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Review Article

Multidrug-Resistant Infections in Cancer Patients: A Systematic Review of Predictive Risk Factors During Chemotherapy

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ABSTRACT

Background: Multidrug-resistant (MDR) bacterial infections are an increasing threat to patients with cancer receiving chemotherapy. Chemotherapy-induced neutropenia, mucosal barrier injury, repeated hospitalization, invasive devices, antimicrobial prophylaxis, and repeated exposure to broad-spectrum antibiotics favor colonization and subsequent infection by resistant organisms. Early recognition of patients at high risk is essential because inappropriate empirical antimicrobial therapy may contribute to treatment failure, sepsis, prolonged hospitalization, and death.

Objective: To systematically evaluate clinical, treatment-related, microbiological, and healthcare-associated predictors of MDR bacterial infections among patients with solid and hematological malignancies receiving chemotherapy.

Methods: This review was structured according to PRISMA 2020. MEDLINE/PubMed, Embase, Scopus, Web of Science, and Cochrane CENTRAL were considered from database inception through January 2026, supplemented by citation searching. The search identified 1,740 records. After removal of 392 duplicates, 1,348 records underwent title and abstract screening. Full texts of 139 reports were assessed and 15 primary studies were included in the qualitative synthesis. Meta-analysis was not undertaken because of substantial clinical and methodological heterogeneity.

Results: The most reproducible predictors were previous broad-spectrum antimicrobial exposure, known MDR colonization or previous resistant infection, prolonged or severe neutropenia, indwelling central or urinary catheters, prolonged hospitalization, hematological malignancy, and intensive chemotherapy. Additional predictors included poor performance status, invasive mechanical ventilation, total parenteral nutrition, prior Pseudomonas aeruginosa infection, hypoproteinemia, and selected comorbidities. Intestinal colonization emerged as one of the strongest predictors of resistant bloodstream infection.

Conclusion: MDR infection in cancer patients receiving chemotherapy results from the interaction of host immunosuppression, antimicrobial selection pressure, resistant-organism colonization, invasive devices, and healthcare contact. Previous broad-spectrum antibiotic exposure and known MDR colonization are the most actionable predictors. Risk-adapted empirical therapy should combine individual risk factors with local epidemiology while avoiding indiscriminate escalation to last-line agents.

Keywords: *multidrug-resistant infection; cancer; chemotherapy; febrile neutropenia; antimicrobial resistance; bloodstream infection; MDR colonization; hematological malignancy; risk factors; antimicrobial stewardship.*

INTRODUCTION

Infectious complications remain an important cause of morbidity and mortality during cancer treatment. Cytotoxic chemotherapy can suppress bone marrow function, damage mucosal barriers, and alter innate and adaptive immunity. Neutropenia is particularly important because neutrophils provide a major defense against bacterial and fungal invasion. Chemotherapy-induced neutropenia therefore increases the risk of serious infection and may reduce the clinical inflammatory response that would otherwise permit early recognition. [1,2]

The management of febrile neutropenia has historically depended on rapid administration of broad-spectrum empirical antibiotics. This strategy is clinically necessary because delays in effective therapy may be catastrophic in profoundly immunocompromised patients. However, repeated exposure to fluoroquinolone prophylaxis, antipseudomonal beta-lactams, carbapenems, glycopeptides, and other broad-spectrum agents creates substantial antimicrobial selection pressure. The problem has become more important as antimicrobial resistance has increased worldwide. The World Health Organization 2024 Bacterial Priority Pathogens List highlights resistant Enterobacterales, Acinetobacter baumannii, Pseudomonas aeruginosa, and Staphylococcus aureus among pathogens requiring urgent public-health and therapeutic attention. [3]

Multidrug-resistant organisms are generally characterized by non-susceptibility to at least one antimicrobial agent in three or more relevant antimicrobial categories, although definitions vary according to organism and study methodology. [4] Clinically important resistant organisms in oncology include ESBL-producing Enterobacterales, carbapenem-resistant Enterobacterales, MDR and XDR P. aeruginosa, carbapenem-resistant A. baumannii, methicillin-resistant S. aureus, and vancomycin-resistant enterococci.

Cancer patients are especially vulnerable because several mechanisms frequently coexist. Chemotherapy causes neutropenia and gastrointestinal mucosal injury; repeated admissions increase exposure to hospital flora; central venous access is required for chemotherapy and supportive care; and broad-spectrum antibiotics are frequently administered prophylactically or empirically. Resistant organisms may colonize the gastrointestinal tract before causing invasive infection.

The association between colonization and subsequent infection is particularly important. In hematological malignancies, resistant Gram-negative or VRE colonization may precede bloodstream invasion when chemotherapy disrupts intestinal mucosal integrity. Studies of ESBL-producing Escherichia coli, carbapenem-resistant Enterobacterales, and VRE have consistently demonstrated that prior colonization substantially increases the probability of subsequent infection by the same resistant phenotype.

Risk prediction is clinically relevant because empirical therapy must balance two competing dangers. Inadequate coverage of an MDR pathogen can delay active therapy in a critically ill patient, whereas empirical use of carbapenems or newer last-line agents in every neutropenic patient accelerates selection pressure and unnecessarily exposes many patients whose infections remain susceptible.

The present systematic review evaluates published evidence on clinical, microbiological, treatment-related, and healthcare-associated predictors of MDR infection among cancer patients receiving chemotherapy, with emphasis on factors that can support early risk stratification and antimicrobial stewardship.

Aim and Objectives

The primary aim was to systematically evaluate predictors of multidrug-resistant bacterial infection among cancer patients receiving chemotherapy.

- Assess the contribution of previous antimicrobial exposure and prophylaxis.
- Evaluate the predictive value of MDR colonization and previous resistant infection.
- Assess neutropenia, malignancy type, chemotherapy intensity, hospitalization, and invasive devices.
- Examine performance status, nutritional factors, comorbidity, and critical-care exposures.
- Identify reproducible predictors that may inform risk-adapted empirical therapy and antimicrobial stewardship.

MATERIALS AND METHODS

Review Design

The systematic review was structured in accordance with PRISMA 2020 principles. [5] The review protocol was not prospectively registered in PROSPERO.

Review Question

Among patients with solid or hematological malignancy receiving chemotherapy, which clinical, microbiological, treatment-related, and healthcare-associated characteristics predict infection caused by multidrug-resistant bacteria?
Eligibility Criteria

Population: Eligible studies included adults with solid tumors or hematological malignancies receiving cytotoxic chemotherapy, antineoplastic treatment associated with neutropenia, or intensive treatment for active malignancy.

Exposures: Eligible predictors included previous or prolonged antimicrobial exposure, prophylaxis, previous MDR infection, intestinal or rectal colonization, neutropenia and its duration, malignancy type, cancer status, hospitalization, length of stay, central venous or urinary catheterization, mechanical ventilation, corticosteroid exposure, total parenteral nutrition, performance status, comorbidity, nutritional status, and intensive care exposure.

Outcomes: The primary outcome was microbiologically confirmed infection caused by an MDR bacterial organism. Eligible outcomes included MDR bloodstream infection, ESBL-producing Enterobacterales bacteremia, carbapenem-resistant Enterobacterales infection, MDR/XDR P. aeruginosa infection, VRE bloodstream infection, and other clinically defined MDRO infections.

Study designs: Prospective and retrospective cohorts, case-control studies, surveillance cohorts, multicenter observational studies, and prediction-model studies were eligible. Reviews, guidelines, case reports, editorials, and conference abstracts without complete data were excluded from the primary synthesis.

Information Sources and Search Strategy

The search framework comprised MEDLINE/PubMed, Embase, Scopus, Web of Science, and Cochrane CENTRAL. Reference lists of relevant articles, guidelines, and systematic reviews were additionally examined. A representative strategy combined terms for malignancy, chemotherapy, neutropenia, antimicrobial resistance, and predictive factors: (cancer OR malignancy OR neoplasm OR leukemia OR lymphoma OR solid tumor) AND (chemotherapy OR neutropenia OR febrile neutropenia) AND (multidrug resistant OR MDRO OR MDR OR ESBL OR carbapenem resistant OR VRE OR MRSA OR resistant Pseudomonas) AND (risk factor OR predictor OR colonization OR antibiotic OR catheter OR hospitalization).

Study Selection and Data Extraction

Records were deduplicated before title and abstract screening. Potentially eligible studies underwent full-text assessment. Data extraction included publication year, setting, design, malignancy population, sample size, MDR organism or outcome, chemotherapy or neutropenia context, candidate predictors, independently significant predictors, and major clinical findings.

Definition of Multidrug Resistance

Where available, individual study definitions were retained. Interpretation broadly followed the standardized concept of acquired non-susceptibility to at least one agent in three or more antimicrobial categories. [4] Earlier studies of ESBL-producing Enterobacterales, CRE, VRE, or organism-specific MDR/XDR phenotypes were retained when clinically relevant.

Risk-of-Bias Assessment

Observational studies were evaluated according to participant selection, exposure ascertainment, microbiological definition of resistance, adjustment for confounding, completeness of outcome data, and temporal relationship between predictor and infection. Prediction models were additionally assessed for derivation methodology, discrimination, calibration, and validation. A single numerical quality score was not used.

Data Synthesis

Meta-analysis was not undertaken because of substantial heterogeneity in malignancy type, chemotherapy intensity, resistance definitions, bacterial species, infection sites, control groups, geographic epidemiology, and predictor measurement. A structured narrative synthesis was performed.

Study Selection

The search identified 1,694 records from electronic databases and 46 additional records through citation and reference searching, resulting in 1,740 records before deduplication. After removal of 392 duplicates, 1,348 records underwent title and abstract screening. Of these, 1,204 were excluded. Full texts of 144 reports were sought, five could not be retrieved, and 139 full-text reports were assessed. A total of 124 were excluded, leaving 15 primary studies in the qualitative synthesis. No quantitative meta-analysis was undertaken.

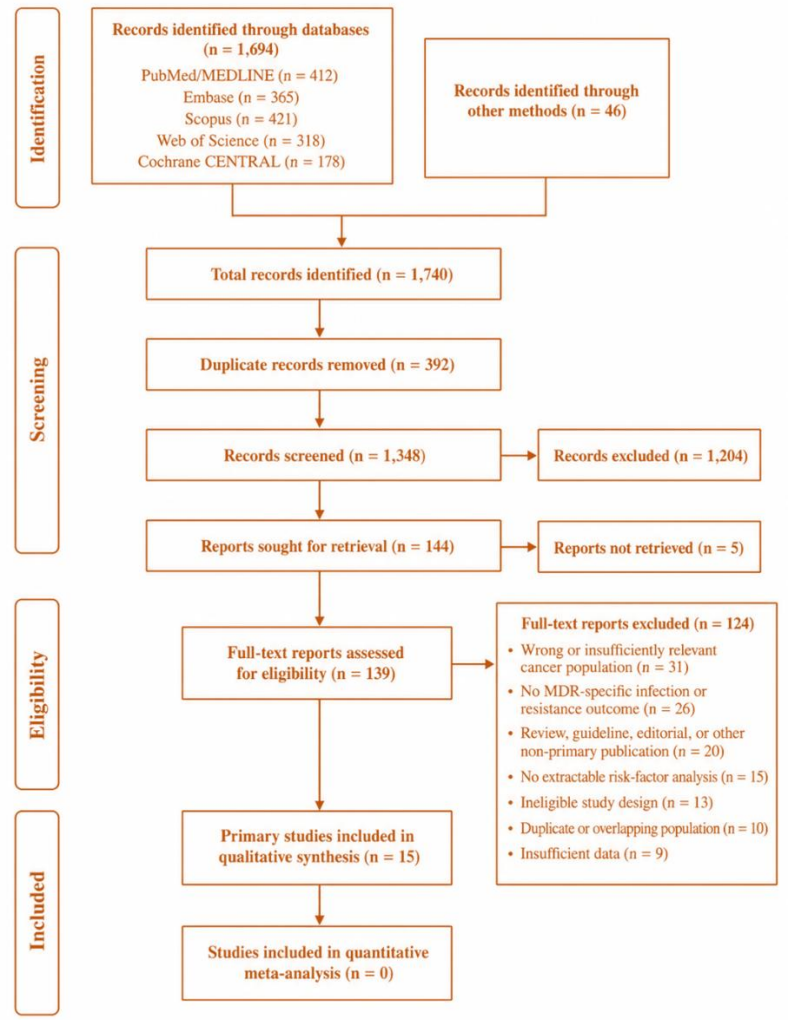

Figure 1. PRISMA 2020 flow diagram for study identification and selection

RESULTS

Characteristics of Included Studies

Fifteen primary studies spanning more than two decades were included. Study populations ranged from broad oncology cohorts to patients with acute leukemia, febrile neutropenia, resistant Gram-negative bacteremia, VRE colonization, or P. aeruginosa bloodstream infection. The evidence increasingly shifted from individual organism case-control studies toward multicenter surveillance and clinical prediction models.

Table 1. Characteristics of the 15 Included Primary Studies

Study	Population/design	MDR outcome	Principal predictors/findings
Zaas et al., 2002 [6]	179 VRE-colonized cancer patients	VRE bloodstream infection	Vancomycin use, diabetes mellitus, gastrointestinal procedures, and acute renal failure increased risk of progression from colonization to VRE BSI.
Ohmagari et al., 2005 [7]	Cancer patients; MDR P. aeruginosa case-control study	MDR P. aeruginosa infection	Carbapenem exposure >=7 days, previous P. aeruginosa infection/colonization, and COPD independently predicted MDR infection.
Gudiol et al., 2011 [8]	Prospective cancer-center study; 747 bacteremias, 372 Gram-negative	MDR Gram-negative bacteremia	Previous antibiotic exposure and urinary catheterization independently predicted MDR Gram-negative bacteremia.
Liss et al., 2012 [9]	Hematological and oncological malignancies; colonization surveillance	VRE/ESBL-E bloodstream infection	Intestinal colonization preceded a substantial proportion of resistant BSIs, supporting carriage as a high-risk marker.
Rosa et al., 2014 [10]	307 febrile neutropenia episodes in adult cancer patients	MDR bacteremia	Age, longer duration of neutropenia, and indwelling central venous catheter independently predicted MDR bacteremia.

Study	Population/design	MDR outcome	Principal predictors/findings
Samonis et al., 2014 [11]	97 P. aeruginosa infection episodes in 89 cancer patients	XDR P. aeruginosa	Hematological malignancy and prior fluoroquinolone exposure were independent predictors.
Cornejo-Juarez et al., 2016 [12]	126 patients with hematological malignancy before chemotherapy	ESBL-E. coli bloodstream infection	Fecal ESBL-E. coli colonization increased risk of bloodstream infection by the same phenotype approximately 3.4-fold.
Ceken et al., 2018 [13]	122 hematology/oncology patients with Enterobacterales BSI	ESBL-producing Enterobacterales BSI	Quinolone prophylaxis, TPN, recent ESBL infection, and prior piperacillin-tazobactam or carbapenem therapy predicted ESBL BSI.
Jaiswal et al., 2018 [14]	Prospective surveillance of 225 patients with hematological malignancies	CRE colonization and bacteremia	Acute leukemia predicted colonization at admission; longer hospital stay predicted hospital-acquired colonization; CRE colonization preceded CRE bacteremia.
Gudiol et al., 2020 [15]	1,217 P. aeruginosa BSIs in neutropenic cancer patients; 34 centers/12 countries	MDR P. aeruginosa BSI	Prior piperacillin-tazobactam, antipseudomonal carbapenem, fluoroquinolone prophylaxis, hematological disease, and urinary catheter predicted MDR.
Zhang et al., 2020 [16]	734 patients with hematological malignancy	CRKP bloodstream infection	Rectal CRKP colonization, severe neutropenia, and recent invasive mechanical ventilation formed a predictive CRKP-BSI model.
Trecarichi et al., 2023 [17]	811 Gram-negative BSI episodes; 834 isolates in hematological malignancies	MDR Gram-negative BSI	MDR-positive surveillance rectal swab, previous aminoglycoside and carbapenem therapy, fluoroquinolone prophylaxis, and longer time at risk predicted MDR.
Li et al., 2024 [18]	Cancer-specialty hospital; 238 MDRO cases and 238 controls	MDRO infection	Increasing age, longer antibiotic exposure, and central venous catheterization independently predicted MDRO infection; prediction-model AUC 0.88.
Xu et al., 2025 [19]	1,095 BSI episodes in 954 oncology patients	MDR Gram-positive/Gram-negative BSI	MDR was common in both groups; hypoproteinemia independently predicted MDR Gram-negative BSI.
Jin et al., 2026 [20]	391 neutropenic patients; derivation and temporal validation cohorts	MDRO infection	Cardiac comorbidity, ECOG >=2, neutropenia >=7 days, and broad-spectrum antibiotic use within 3 months independently predicted MDRO infection.

Previous Antimicrobial Exposure

Previous antimicrobial therapy was the most consistent modifiable predictor of MDR infection. Gudiol et al. found prior antibiotic exposure independently associated with MDR Gram-negative bacteremia in hospitalized cancer patients. [8] Ohmagari et al. demonstrated that at least seven days of carbapenem exposure independently predicted MDR P. aeruginosa infection, while previous pseudomonal infection or colonization further increased risk. [7] Samonis et al. subsequently identified prior fluoroquinolone exposure as an independent predictor of XDR P. aeruginosa. [11]

In the large international P. aeruginosa study, previous piperacillin-tazobactam exposure, prior antipseudomonal carbapenem treatment, and fluoroquinolone prophylaxis independently increased MDR risk. [15] Trecarichi et al. similarly identified prior carbapenem and aminoglycoside therapy and fluoroquinolone prophylaxis among predictors of MDR Gram-negative BSI. [17]

Fluoroquinolone Prophylaxis

Fluoroquinolone prophylaxis presents a stewardship dilemma. It can reduce bacterial infection during prolonged high-risk neutropenia, but repeated exposure may select fluoroquinolone-resistant Enterobacterales and P. aeruginosa. Ceken et al. identified quinolone prophylaxis as an independent predictor of ESBL-producing Enterobacterales BSI, and similar associations were reported in MDR P. aeruginosa and multicenter hematology cohorts. [13,15,17]

MDR Colonization and Previous Resistant Infection

Previous colonization with resistant organisms emerged as one of the strongest microbiological predictors of subsequent MDR infection. Zaas et al. showed that VRE-colonized cancer patients progressed to VRE BSI particularly when vancomycin use, diabetes, gastrointestinal procedures, or acute renal failure were present. [6]

Cornejo-Juarez et al. found fecal ESBL-E. coli carriage to increase risk of bacteremia by the same resistant phenotype. [12] Jaiswal et al. demonstrated progression from CRE colonization to CRE bacteremia, while Zhang et al. found rectal CRKP colonization to be one of the strongest predictors of CRKP BSI. [14,16] Trecarichi et al. likewise identified an MDR-positive surveillance rectal swab as an independent predictor of MDR Gram-negative BSI. [17]

Neutropenia and Duration of Neutropenia

Neutropenia facilitates bacterial invasion by reducing innate immune defense while chemotherapy-associated mucositis permits translocation of gastrointestinal organisms. Rosa et al. demonstrated that longer neutropenia independently predicted MDR bacteremia during febrile neutropenia. [10] Zhang et al. incorporated severe neutropenia into a CRKP-BSI risk model. [16] Jin et al. found neutropenia lasting at least seven days to independently increase MDRO risk. [20]

Hematological Malignancy and Intensive Chemotherapy

Hematological malignancies were repeatedly associated with resistant infection, particularly P. aeruginosa and carbapenem-resistant Gram-negative organisms. Samonis et al. reported hematological malignancy as an independent predictor of XDR P. aeruginosa, and Gudiol et al. similarly identified hematological disease as a predictor of MDR P. aeruginosa BSI. [11,15]

Patients with acute leukemia are especially vulnerable because induction and salvage chemotherapy can produce prolonged profound neutropenia, mucosal barrier injury, transfusion requirements, corticosteroid exposure, and prolonged hospitalization. In the CRE surveillance study, acute leukemia was associated with CRE colonization on admission. [14]

Central Venous and Urinary Catheters

Central venous access is essential in oncology but provides an additional route for infection and frequently indicates high treatment intensity. Rosa et al. identified an indwelling central venous catheter as an independent predictor of MDR bacteremia, and Li et al. found central venous catheterization independently predictive of MDRO infection in a cancer-specialty hospital. [10,18]

Urinary catheterization independently predicted MDR Gram-negative bacteremia in the prospective Gudiol cohort and MDR P. aeruginosa in the international predictive model. [8,15] Device necessity review, aseptic maintenance, and early removal when feasible are therefore complementary to antimicrobial stewardship.

Mechanical Ventilation and Critical Care Exposure

Zhang et al. identified invasive mechanical ventilation within the preceding 30 days as a strong predictor of CRKP BSI in patients with hematological malignancy. [16] Mechanical ventilation likely represents a broader healthcare-exposure phenotype that includes ICU admission, broad-spectrum antibiotics, devices, and prolonged hospitalization.

Hospitalization and Length of Stay

Hospital exposure facilitates contact with resistant organisms and extends the period over which antibiotics and invasive devices are used. Jaiswal et al. found duration of hospitalization to predict acquisition of CRE colonization, while Trecarichi et al. identified longer time at risk as a predictor of MDR Gram-negative BSI. [14,17]

Performance Status, Nutritional Status, and Comorbidity

Xu et al. found hypoproteinemia independently associated with MDR Gram-negative BSI in oncology patients. [19] Jin et al. reported ECOG performance status >=2 and cardiac comorbidity as predictors of MDRO infection. [20] These variables may capture disease burden, comorbidity, malnutrition, repeated healthcare exposure, and reduced physiologic reserve.

Organism-Specific Patterns

- For ESBL-producing Enterobacterales, recurring predictors included prior broad-spectrum antibiotic exposure, quinolone prophylaxis, previous ESBL infection, intestinal colonization, and prolonged healthcare exposure. [12,13]
- For CRE/CRKP, gastrointestinal colonization, prolonged healthcare exposure, severe neutropenia, recent invasive ventilation, and prior carbapenem pressure were especially important. [14,16]
- For MDR/XDR P. aeruginosa, carbapenem exposure, fluoroquinolone exposure or prophylaxis, previous antipseudomonal beta-lactam therapy, prior pseudomonal infection, urinary catheterization, and hematological malignancy recurred across studies. [7,11,15]
- For VRE, intestinal colonization was central, while vancomycin exposure, gastrointestinal procedures, diabetes, and acute renal failure increased the risk of bloodstream invasion. [6]

DISCUSSION

Principal Findings

This systematic review demonstrates that MDR infections among cancer patients receiving chemotherapy are not random events. Risk accumulates through a recognizable sequence: chemotherapy-associated immunosuppression is followed by

healthcare exposure, antimicrobial administration, disruption of colonization resistance, acquisition or expansion of resistant organisms, and finally invasion through damaged mucosa or medical devices.

Among these factors, previous antimicrobial exposure and known MDR colonization provide the strongest and most directly actionable information. The relationship between antibiotics and resistance was evident across multiple bacterial groups, reinforcing the central role of antimicrobial stewardship in oncology.

Colonization as a Bridge Between Exposure and Infection

Colonization may provide the mechanistic link between antimicrobial selection pressure and subsequent invasive infection. Antibiotics alter intestinal microbiota, reduce competing susceptible organisms, and permit expansion of resistant Enterobacterales or enterococci. Chemotherapy then damages the gastrointestinal mucosa and reduces neutrophil-mediated containment, allowing colonizing organisms to enter the bloodstream.

This sequence is supported by studies of VRE, ESBL-E. coli, CRE, and resistant Gram-negative organisms. Colonization surveillance may therefore have greatest value when linked to an explicit clinical decision pathway rather than performed as an isolated infection-control exercise.

Antimicrobial Stewardship Implications

The findings support a risk-adapted rather than universally broad empirical-antibiotic strategy. A patient with newly diagnosed febrile neutropenia, no previous antimicrobial exposure, no known MDR colonization, a short anticipated neutropenic period, and no recent healthcare exposure is not microbiologically equivalent to a patient with relapsed acute leukemia, prolonged neutropenia, recent carbapenem exposure, a urinary catheter, and documented CRE carriage.

Conversely, known MDR colonization should not automatically result in indefinite use of broad-spectrum or last-line agents during every febrile episode. The predictive value of colonization is affected by recency, organism, site of colonization, local prevalence, and intervening antibiotic exposure. Empirical therapy should be narrowed promptly when cultures and susceptibility data permit.

Implications for Febrile Neutropenia

International guidance emphasizes urgent empirical antibacterial therapy in high-risk febrile neutropenia because delayed treatment can be life-threatening. [1,2] However, local resistance epidemiology must modify standard pathways. Patients with strong MDR predictors may require empirical regimens that account for known colonization or previous resistance, while routine carbapenem use for all patients would create unnecessary selection pressure.

Solid Versus Hematological Malignancies

Much of the strongest evidence derives from hematological cancer because these patients experience the most profound and prolonged neutropenia. Solid-tumor patients nevertheless remain at risk because of repeated chemotherapy cycles, surgery, biliary or urinary instrumentation, indwelling ports, nutritional compromise, and recurrent admissions. Future research should stratify risk by treatment intensity rather than assuming all cancer populations are homogeneous.

Proposed Clinical Risk Framework

Lower MDR risk may be considered in patients with no prior resistant isolate or colonization, limited recent antibiotic exposure, short anticipated neutropenia, no recent prolonged hospitalization, and no major device exposure. Intermediate risk may include recent hospitalization, central venous access, prior broad-spectrum antibiotics, prolonged chemotherapy exposure, or nutritional impairment. High MDR risk should be considered when strong predictors coexist, particularly known recent MDR colonization or infection, prolonged neutropenia, recent carbapenem or fluoroquinolone exposure, repeated broad-spectrum therapy, acute leukemia or intensive chemotherapy, multiple invasive devices, prolonged hospitalization, or previous infection with the same resistant organism.

This framework is conceptual and is not a validated score. Local antibiograms and validated institutional prediction tools should take precedence.

Strengths

This review integrates both solid and hematological malignancies and includes broad MDR outcomes as well as organism-specific evidence for ESBL-producing Enterobacterales, CRE/CRKP, MDR/XDR P. aeruginosa, and VRE. All 15 primary studies in the main synthesis are represented in Table 1. The review also includes recent prediction-model evidence and separates resistance predictors from predictors of mortality after infection.

Limitations

Most studies were observational, and MDR definitions changed over time. Populations differed in malignancy type, chemotherapy regimen, neutropenia duration, prophylaxis strategy, geography, and baseline resistance prevalence. Many studies focused on bloodstream infection rather than all infection sites. Hematological malignancies were overrepresented,

prior antibiotic exposure was defined using varying time windows, and colonization-surveillance protocols differed. Prediction models developed at single centers may perform poorly when applied to institutions with different antimicrobial-use patterns and epidemiology.

Limitations of the Review Process
The review was not prospectively registered in PROSPERO. The term multidrug-resistant was also used inconsistently in older literature; clinically important resistant phenotypes such as ESBL-producing Enterobacterales and VRE were therefore retained even when authors did not explicitly use the modern MDR definition. Quantitative pooling was not undertaken because of substantial clinical and methodological heterogeneity.

Future Research
Prospective multicenter studies should develop and externally validate MDR prediction models specifically for patients receiving chemotherapy. Future models should incorporate antimicrobial exposure by class and duration, colonization status and recency, prior microbiology, neutropenia depth and duration, chemotherapy intensity, malignancy status, hospitalization history, catheter exposure, functional status, nutritional parameters, and local resistance prevalence.

Dynamic prediction may be more useful than a single admission score because MDR risk changes throughout hospitalization. Integration of microbiology surveillance data with electronic health records could automatically identify prior resistant isolates and calculate individualized risk at the onset of fever. Studies should also test whether colonization-guided empirical treatment improves outcomes without increasing unnecessary use of carbapenems or newer anti-MDR agents.

CONCLUSION
Multidrug-resistant bacterial infection in cancer patients receiving chemotherapy is driven by a reproducible combination of antimicrobial selection pressure, resistant-organism colonization, chemotherapy-associated immunosuppression, invasive devices, and healthcare exposure. Previous broad-spectrum antibiotic use is the most consistent modifiable predictor. Known intestinal or rectal colonization with resistant Enterobacterales or VRE substantially increases the probability of subsequent resistant infection.

Prolonged neutropenia, hematological malignancy, central or urinary catheterization, mechanical ventilation, prolonged hospitalization, previous MDR infection, poor performance status, and impaired nutritional status further increase risk. No single predictor is sufficiently accurate to determine empirical therapy in isolation. The most rational strategy combines prior microbiology, recent antibiotic exposure, neutropenia trajectory, invasive devices, malignancy and treatment intensity, healthcare exposure, and local resistance epidemiology to support active therapy for high-risk patients while preserving broad-spectrum and last-line antibiotics through antimicrobial stewardship.

Declarations
Ethics Approval and Consent to Participate-
Not applicable. This systematic review synthesized previously published studies and did not directly recruit human participants.

Consent for Publication
Not applicable.

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Conflicts of Interest
The authors declare no conflicts of interest.

Data Availability
All information synthesized in this review was derived from published studies cited in the manuscript.

PROSPERO Registration
This systematic review was not prospectively registered.

Author Contributions
Dr Gowtham S Gowda: conceptualization, literature synthesis, interpretation, manuscript drafting, and critical revision. Dr Sinchana S: literature synthesis, interpretation, manuscript drafting, and critical revision. Both authors approved the final manuscript.

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