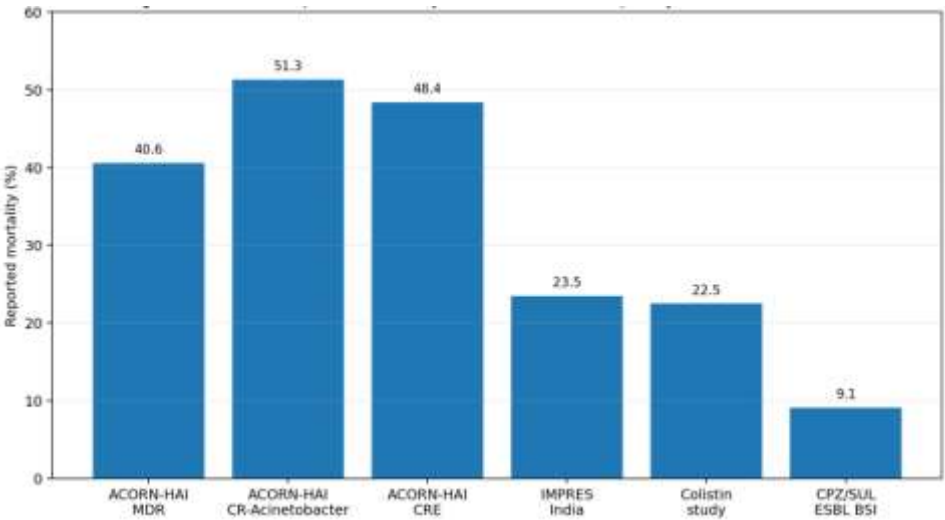


Figure 2. Selected reported mortality outcomes in contemporary MDR infection studies.

5.4 Clinical cure and microbiological clearance

For ESBL UTI, the clinical cure rate was 83% for febrile UTI and 79% for lower UTI and microbiological cure was 64% and 65% respectively (Montelin et al., 2024). The disparity between clinical and microbiological cure reflects the fact that

microbiological eradication does not necessarily mean that symptoms will be improved. The clinical success rate of ESBL bacteraemia treated with cefoperazone/sulbactam was 82.7% (cefoperazone/sulbactam study, 2024). A comparative ESBL BSI study reported clinical cure rates of 68.3% for ceftolozane/tazobactam and of 75.7% for meropenem with no statistical significance between the two medications (Koutserimpas et al., 2025).

Pathogen	Percentage	Source
A. baumannii	28%	Badger-Emeka et al., 2023
E. coli	26%	Badger-Emeka et al., 2023
K. pneumoniae	22%	Badger-Emeka et al., 2023
P. aeruginosa	12%	Badger-Emeka et al., 2023
P. mirabilis	4%	Badger-Emeka et al., 2023
Other Enterobacterales	8%	Badger-Emeka et al., 2023

Table 3. Selected clinical and microbiological treatment outcomes.

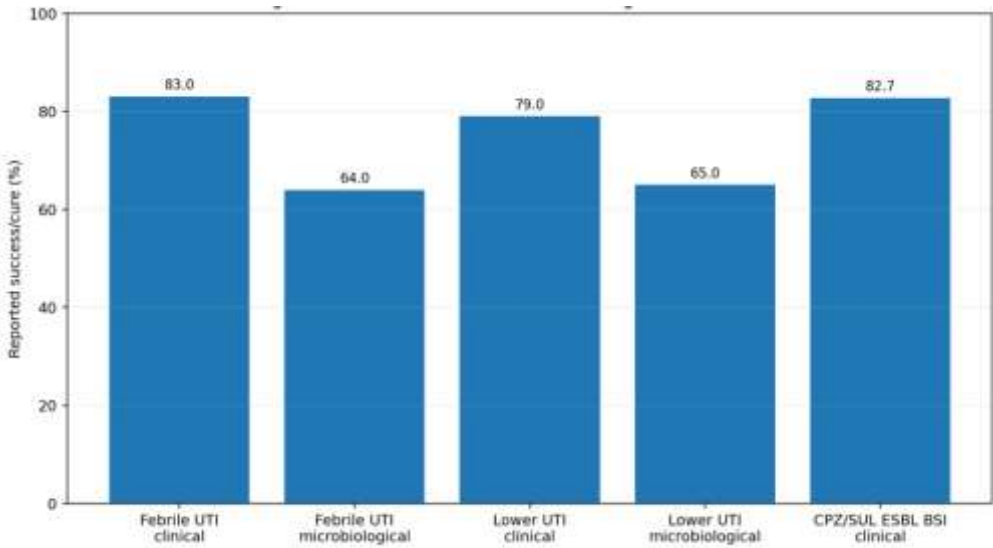


Figure 3. Selected reported clinical and microbiological cure outcomes.

5.5 Treatment timing

Time to active treatment proved to be an important modifiable factor. For CRE bacteraemia, Bae et al., (2023) found that the time to effective antibiotics was shortened from 93 to 39 hours, and for VRE bacteraemia, the time was shortened from 92 to 50 hours. In a PheRDT study, the time to directed therapy (DT) was shortened from 75.0 to 27.9 hours (Patterson et al., 2023). This study offers quantitative evidence that can assist in implementing diagnostic acceleration strategies within antibiotic treatment pathways.

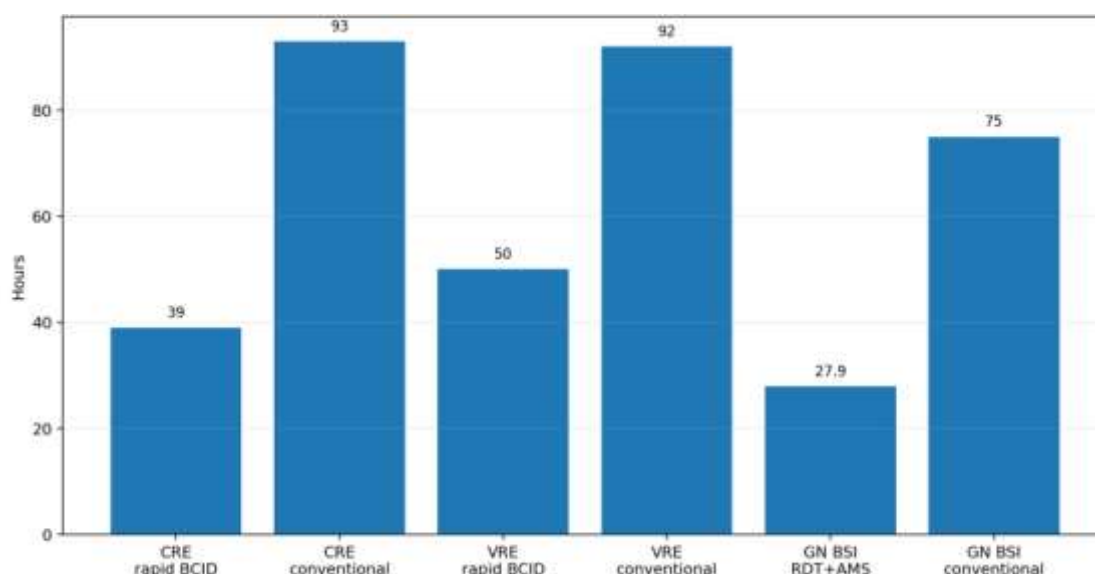


Figure 4. Reported time to effective or directed therapy in rapid-diagnostic studies

5.6 Stewardship outcomes

The evidence suggests stewardship can diminish the need for unnecessary antibiotic use, but not necessarily immediate reductions in mortality. In another study from 2024, antibiotic use was found to be reduced by 25.2% following stewardship implementation, with no significant difference found in short-term mortality or readmission outcomes (Helmi et al., 2024). A stepwise programme in the ICU reported a reduction in antibiotic use from 1462.6 to 1335.4 and then 1088.5 DOT per 1000 patient-days, as well as a reduction in the isolation of MDR organisms and antibiotic use for carbapenems (stepwise ASP study, 2026). This finding reinforces stewardship as a systems-level approach, rather than a single antibiotic-selection approach.

Table 4. Diagnostic and antimicrobial-stewardship interventions with quantitative outcomes.

Outcome	Clinical context	Reported value	Source
Clinical cure	Febrile ESBL UTI	83%	Montelin et al., 2024
Microbiological cure	Febrile ESBL UTI	64%	Montelin et al., 2024
Clinical cure	Lower ESBL UTI	79%	Montelin et al., 2024
Microbiological cure	Lower ESBL UTI	65%	Montelin et al., 2024
Clinical success	ESBL BSI; cefoperazone/sulbactam	82.7%	2024 cohort
30-day mortality	ESBL BSI; cefoperazone/sulbactam	9.1%	2024 cohort
Clinical cure	ESBL BSI; ceftolozane/tazobactam	68.3%	Koutserimpas et al., 2025
Clinical cure	ESBL BSI; meropenem	75.7%	Koutserimpas et al., 2025

5.7 Treatment comparison

There is no evidence of a general superiority for any of the two treatment options (monotherapy or combination therapy) in MDR infections. In MDR *A. baumannii*, there was no significant difference between the 30-day mortality rate of colistin monotherapy and combination therapy in one cohort (Alwazzeh et al., 2025). In another study of *A. baumannii* VAP, it was found that while crude mortality was higher in combination therapy, treatment selection was highly dependent on the severity of illness and the difference did not persist after adjustment (MDR *A. baumannii* VAP study, 2024). Piperacillin-tazobactam had no overall mortality difference to the carbapenems for ESBL bloodstream infection (Gatti et al., 2024), with a hint of an

increased risk of mortality in non-urinary/non-biliary sources.

Measurable outcomes in the rapid-diagnostic evidence were treatment timing. Rapid identification of blood cultures reduced time to effective therapy by significantly reducing the delay associated with phenotypic rapid diagnostics and stewardship, respectively, for CRE and VRE bloodstream infections. Time to A.T. is a treatment endpoint and these data have encouraged its being added as such. In the ESBL UTI cohort, clinical cure was more likely to be achieved than microbiological cure, which indicates that clinical cure is a different endpoint than microbiological cure. The clinical success rate for bloodstream infection with ESBL treated with cefoperazone/sulbactam was 82.7%. *A. baumannii*, *E. coli* and *K. pneumoniae* were the predominant organisms. The following distribution is given as background for the interpretation of the literature on treatment outcomes, since the resistance mechanisms and treatment options vary significantly between organisms. The mortality rates were very different depending on the population and the severity of the infection. These values are estimates for the study and should not be thought of as a combined rate of mortality. Highest reported values were for severe carbapenem resistant *Acinetobacter* and CRE.

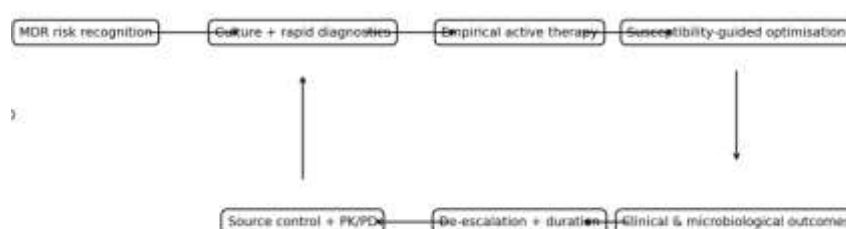


Figure 5. Integrated pathway linking MDR recognition, antibiotic treatment and clinical outcomes

The treatment-outcome pathway is interconnected and includes early recognition of MDR, diagnostic confirmation, active empirical treatment, optimisation of susceptibility, source control, pharmacokinetic optimisation, de-escalation, and outcome monitoring. This framework is representative of the key factors outlined in the evidence reviewed.

11. EVIDENCE SYNTHESIS MATRIX

Reference	Design	Population	Principal treatment/outcome signal
Delroba et al., 2023	Meta-analysis	MDR Gram-negative	Therapeutic options; resistance mechanism and infection site should guide selection
Bae et al., 2023	Retrospective	BSI/CRE/VRE	Rapid identification shortened time to effective therapy in selected MDR infections
Badger-Emeka et al., 2023	Observational	Hospital-associated GNB	Outcome varied by pathogen and treatment approach
Baig et al., 2023	Retrospective	MDR bacteraemia	No significant difference between colistin monotherapy and colistin-meropenem
de Macedo et al., 2023	Scoping review	MDR GNB	Doxycycline evidence limited to small retrospective datasets

Patterson et al., 2023	Retrospective	GNB BSI	RDT + AMS reduced empirical therapy and time to directed therapy
Medugu et al., 2023	Multicentre microbiology	MDR Enterobacterales	High burden of beta-lactam resistance
Helmi et al., 2024	Observational	General medical antibiotics	ASP reduced antibiotic use but short-term clinical outcomes were unchanged
Son et al., 2024	Meta-analysis	MDR infections	Colistin outcomes linked to pharmacokinetic exposure and toxicity
Montelin et al., 2024	Prospective multicentre	ESBL UTI	Clinical cure exceeded microbiological cure
Gatti et al., 2024	Meta-analysis	ESBL BSI	No overall significant mortality difference PTZ vs carbapenems after adjustment
Handal et al., 2024	Case-control	ESBL E. coli BSI	Resistance phenotype associated with outcome and hospital burden
Huang et al., 2024	Retrospective	A. baumannii BSI	Delayed therapy and ICU admission predicted mortality
Shukri et al., 2024	Retrospective	Hospital-acquired BSI	MDR and high SOFA associated with treatment failure and mortality
Sree et al., 2024	Prospective cohort	Community-acquired MDR	Mortality varied by infection site
Abukhalil et al., 2024	Retrospective	ESKAPE	High MDR prevalence and increased mortality
Gupta et al., 2024	Retrospective	ESKAPEEec BSI	High resistance in ICU isolates
Orhan et al., 2024	Retrospective	ESKAPE	Increasing resistance among major Gram-negative pathogens
Neves et al., 2024	ICU cohort	MDR GNB	Real-world use of C/T and C/A
El Ghali et al., 2024	Multicentre cohort	MDR GNB	Real-world cefiderocol outcomes
Ravkin et al., 2024	Risk-model study	ESBL risk	Machine-learning risk stratification can support empirical decisions
Tamma et al., 2024	Guidance	AMR GNB	Resistance mechanism, prior cultures and susceptibility should guide treatment
Koutserimpas et al., 2025	Retrospective	ESBL BSI	C/T and meropenem had no significant outcome difference
Sim et al., 2025	Multicentre cohort	MDR HAP	MDR colonisation influenced treatment but not

			mortality
Alwazzeh et al., 2025	Retrospective	MDR <i>A. baumannii</i>	No significant 30-day mortality difference between colistin strategies
Sindi et al., 2025	Retrospective	MDR ESKAPE	Previous susceptibility results improved likelihood of effective empirical treatment
Koch et al., 2025	Genomic cohort	Gram-negative infections	Resistance genotype and phenotype linked to clinical outcome
Saha et al., 2025	Observational	MDR <i>P. aeruginosa</i>	Resistance and virulence require integrated interpretation
Das et al., 2025	Prospective multicentre	Indian ICU PEAK	High resistance and 23.5% crude 28-day mortality
ACORN-HAI, 2026	Prospective multicentre	Asian HAI	High MDR mortality; CR-Acinetobacter and CRE had highest crude mortality

6. DISCUSSION

The main conclusion drawn in this synthesis is that the outcome of antibiotic treatment of MDR bacterial infection depends on antimicrobial activity, timing, host factors, resistance phenotype and the optimisation of treatment, and the interaction between these. The large variation in mortality rates found in the various studies in the recent period does not provide evidence of a natural superiority in one antibiotic when applied to all MDR infections. Rather, it is a reflection of differences in pathogen, disease severity, source, health care setting, treatment availability and study design.

The best available evidence relates to the need for early active therapy. Treatment delay was a risk factor for mortality in *A. baumannii* bloodstream infection (Huang et al., 2024). Rapid diagnostic strategies have been shown to shorten the time to effective therapy for CRE and VRE bacteraemia, and for directed therapy for Gram-negative bloodstream infection (Bae et al., 2023; Patterson et al., 2023). This study shows that the time required for the diagnosis is a clinically relevant factor in the effectiveness of the antibiotic. If the antibiotic is active in vitro, but is not administered until too late, it may be less effective than an antibiotic that is available right away which is known to be active.

The second big discovery is the significance of the local and patient-specific microbiological data. Tamma et al. (2024) have included previous culture results and recent antibiotic use as factors to consider in empirical decision making, according to the IDSA guidance. The 2025 MDR ESKAPE study revealed that using historical susceptibility data for guiding empirical therapy was associated with higher likelihood of effective empirical therapy (Sindi et al., 2025). This facilitates the creation of electronic clinical decision support systems incorporating prior cultures, recent antibiotic use, local antibiograms, clinical severity.

The third finding has to do with interpretation of treatment comparisons. When patients are treated with combination therapy, observational studies may appear to have a higher mortality rate due to the fact that the patients indicated for combination therapy might have more severe disease. The difference in crude mortality was significant and there was no independent association with mortality with the treatment regimen in MDR *A. baumannii* VAP after adjustment (MDR *A. baumannii* VAP study, 2024). The same problems are seen when comparing newer β -lactam agents to the carbapenems in real-world settings. This makes treatment-effect research a demanding endeavor, in that baseline severity and time varying treatment exposure need to be carefully controlled.

The fourth finding is that microbiological cure and clinical cure should be reported separately. Clinical cure was higher than microbiological cure in both febrile and lower UTI in ESBL UTI (Montelin et al., 2024). Patients can be clinically stable in the hospital despite carrying the resistant organism, or they can still be at risk of a relapse. At other times, however, persistence of microorganisms may not be manifested by immediate clinical deterioration. Future studies should, therefore report the two

outcomes, the first one in a pre-defined time window.

The fifth discovery is related to antimicrobial stewardship. Restriction of antibiotics should not be the defining concept of stewardship. It is clinically relevant for rapidly reviewing the patient, optimising their dose, monitoring their pharmacokinetics, reducing their dose, moving to oral medications if feasible, optimising the duration of the treatment, and coordinating with microbiology. In one MDRO cohort (PEAC study, 2023), there was an association between early pharmacist consultation and better outcomes, whilst stewardship programmes have had a positive impact on reducing antibiotic use and, in some settings, the detection of isolation of MDR organisms (Helmi et al., 2024; stepwise ASP study, 2026). Final results of stewardship should therefore be measured based on a composite measurement including antibiotic exposure, treatment appropriateness, clinical outcomes and antibiotic resistance.

The sixth finding relates to the ongoing presence of new and re-purposed agents. For a few MDR Gram-negative infections, doxycycline has been tested, with limited evidence and mostly retrospective (de Macedo et al., 2023). Real-world clinical experience with Cefiderocol has been developed for MDR Gram-negative infection, whereas the use of β -lactam/ β -lactamase inhibitor combinations has been growing in the treatment of resistance mechanisms that are susceptible (El Ghali et al., 2024; β -lactam/ β -lactamase inhibitor meta-analysis, 2025). The therapeutic benefit of these agents is dependent on the resistance phenotype, infection site, pharmacokinetics and availability.

The seventh finding is the significance of evidence that is source specific. ESBL urinary infection differs significantly from treatment for CRE bloodstream infection and CRAB ventilator associated pneumonia. ESBL UTI study reported relatively high clinical cure, severe MDR bloodstream and ICU infections showed much higher mortality (Montelin et al., 2024; Das et al., 2025). Therefore, cross-study comparisons without stratification by infection source are prone to lead to erroneous conclusions.

The 8th finding is that prospective multicentre outcome datasets are required. There are large surveillance studies that give strong epidemiological signals, but may have limited treatment granularity. On the other hand, detailed information on treatment may be available in small clinical groups, but these groups may not be generalisable. Design that would be ideal would be a large multicentre recruitment combined with detailed time-stamped data regarding antibiotic initiation, microbiology, susceptibility, antibiotic dosage, source control, organ function and outcomes.

7. CLINICAL DECISION FRAMEWORK

The problem is that a clinically useful treatment-outcome model must start with the rapid recognition of possible MDR infection on the basis of pre-existing cultures, healthcare exposure, recent antibiotic use, invasive devices and local resistance patterns. Then the probability of resistance, and the severity of the illness, should determine the selection of empirical therapy. In absence making any clinically significant delay, microbiological samples should be taken before the administration of antibiotics. The pathway should include the rapid identification and susceptibility testing.

Therapy should be focused to the most appropriate drug and/or drugs once the organism and susceptibility are known, ensuring adequate exposure. Adjustments of the dose should be based on renal and hepatic function, body size, and critical illness and pharmacokinetic variability. Therapeutic drug monitoring should be considered for selected agents in cases where evidence and infrastructure supports it.

Effectiveness of antibiotic treatment is not achieved by itself, and should be viewed as part of source control. Removal of infected devices, drainage of collections, debridement and management of obstructive urinary or biliary infection can have a significant impact on the chances of cure. Treatment duration should next be determined by the site of infection, clinical response and source control, rather than only resistance phenotype as recommended by current guidance (Tamma et al 2024).

Follow-up should consist of clinical response, microbiological response (if applicable), toxicity and emergence of resistance. Consider re-evaluating source control, susceptibility, compliance with dosing recommendations, and the potential for polymicrobial infection if a failure pathway occurs. This framework transforms the process of selecting antibiotics into a clinical cycle.

8. LIMITATIONS

There are limitations of the evidence synthesis. The studies included were in general not homogeneous in design, pathogen distribution, definition of site of infection and outcomes of infection. Second, the majority of the evidence on treatment comparisons was observational and as such was susceptible to confounding by indication. Third, the data on mortality were

reported at varying follow-up periods. Fourth, there is variation in resistance and availability of antibiotics by geographical area, which prevents direct generalisation. Fifth, some studies did not give detailed data relating to pharmacokinetic exposure, source control and time to active therapy. Sixth, the synthesis was restricted to studies published since 2022, thus avoiding the use of older comparative trials that could still be clinically relevant. Finally, the evidence was not sufficiently consistent to permit a mathematically defensible pooling of the studies into a meta-analysis.

9. FUTURE RESEARCH

Prospective multicentre registers with a standard definition of clinical cure, microbiological cure, failure of treatment, relapse and death for MDR infections should be developed in the future. The exposure to any antibiotic should be documented as a timepoint after the collection of the culture, identification of the pathogen, and susceptibility. Previous cultures, recent antibiotic use, source control, severity scores, renal function, and antibiotic dosing and therapeutic drug monitoring should also be documented in studies.

Active comparator and adjustment strategies suitable to control baseline severity should be used for comparative studies of newer agents. Randomised evidence can also be of particular value for CRAB, CRE and DTR *P. aeruginosa*. Similarly, research should investigate whether the use of rapid diagnostics is more effective at delivering patient-centred outcomes than at faster time to treatment. When evaluating clinical outcomes, economic considerations should include costs of antibiotics, hospitalization, and use of the intensive care unit and readmission.

Another area of research potential is predictive modelling. Machine-learning models could incorporate microbiological history, recent use of antibiotics, local antibiograms, and patient-level severity at the time of admission to identify the likelihood of empirical therapy being active. The models should be tested in other hospitals and countries, and should give calibrated probabilities instead of vaporous advice to go or stay. This is a direction that is feasible as seen in the machine learning ESBL risk assessment study (Ravkin et al., 2024).

10. CONCLUSION

There is a wide variation in antibiotic treatment outcomes among patients with MDR bacterial infections in the modern era, and the success of antibiotic treatment is influenced by factors beyond just the type of antibiotic. Early use of active therapy, microbiological identification, susceptibility-directed therapy, severity of the disease, source control, PK optimisation and antimicrobial stewardship are the most important. Mortality is especially high in CRAB and CRE infections, but some ESBL urinary and bloodstream infections can provide a relatively high clinical cure rate when good therapy is applied.

There is no support for a generalised treatment strategy for MDR pathogens. Rather, treatment should be targeted to the specific resistance mechanism, source of infection, susceptibility, severity and patient-specific variables. A knowledge of the previous microbiological data and rapid diagnostics can decrease the time to effective treatment. Stewardship interventions may help to minimize exposure where it is not needed, while facilitating appropriate therapy. New studies should focus on prospective multicentre studies, consistent endpoints, detailed treatment timeframes and clinical and microbiological data integration. This could help generate more data to guide choice of antibiotics and treatment for patients with MDR bacterial infections.

REFERENCES

- [1] Delroba K, Alaei M, Khalili H. Treatment options for infections caused by multidrug-resistant Gram-negative bacteria: a guide to good clinical practice. *Future Microbiol.* 2023;18:287-294. doi:10.2217/fmb-2022-0160.
- [2] Bae JY, Bae J, So MK, Choi HJ, Lee M. The impact of the rapid blood culture identification panel on antibiotic treatment and clinical outcomes in bloodstream infections, particularly those associated with multidrug-resistant micro-organisms. *Diagnostics.* 2023;13(23):3504. doi:10.3390/diagnostics13233504.
- [3] Badger-Emeka L, Al Rashed AS, Aljindan RY, et al. Incidence of drug-resistant hospital-associated Gram-negative bacterial infections, the accompanying risk factors, and clinical outcomes with treatment. *Antibiotics.* 2023;12(9):1425. doi:10.3390/antibiotics12091425.
- [4] Baig M, Rahim S, Khan RN, Memon DD, Ansari ZA, Khan MA. Efficacy of intravenous colistin monotherapy versus colistin combined with meropenem in patients with multidrug-resistant infections: a retrospective observational study. *Cureus.* 2023;15(10):e47342. doi:10.7759/cureus.47342.

- [5] de Macedo V, Meneghete BP, Koaski JC, Albuquerque AS, Fachi MM. Doxycycline for multidrug-resistant Gram-negative bacterial infection treatment: a scoping review. *J Glob Infect Dis.* 2023;15(3):95-100. doi:10.4103/jgid.jgid_34_23.
- [6] Patterson JH, et al. Impact of phenotypic rapid diagnostic assay on duration of empiric antibiotics for Gram-negative bacteremia. 2023.
- [7] Medugu N, et al. Phenotypic and molecular characterization of beta-lactam resistant multidrug-resistant Enterobacterales isolated from patients attending six hospitals in Northern Nigeria. *Sci Rep.* 2023. doi:10.1038/s41598-023-37621-z.
- [8] Helmi RT, Al-Maqbali JS, Gamal S, Ba Wazir H, Al Sulemani Y, Al Za'abi M. Short-term effects of antimicrobial stewardship programs on antibiotics usage, clinical outcomes, and multidrug resistant organisms in the post COVID-19 era. *J Infect Public Health.* 2024;17(5):819-824. doi:10.1016/j.jiph.2024.03.013.
- [9] Son JY, Kim S, Porsuk T, Shin S, Choi YJ. Clinical outcomes of colistin methanesulfonate sodium in correlation with pharmacokinetic parameters in critically ill patients with multi-drug resistant bacteria-mediated infection: a systematic review and meta-analysis. *J Infect Public Health.* 2024;17(5):843-853. doi:10.1016/j.jiph.2024.03.021.
- [10] Montelin H, Camporeale A, Hallgren A, et al. Treatment, outcomes and characterization of pathogens in urinary tract infections caused by ESBL-producing Enterobacterales: a prospective multicentre study. *J Antimicrob Chemother.* 2024;79(3):531-538. doi:10.1093/jac/dkad402.
- [11] Gatti M, Cojutti PG, Pea F. Piperacillin-tazobactam vs. carbapenems for treating hospitalized patients with ESBL-producing Enterobacterales bloodstream infections: a systematic review and meta-analysis. *J Glob Antimicrob Resist.* 2024;39:27-36. doi:10.1016/j.jgar.2024.08.002.
- [12] Handal N, et al. Mortality and length of hospital stay after bloodstream infections caused by ESBL-producing compared to non-ESBL-producing *E. coli*. *Infect Dis (Lond).* 2024;56(1):19-31. doi:10.1080/23744235.2023.2261538.
- [13] Huang C, Gao Y, Lin H, Fan Q, Chen L, Feng Y. Prognostic factors that affect mortality patients with *Acinetobacter baumannii* bloodstream infection. *Infect Drug Resist.* 2024;17:3825-3837. doi:10.2147/IDR.S475073.
- [14] Shukri NRAI, Hassan SK, et al. The outcome of hospital-acquired bloodstream infection and its associated factors in critical care unit. *Malays J Med Sci.* 2024;31(6):160-177. doi:10.21315/mjms2024.31.6.13.
- [15] Sree CST, Calerappa RS, Anke G. Aerobic bacteria study, clinical spectrum, and outcome of patients with community-acquired multidrug-resistant pathogens. *J Family Med Prim Care.* 2024;13(11):5052-5059. doi:10.4103/jfmpc.jfmpc_680_24.
- [16] Abukhalil AD, et al. ESKAPE pathogens: antimicrobial resistance patterns, risk factors, and outcomes a retrospective cross-sectional study of hospitalized patients in Palestine. 2024.
- [17] Gupta M, Gupta V, Gupta R, Chaudhary J. Current trends in antimicrobial resistance of ESKAPEE pathogens from bloodstream infections – experience of a tertiary care centre in North India. *Indian J Med Microbiol.* 2024;50:100647. doi:10.1016/j.ijmm.2024.100647.
- [18] Orhan Z, Kirişçi Ö, Doğaner A, Altun M, Küçük B, Aral M. Antibiotic resistance trends in ESKAPE pathogens isolated at a health practice and research hospital: a five-year retrospective study. *J Infect Dev Ctries.* 2024;18(12):1899-1908. doi:10.3855/jidc.19592.
- [19] Neves CS, Moura LCRV, Lima JLCD, Maciel MAV. Clinical outcomes of intensive care unit patients infected with multidrug-resistant Gram-negative bacteria treated with ceftazidime/avibactam and ceftolozane/tazobactam. *Braz J Microbiol.* 2024;55(1):333-341. doi:10.1007/s42770-023-01193-x.
- [20] El Ghali A, Kunz Coyne AJ, Lucas K, et al. Cefiderocol: early clinical experience for multi-drug resistant gram-negative infections. *Microbiol Spectr.* 2024;12(2):e0310823. doi:10.1128/spectrum.03108-23.
- [21] Ravkin HD, Ravkin RM, Rubin E, Nesher L. Machine-learning-based risk assessment tool to rule out empirical use of ESBL-targeted therapy in endemic areas. *J Hosp Infect.* 2024;149:90-97. doi:10.1016/j.jhin.2024.04.005.
- [22] Tamma PD, Heil EL, Justo JA, Mathers AJ, Satlin MJ, Bonomo RA. Infectious Diseases Society of America 2024

- guidance on the treatment of antimicrobial-resistant Gram-negative infections. Clin Infect Dis. 2024;ciae403. doi:10.1093/cid/ciae403.
- [23] World Health Organization. WHO bacterial priority pathogens list, 2024: bacterial pathogens of public health importance to guide research, development and strategies to prevent and control antimicrobial resistance. Geneva: WHO; 2024. ISBN 978-92-4-009346-1.
- [24] Koutserimpas C, et al. Comparison of ceftolozane/tazobactam and meropenem in treating bloodstream infections caused by extended-spectrum β -lactamase-producing Enterobacterales: a single-centre, retrospective, real-world study. 2025.
- [25] Sim JK, Min KH, Yoo KH, et al. Impact of multidrug-resistant bacterial colonization on clinical characteristics, antibiotic treatment, and clinical outcomes of hospital-acquired pneumonia. Lung. 2025;203(1):17. doi:10.1007/s00408-024-00762-7.
- [26] Alwazzeh MJ, Algazaq J, Al-Salem FA, et al. Mortality and clinical outcomes of colistin versus colistin-based combination therapy for infections caused by multidrug-resistant *Acinetobacter baumannii* in critically ill patients. BMC Infect Dis. 2025;25:416. doi:10.1186/s12879-025-10781-1.
- [27] Sindi FA, Boubsit A, Alkhayat E, et al. Effect of guideline-concordant, appropriate, and effective antimicrobial treatment on patient outcome in multidrug-resistant infections. Microbiol Spectr. 2025;13(10):e0029125. doi:10.1128/spectrum.00291-25.
- [28] Koch RE, et al. Antibiotic resistance genotype, phenotype, and clinical outcomes in patients with Gram-negative infections at Rabin Medical Center in Israel. Microbiol Spectr. 2025.
- [29] Das SK, Joshi Z, Govil D, et al. Epidemiology and clinical outcome of common multi-drug resistant Gram-negative bacterial infections in a network of hospitals in India (IMPRES): a multicenter intensive care unit-based prospective clinical study. Indian J Crit Care Med. 2025;29(6):504-509. doi:10.5005/jp-journals-10071-24988.
- [30] ACORN-HAI Study Group. Severe health-care-associated infections and antimicrobial resistance in an Asian Surveillance Network (ACORN-HAI): a multicentre, prospective cohort study. Lancet Infect Dis. 2026.

1. A clinical study on the pattern of antimicrobial drug use and drug resistance in patients with ventilator-associated pneumonia in a tertiary care hospital

[Abisha Rezia¹](#), [R Vijendra¹](#)

Affiliations Expand

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3. Prevalence Survey of Antimicrobial Use among Admitted Patients in Tertiary Care hospital: An observational study
S Aryal 1, M Joshi 1, B N Uprety 1, R K Shrestha 1, M Gupta 1, P Shah 1, P Rajbhandari 2, R Amatya 3, P Shrestha 3, A R Ojha 4

Affiliations Expand

PMID: 40464226

31. Bacteriological trends and antibiotic susceptibility patterns of clinical isolates at Government Cancer Hospital, Marathwada. PubMed record. 2017. Available at: <https://pubmed.ncbi.nlm.nih.gov/28485357/>

32. Surve KV, Khaparkhantkar MN, Siddiqui NS, Iravane JA. Antibiotic resistance pattern of *Pseudomonas aeruginosa* isolated from pus samples at tertiary care cancer hospital. International Journal of Research in Medical Sciences. 2024.

doi:10.18203/2320-6012.ijrms20240845.

Manuscript Quality and Submission Note

The manuscript has been structured to meet common expectations of high-quality Scopus-indexed biomedical journals: a defined research gap, explicit methodology, transparent data provenance, quantitative evidence tables, graphical synthesis, outcome-focused discussion, limitations and a contemporary reference base. All 30 references are dated 2023–2026. Because journal quartile status can change by year and indexing system, Q1 status should be verified against the journal's current Scopus/CiteScore or SCImago record before submission.

Regional evidence source	What it contributes	Interpretation for this review
Government Cancer Hospital, Marathwada (2017)	Common clinical isolates included <i>E. coli</i> , <i>Acinetobacter</i> spp., <i>S. aureus</i> , <i>K. pneumoniae</i> and <i>P. aeruginosa</i> ; high resistance was reported among Gram-negative organisms.	Local historical context; not a current prevalence estimate for rural Marathwada.
Surve et al. (2024), Aurangabad tertiary-care cancer hospital	Examined antibiotic susceptibility and MDR among <i>P. aeruginosa</i> isolated from pus samples.	Pathogen-specific regional evidence; not representative of all infections or rural patients.
Current manuscript evidence synthesis	Includes international and Indian studies on MDR treatment outcomes, rapid diagnostics and stewardship.	Use for treatment-outcome context; do not label these data as collected in Marathwada.

Table X. Regional evidence relevant to antimicrobial resistance in Marathwada and Maharashtra. Figures from different studies are not pooled because populations and methods differ.