BKM
Berita Kedokteran Masyarakat

Volume 42 Number 08, 2026, Pages e29284
DOI: 10.22146/bkm.v42i08.29284

Antimicrobial resistance among WHO priority carbapenem-resistant pathogens in Indonesia: a bibliometric analysis and scoping review

Anwar Rovik[1,2]*, Dian Asti Umaroh[3], Ahmad Ikhsanudin[4], Dion Saputra[5]

Submitted:
March 12th, 2026
Accepted:
August 20th, 2026
Published:
August 29th, 2026

[1]Clinical Research Unit (CRU), Universitas Gadjah Mada Academic Hospital, Yogyakarta, Indonesia

[2]Indonesian Society of Microbiology, Indonesia

[3]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Tanjungpura, Pontianak, Kalimantan Barat, Indonesia

[4]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Lampung, Bandar Lampung, Indonesia

[5]Genome Science Laboratory, Tokyo University of Marine Science and Technology, Konan, Minato-ku, Tokyo, Japan

***Correspondence:**
anwarrovik@mail.ugm.ac.id

Abstract

Purpose: Carbapenem-resistant organisms (CROs) designated as "Critical Priority" on the 2024 Bacterial Priority Pathogens List (BPPL) pose a major public health risk in Indonesia. However, the country's research focus and the precise epidemiological burden of these pathogens remain poorly understood. **Methods:** This study combined bibliometric analysis with a scoping review. Metadata were extracted from Scopus and PubMed (February 2026) using targeted Boolean queries. Bibliometric mapping was conducted in VOSviewer (v1.6.20), and the scoping review followed PRISMA-ScR guidelines and the PECO framework. The analysis focused on carbapenem-resistant *Acinetobacter baumannii* (CRAB), *Pseudomonas aeruginosa* (CRPA), and Enterobacterales (CRE) in Indonesian clinical settings. **Results:** Eleven studies were included from 31 identified records. Research output increased after 2019, with activity primarily centered in Jakarta and Surabaya, and a noticeable shift from phenotypic to molecular characterization after 2020. Key findings include a 50.5% resistance rate in CRAB and high rates of carbapenemase gene carriage in CRPA (69.7%) and *K. pneumoniae* (96.0%), with bla_{NDM} identified as the predominant genotype. Clinically, CRAB infections were associated with significantly longer ICU stays and more than twice the hospitalization costs compared with susceptible cases. **Conclusion:** Carbapenem resistance among WHO critical priority pathogens in Indonesia is significant and genetically diverse, imposing a serious clinical and economic burden. Current research is largely concentrated in Java. To address this crisis, expanded national surveillance, decentralized research capabilities, and stronger infection prevention and control (IPC) programs are needed nationwide.

Keywords: *Acinetobacter baumannii;* bibliometrics; Carbapenem-Resistant Enterobacteriaceae; drug resistance; molecular epidemiology

INTRODUCTION

Antimicrobial resistance (AMR) has evolved from a localized clinical problem into a major global health crisis. According to the WHO, AMR causes millions of infections and tens of thousands of deaths annually, necessitating a coordinated international response. To prioritize global research and development, the WHO updated its Bacterial Priority Pathogens List (BPPL) in 2024. The framework identifies carbapenem-resistant Gram-negative bacilli—specifically *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and members of the Enterobacterales—as 'Critical Priority' threats because of their high mortality rates and the exhaustion of last-resort treatment options [1,2].

These "Critical Priority" pathogens hit hardest in developing regions. In Southeast Asia, high population density and uneven healthcare infrastructure have accelerated the spread of drug-resistant infections. The

region is a critical focal point for global AMR surveillance because its transmission dynamics often mirror the broader challenges of antibiotic stewardship in rapidly developing economies [3–5]. Within this regional landscape, Indonesia faces a particularly daunting burden. What were once sporadic cases of carbapenem resistance have now become endemic. Current predictive models indicate a sobering trajectory: without immediate intervention, Indonesia could face up to 182,000 AMR-related deaths annually by 2030 [6,7]. The Indonesian clinical microbiology sector is at a crossroads and urgently needs to align national surveillance and research with international standards to mitigate this escalating threat [4].

The PAMK (2025) report states that *A. baumannii, P. aeruginosa,* and *Klebsiella pneumoniae* now account for most multidrug-resistant (MDR) infections in Indonesia's tertiary care settings [8]. The spread of these pathogens not only worsens patient morbidity and mortality but also imposes an unsustainable financial burden on the national health insurance system (Jaminan Kesehatan Nasional) because of longer hospital stays and the high costs of alternative treatments [9–11]. Because carbapenem-resistant organisms are classified as 'Critical Priority,' indicating pathogens for which new antibiotics are most urgently needed, this study focuses on carbapenem resistance as the primary clinical and molecular marker of antimicrobial resistance severity in Indonesia.

The rise of carbapenem resistance marks a critical turning point in this crisis, as these antibiotics have long served as the primary defense against severe Gram-negative infections [7,12]. Surveillance data indicate that carbapenem resistance among *A. baumannii* isolates ranges from 54% to 69% in Indonesian intensive care units (ICUs) [8]. This phenotypic resistance is mirrored by a concerning molecular landscape, marked by the widespread presence of the New Delhi metallo-β-lactamase (NDM-1) enzyme, which enables rapid horizontal transfer of resistance genes between species [12]. Along with a 19% carbapenem resistance rate among *K. pneumoniae*, these trends underscore a fragile situation in which common hospital-acquired infections (HAIs) are increasingly difficult to treat [8].

Despite the urgent clinical need, the Indonesian AMR research landscape remains fragmented and geographically uneven. While academic centers on Java Island generate robust genomic and clinical data, a significant information gap persists regarding the prevalence and molecular epidemiology of WHO priority pathogens in Eastern Indonesia and in secondary healthcare facilities [3,13]. This knowledge gap hinders the development of a truly representative National Action Plan. Therefore, this study aims to (1) analyze publication trends and research networks related to carbapenem-resistant WHO priority pathogens in Indonesia using bibliometric analysis and (2) synthesize existing evidence on antimicrobial resistance patterns through a scoping review.

METHODS

The study uses an approach: bibliometric analysis to examine research trends and a scoping review to synthesize clinical evidence on carbapenem-resistant WHO Critical Priority Pathogens in Indonesian healthcare settings.

Bibliometric mapping and visualization

Search strategy and data acquisition

A bibliometric analysis was conducted to assess research output on AMR among the WHO 'Critical Priority' pathogens in Indonesia. Primary metadata were collected independently from the Scopus and PubMed databases, selected for their extensive coverage of the biomedical and clinical microbiology literature. The records were then merged, and duplicates were removed before analysis. The search was conducted in February 2026 with no date restrictions, providing a comprehensive view of historical research on AMR in Indonesia. The document types included original research articles, reviews, and conference papers. The search string used Boolean operators to combine geographic and pathogen-specific terms: ("Antimicrobial Resistance" OR "Antibiotic Resistance") AND ("WHO Priority Pathogens" OR "Carbapenem-resistant") AND ("Indonesia").

Bibliometric analysis and visualization

Including "carbapenem-resistant" reflects the study's focus on the WHO BPPL 2024 Critical Priority tier, where carbapenem resistance marks the last-resort treatment threshold of greatest clinical concern [4,12]. Refined datasets were exported in .bib and .csv formats for analysis. Bibliometric mapping was performed using VOSviewer (version 1.6.20) to visualize co-authorship networks and keyword co-occurrence patterns, with a minimum keyword occurrence threshold of 5 and author keywords as the unit of analysis. Co-authorship network analysis required at least one document and one citation per author, with association-strength normalization applied across all mapping procedures.

Scoping review

The scoping review was conducted in accordance with the PRISMA-ScR guidelines to ensure a trans-

parent, iterative synthesis of evidence. The study was registered on the Open Science Framework (OSF), with the protocol available at 10.17605/OSF.IO/9RZEF.

Study framework

This scoping review used the Population, Exposure, Comparator, and Outcome (PECO) framework. Population: hospitalized patients in Indonesian clinical settings. Exposure: infection or colonization with WHO Critical Priority carbapenem-resistant organisms, including carbapenem-resistant *Acinetobacter baumannii* (CRAB), carbapenem-resistant *Pseudomonas aeruginosa* (CRPA), and carbapenem-resistant Enterobacterales (CRE, including *Klebsiella pneumoniae* and *Escherichia coli*). Given the scoping nature of this review, a formal comparator was not specified; carbapenem-susceptible isolates were reported, but the lack of a consistent comparator across the literature precluded its use as a systematic basis for comparison. The primary outcome was the prevalence of carbapenem resistance and the distribution of carbapenemase genes (e.g., bla_{OXA}, bla_{NDM}, bla_{IMP}, and bla_{VIM}) among WHO Critical Priority Pathogens in Indonesian clinical settings. Secondary outcomes included clinical endpoints associated with carbapenem-resistant infections, in-hospital mortality, ICU length of stay (LOS), and hospitalization costs, where reported.

Eligibility criteria, data extraction, and synthesis

This study included peer-reviewed original research and clinical reports that provided primary data on the prevalence, resistance profiles, or molecular mechanisms of WHO Critical Priority Pathogens, specifically CRAB, CRPA, and CRE, isolated from Indonesian clinical or healthcare-associated settings. The focus on carbapenem-resistant phenotypes reflects their designation as the most clinically urgent tier in the WHO BPPL 2024, which includes organisms for which carbapenems are the last effective therapy. Studies were limited to those involving human subjects and published in English. We excluded reviews, editorials, and opinion pieces from the quantitative synthesis but retained them for cross-referencing. We also excluded studies conducted outside Indonesian healthcare settings, those that did not report carbapenem-specific resistance data, those involving non-human subjects, and machine learning-focused studies.

Given the nature of scoping reviews, a formal quality appraisal was not conducted to inform exclusions. The methodological details of each study, including study design, sample size, and resistance-detection method, were documented and considered in the narrative synthesis to contextualize the strength. Variables extracted from each included study included first author and year, study design, clinical setting, geographic location within Indonesia, sample type, sample size, target pathogen(s), phenotypic resistance rates, carbapenemase gene profiles, and reported clinical outcomes.

Two reviewers (A.R. and D.A.U.) extracted data independently, screening titles, abstracts, and full texts against the eligibility criteria without reference to the other's decisions. Discrepancies between the two reviewers were identified through a structured comparison of extraction records and resolved through discussion and consensus; when agreement could not be reached, a third party was consulted.

RESULTS

This study combines a bibliometric analysis and a scoping review to examine antimicrobial resistance among the WHO-critical-priority carbapenem-resistant pathogens in Indonesia. The carbapenem resistance rates reported in the studies included in this review are relatively high. However, most data come from tertiary hospitals on the island of Java. These findings can be used to map and describe the situation across several regions of Indonesia. The consistent findings from both methods show that carbapenem resistance rates in clinical settings are high and rising, that the diversity of carbapenemase genes is increasing, and that the clinical impacts of resistant infections are serious. At the same time, the bibliometric analysis reveals a research landscape that, although expanding, remains largely focused on Java-based tertiary institutions and phenotypic and ICU-related studies.

The electronic database search retrieved 31 records, including 17 from Scopus and 14 from PubMed. After removing 2 duplicate records, 29 unique records remained for title and abstract screening. Of these, 18 were excluded for the following reasons: non-Indonesian setting (n = 7), review rather than primary resistance research (n = 7), non-resistance research (n = 3), and a focus on machine learning (n = 1) (Figure 1). The remaining 11 reports were retrieved in full. No additional records were excluded after full-text review. Consequently, 11 studies were included in the final scoping review. The PRISMA 2020 flow diagram (Figure 1) illustrates the complete study selection process.

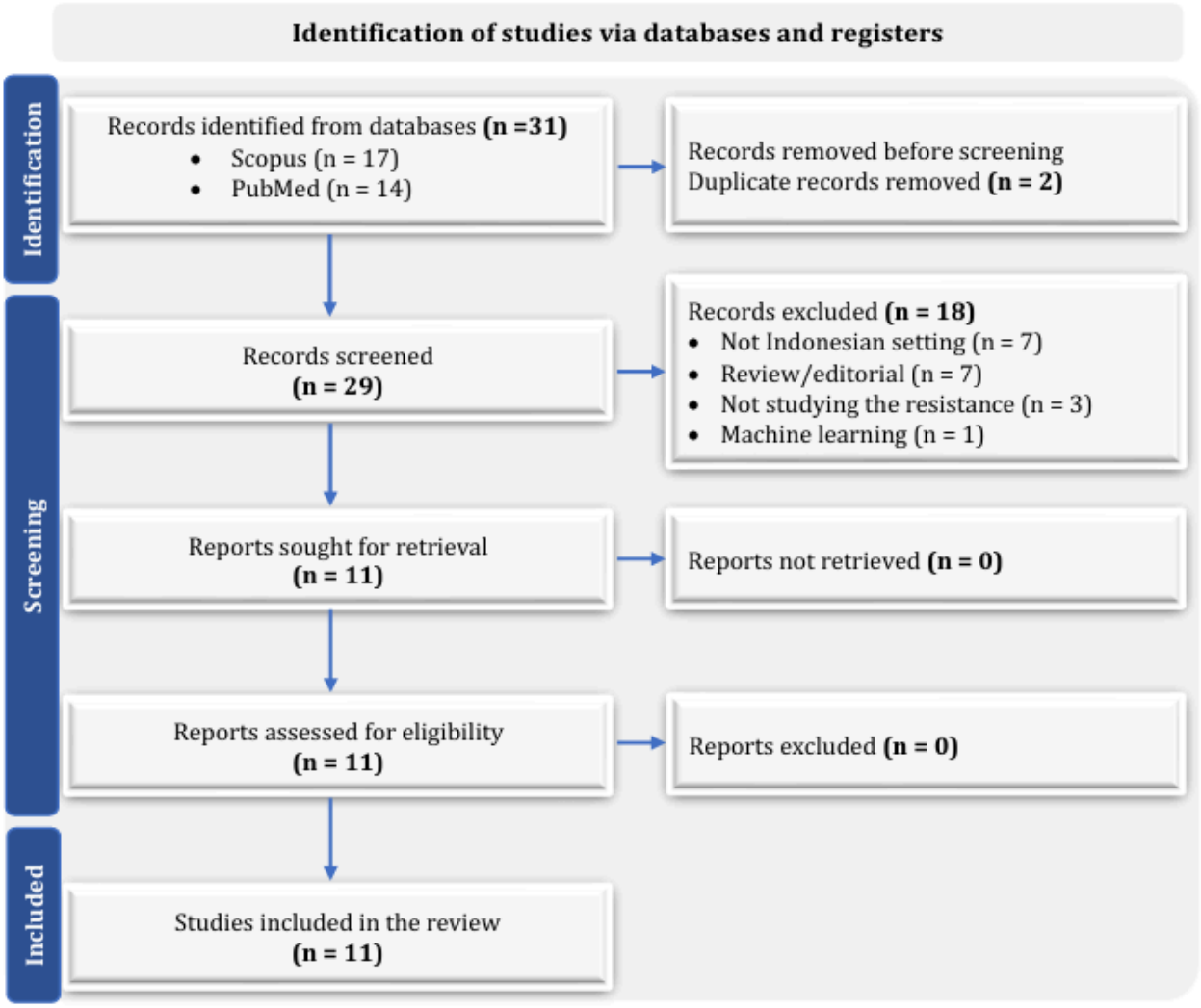


Figure 1. PRISMA 2020 flow diagram used in this study

The publications on AMR in Indonesia indexed in Scopus and PubMed first appeared in 2013 (Figure 2). Before 2018, publication output was low, with fewer than 5 articles per year. Research activity rose notably around 2019, coinciding with the development of national AMR surveillance systems and increased international collaboration. This pattern reflects growing scientific and clinical awareness of the AMR crisis in Indonesia. However, the total number of publications remains low relative to the epidemiological impact, highlighting a significant research-capacity gap that warrants attention.

Most Indonesian AMR literature appears in a few key journals, with Biodiversitas, Acta Medica Indonesiana, Antibiotics, Antimicrobial Resistance and Infection Control, and Archives of Clinical Infectious Diseases publishing a significant share of the indexed work (Table 1). Notably, these journals span a wide range of CiteScore and SJR indices (CiteScore: 0.7–8.7; SJR: 0.149–1.278), reflecting differences in the quality and visibility of the research they publish. Publishing in higher-impact journals (CiteScore >8) indicates that some Indonesian studies achieve international recognition, although most are published in lower-ranked outlets. Most Indonesian AMR research appears in a limited number of journals. In addition, other journals such as Asian Pacific Journal of Tropical Biomedicine, Bali Journal of Anesthesiology, F1000Research, Indonesian Journal of Tropical and Infectious Disease, International Journal of Antimicrobial Agents, Journal of Global Antimicrobial Resistance, Journal of Infection in Developing Countries, Journal of Thoracic Disease, Lancet Regional Health Southeast Asia, Research Journal of Pharmacy and Technology, and Travel Medicine and Infectious Disease each contributed one publication. This pattern reflects the broad yet fragmented dissemination of Indonesian AMR research spanning clinical medicine, microbiology, pharmacology, and regional health, with no single dominant publication outlet.

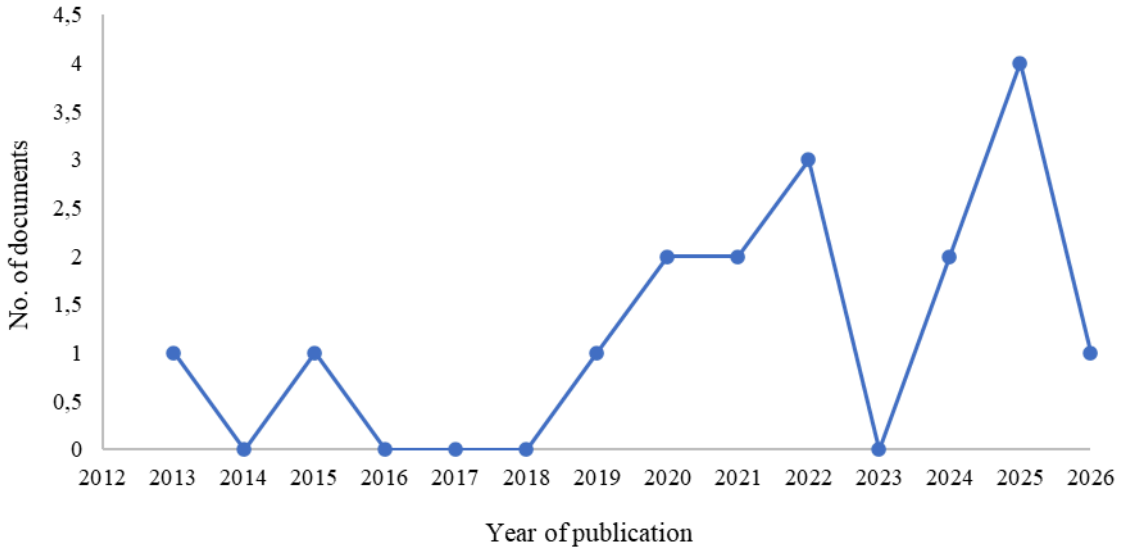
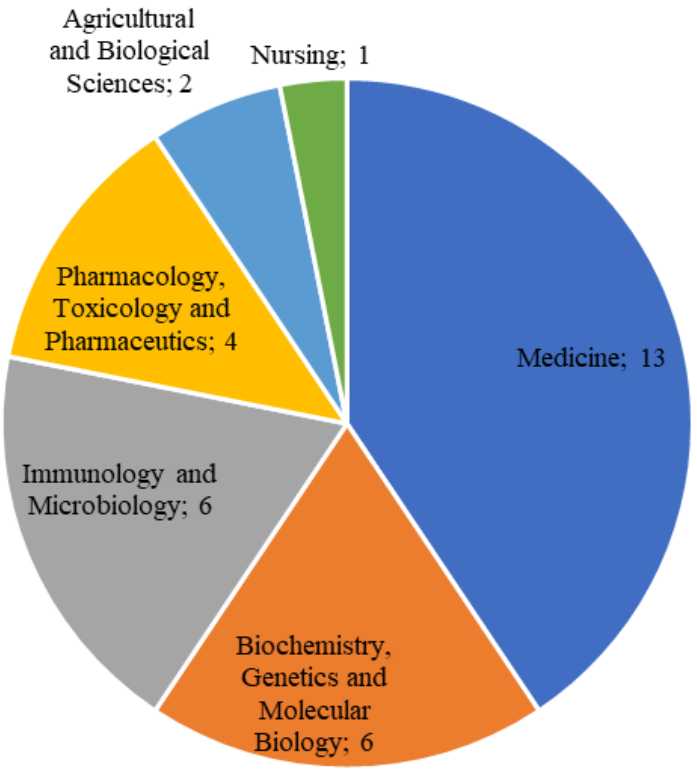


Figure 2. Distribution of documents by year

Table 1. Documents by source and their reputation by 2024

Journal	CiteScore	SJR
Biodiversitas	3.1	0.366
Acta Medica Indonesiana	1.3	0.231
Antibiotics	8.7	1.114
Antimicrobial Resistance and Infection Control	8.6	1.278
Archives of Clinical Infectious Diseases	0.7	0.149

Notes: CiteScore and SJR values were retrieved from Scopus Journal Metrics (2024). CiteScore measures the average citations per document published in the last four years. SJR (SCImago Journal Rank) measures journal prestige, weighted by the subject field, quality, and reputation of the citing journal

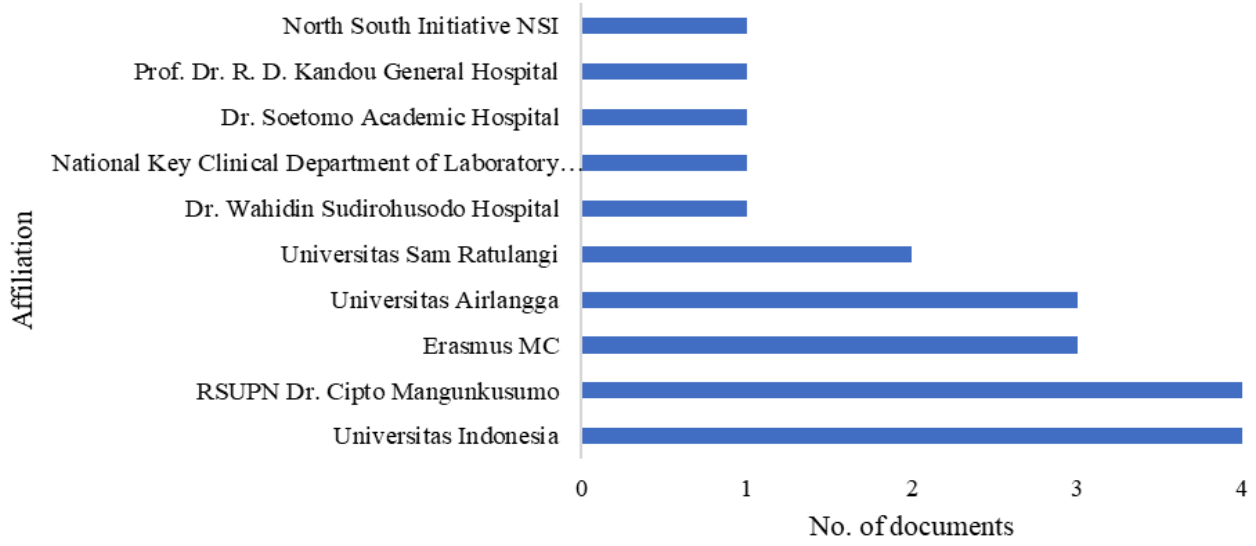


Notes: The data were calculated from the initial raw dataset retrieved from the database search (n = 29) prior to formal screening and exclusion criteria being applied

Figure 3. Documents by scope

Medicine was the largest category (n=13), followed by Biochemistry, Genetics, and Molecular Biology (n=6); Immunology and Microbiology (n=6); and Pharmacology, Toxicology, and Pharmaceutics (n=4). The limited presence of Agricultural and Biological Sciences (n=2) and Nursing (n=1) indicates that Indonesian AMR research remains largely hospital-based and clinically focused, with relatively less output from environmental and community health perspectives (Figure 3). The most productive research team was Karuniawati and Saharman, each with five published papers. Universitas Indonesia and RSUPN Dr. Cipto Mangunkusumo contributed the most publications (n=4), followed by Erasmus MC and Universitas Airlangga (n=3 each). Universitas Sam Ratulangi contributed two publications, while Dr. Wahidin Sudirohusodo Hospital, the National Key Clinical Department of Laboratory Medicine, Dr. Soetomo Academic Hospital, Prof. Dr. R. D. Kandou General Hospital, and North South Initiative each contributed one publication.

The main affiliations are in Jakarta (Universitas Indonesia, RSUPN Dr. Cipto Mangunkusumo) and Surabaya (Universitas Airlangga, Dr. Soetomo), with international collaboration with Erasmus MC in the Netherlands (Figure 4). The presence of Universitas Sam Ratulangi (Manado, Sulawesi) and Prof. Dr. R. D. Kandou General Hospital (Sulawesi) indicates limited but important contributions from Eastern Indonesia, suggesting that AMR research capacity outside Java remains underdeveloped and requires targeted support.

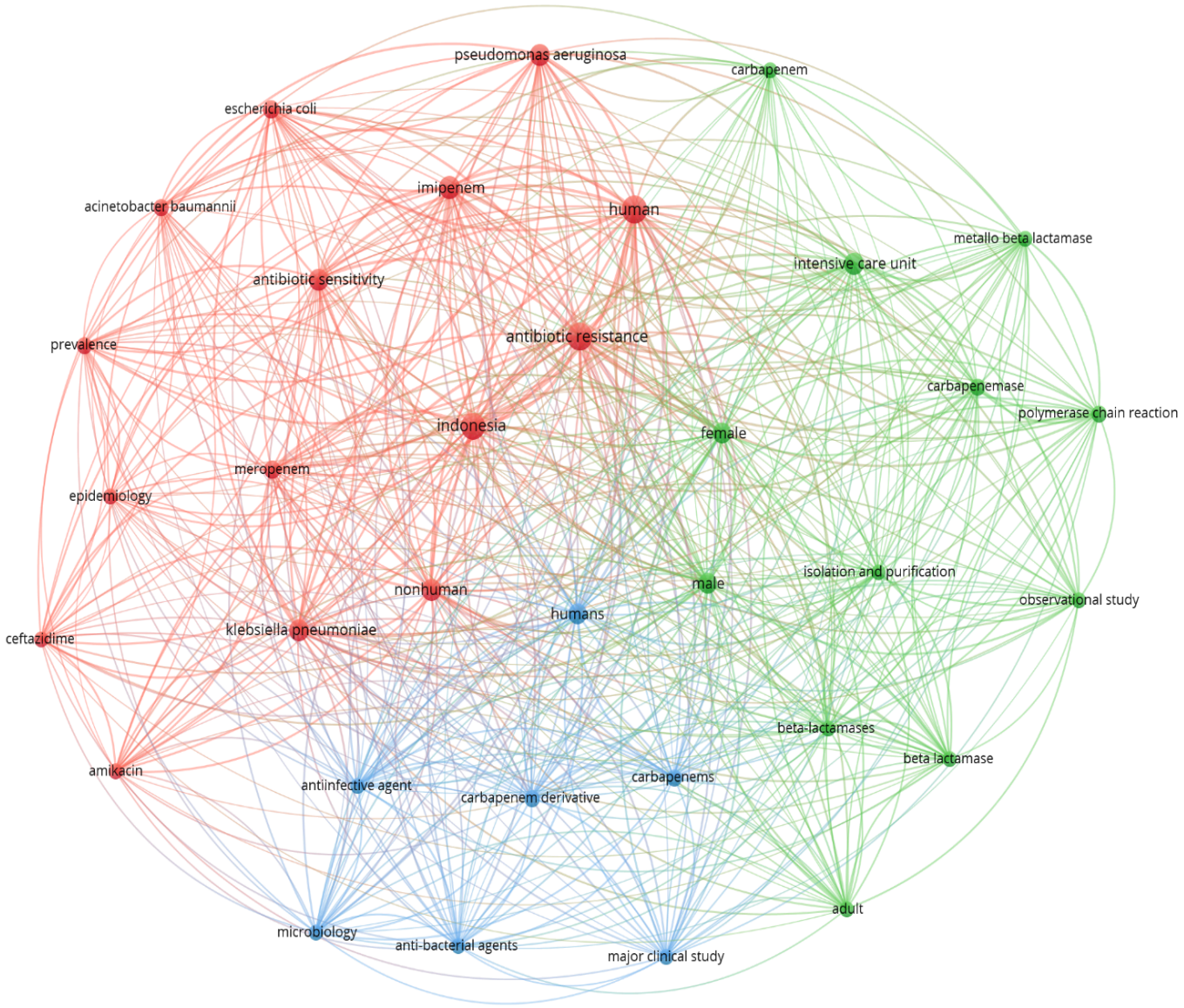


Notes: The data were calculated based on the initial raw dataset retrieved from the database search (n = 29) prior to the formal screening and exclusion criteria

Figure 4. Documents by affiliation

The network visualization likely shows two main clusters: the pathogen and the resistance mechanism (Figure 5). *K. pneumoniae* and *A. baumannii* often appear as the most central nodes (red lines). This data indicates that they are the most frequently studied CRE in Indonesia. Their strong associations with terms such as "neonatal," "ICU," and "outbreak" reflect their status as major drivers of healthcare-associated infections (HAIs) in tertiary hospitals. The strong association among carbapenem-resistant *K. pneumoniae, A. baumannii,* and "multidrug resistance" highlights their extreme resistance profiles. The other main cluster focuses on molecular epidemiology.

The overlay visualization highlights how the volume, geographic distribution, and specific focus of Indonesian AMR research have evolved over time. While molecular characterization and advanced resistance detection (such as $bla_{\text{NDM-1}}$ identification) had already been initiated during the 2013–2020 period by national referral centers, the broader literature from this era remained predominantly baseline and descriptive, frequently utilizing terms such as 'antimicrobial resistance,' 'nosocomial infection,' and 'hospital-acquired.' A significant diagnostic and technological acceleration occurred during 2020–2022, likely driven by the expansion of nationwide laboratory capacity during the COVID-19 pandemic. From 2023 onward, this expanded capacity enabled a distinct shift from generalized bacterial surveillance toward highly targeted, widespread research on high-threat pathogens from the WHO priority list, particularly *K. pneumoniae* and *A. baumannii.*



Notes: The data were calculated based on the initial raw dataset retrieved from the database search (n = 29) prior to the formal screening and exclusion criteria

Figure 5. Network visualization based on the Boolean strings

Table 2. Top 10 most common keywords

Keywords	Occurrences	Total link strength (TLS)
Antibiotic resistance	13	203
Human	13	203
Imipenem	9	144
Klebsiella pneumoniae	8	137
Antibiotic sensitivity	8	118
Intensive care unit	8	112
Meropenem	6	111
Pseudomonas aeruginosa	8	109
Carbapenem derivative	5	102
Escherichia coli	6	97

Note: Keyword occurrences were calculated based on the initial raw dataset retrieved from the database search (n = 29) prior to the formal screening and exclusion criteria.

The ten most frequently co-occurring keywords are shown in Table 2. Antibiotic resistance and humans each appeared in 13 documents, with a total link strength of 203, indicating a consistent clinical focus in Indonesian AMR publications. Imipenem (n=9, TLS=144) and meropenem (n=6, TLS=111) are the most cited carbapenem agents, consistent with their role as last-resort treatments for critical-priority pathogens. The co-occurrence of ICUs (n=8, TLS=112) with resistance terms underscores the hospital-acquired, ICU-centered origin of most of the indexed data.

Table 3. Documents included in the scoping review

Author and year	Title	Study design	Result	Note
Rosyid et al. [14]	Demystify the carbapenem-resistant *Acinetobacter baumannii* pneumonia burden: 2-year cohort study	Retrospective cohort study (2022-2023) of sputum samples from adult patients with pneumonia at Universitas Airlangga Hospital (aged 21-70 years).	Of 50 patients, 26 had CRAB and 24 had carbapenem-sensitive *Acinetobacter baumannii* (CSAB). CRAB was associated with poorer clinical outcomes, including higher mortality, longer hospital stays, and higher healthcare costs compared with CSAB infections.	CRAB cases had higher complication rates (respiratory failure, sepsis, ARDS). Mean length of stay: 17.92 days (CRAB) vs. 11.00 days (CSAB). Mean hospitalization cost: $6,993 vs. $3,264. The neutrophil-to-lymphocyte ratio was higher in CRAB (20.4) than in CSAB (10.6).
Karuniawati et al. [15]	Detection of carbapenemase-encoding genes in *Enterobacteriaceae*, *Pseudomonas aeruginosa*, and *Acinetobacter baumanii* isolated from patients at the ICU, Dr. Cipto Mangunkusumo Hospital in 2011	Molecular detection of carbapenemase-encoding genes in ICU isolates from a national referral hospital in Jakarta using duplex and simplex PCR.	The highest resistance rate was reported in *A. baumannii* (50.5%), whereas Enterobacteriaceae and *P. aeruginosa* showed resistance rates of 27.6% and 21.9%, respectively.	The $bla_{\text{IMP-1}}$ gene was detected in 5% of *P. aeruginosa* isolates. In addition, $bla_{\text{NDM-1}}$ was detected in a single *Klebsiella pneumoniae* isolate, suggesting an early indication of NDM-associated carbapenem resistance in Indonesia.
Saharman et al. [16]	Epidemiology and characterization of carbapenem-nonsusceptible *Pseudomonas aeruginosa* (CNPA) in a large ICU in Jakarta, Indonesia	A prospective observational study conducted between April and October 2013 and between April and August 2014 included adult ICU patients (≥ 18 years) hospitalized for > 48 h at a national referral hospital in Jakarta. We assessed carbapenemase-encoding genes using phenotypic assays and PCR-based methods.	The study included 412 patients, comprising 188 from the ICU and 224 from the ER-ICU. Among CNPA isolates, 69.7% harbored carbapenemase genes, including bla_{VIM} (n = 36), bla_{IMP} (n = 23), and $bla_{\text{GES-5}}$ (n = 24).	Acquisition of carbapenem-nonsusceptible *P. aeruginosa* (CNPA) was associated with longer ICU stays and higher mortality. The mortality rate was above 40% among patients with CNPA, compared with less than 30% in those without CNPA. In addition, individuals with CNPA had significantly longer ICU stays, while more than 80% of other patients were discharged within 7-12 days.
Saharman et al. [17]	Clinical impact of endemic NDM-producing *Klebsiella pneumoniae* in the ICUs of the national referral hospital in Jakarta, Indonesia	A prospective observational study was conducted in the ICUs of a national referral hospital in Jakarta. The study included adult patients hospitalized for > 48 hours, with data collected during two periods: April-October 2013 and April-August 2014. Carbapenemase-encoding gene detection was performed using phenotypic assays combined with PCR-based analysis.	Among 412 patients, 22 (5.3%) were already colonized with carbapenem-non-susceptible *Klebsiella pneumoniae* (CNKP) at admission, and 37 of 390 patients (9.5%) acquired CNKP during their ICU stay. Environmental screening detected CNKP in 1 of 31 isolates (3.2%). Most isolates (96%) carried carbapenemase genes, predominantly $bla_{\text{NDM-1}}$.	Acquisition of carbapenem-non-susceptible *Klebsiella pneumoniae* (CNKP) was associated with longer ICU hospitalization. In addition, patients with CNKP had lower survival rates in the ICU than those infected with carbapenem-susceptible *K. pneumoniae,* indicating an increased risk of mortality during ICU admission.
Endraputra et al. [18]	Profile variation of *bla* genes among non-lactose fermenting Gram-negative bacilli between clinical and environmental isolates of Dr. Soetomo Hospital, Surabaya, Indonesia	A molecular epidemiological investigation was conducted using multiplex PCR to detect carbapenemase-encoding genes in non-fermenting Gram-negative bacilli isolated from clinical specimens and hospital wastewater at a tertiary hospital in Surabaya.	A total of 121 isolates were examined, consisting of 76 clinical isolates, including 41 CRAB and 35 carbapenem-resistant *Pseudomonas aeruginosa,* as well as 45 environmental isolates comprising 6 CRPA and 32 carbapenem-resistant *Pseudomonas* spp.	Several carbapenemase genes were detected among the isolates. Among clinical isolates, the most frequently observed genes were $bla_{\text{OXA-24-like}}$ (39%), followed by $bla_{\text{OXA-23-like}}$ (28%), $bla_{\text{IMP-1}}$ (8%), and $bla_{\text{NDM-1}}$ (1%). In contrast, environmental isolates showed a higher occurrence of $bla_{\text{NDM-1}}$ (34%) and bla_{VIM} (32%), along with $bla_{\text{OXA-23-like}}$ (13%), $bla_{\text{OXA-24-like}}$ (11%), $bla_{\text{OXA-48-like}}$ (5%), and bla_{IMP} (11%), indicating that environmental sources may serve as reservoirs of carbapenem resistance. Screening of rectal swab

Author and year	Title	Study design	Result	Note
				samples also revealed the presence of $bla_{\text{OXA-23-like}}$, $bla_{\text{OXA-like}}$, and $bla_{\text{NDM-1}}$ genes.
Inggraini et al. [19]	Antimicrobial susceptibility and molecular species identification of clinical carbapenem-resistant bacteria	Antimicrobial susceptibility and molecular identification of carbapenem-resistant bacteria from human clinical samples.	Nine isolates were obtained in 2020 from a teaching hospital in Indonesia. They were recovered from clinical specimens, including urine, blood, pus, and sputum.	*K. pneumoniae* was classified as an MDR pathogen because it exhibited resistance to at least six antibiotic classes.
Sumardika et al. [20]	Multidrug-resistant organism infections correlate with increased mortality in COVID-19 patients: A retrospective, observational cohort study .	A retrospective cohort analysis was conducted at a tertiary healthcare center in Indonesia, including 120 participants.	CRAB was the most frequently identified Multidrug-Resistant Organism (MDRO) (30%), followed by extended-spectrum beta-lactamase-producing bacteria (26.6%).	Infections caused by Multidrug-Resistant Organisms (MDROs) were associated with a fourfold higher mortality risk than infections caused by non-MDRO pathogens.
Karmila et al. [21]	Clinical and bacteriological profile of culture-negative and culture-proven neonatal sepsis in Palembang, Indonesia	A retrospective study of electronic medical records from 2016 to 2018. A total of 356 cases of neonatal sepsis were admitted during the study period.	Approximately 62.6% of the identified isolates were MDR, with notable rates of extended-spectrum cephalosporins and carbapenems.	*Klebsiella pneumoniae* was the most frequently identified pathogen in culture-confirmed cases of early-onset sepsis (EOS) associated with mortality. In comparison, *Acinetobacter* spp. and *Enterobacter* spp. were the predominant pathogens detected in fatal cases of late-onset sepsis. Overall, 20 isolates (36.4%) from neonatal sepsis-related deaths were classified as MDR bacteria.
Endaswari et al. [22]	Epidemiology of *Escherichia coli* as a critical pathogen of bloodstream infection patients in Dr. Soetomo General Hospital, Surabaya, Indonesia	A retrospective descriptive observational study was conducted among patients with bloodstream infections on the inpatient wards of a tertiary hospital in 2021.	Of 973 positive blood cultures, 276 isolates (28.4%) were identified as Gram-negative bacteria from hospitalized patients at a hospital in Surabaya during a six-month study period. 63% of *E. coli* isolates were positive for Extended-Spectrum Beta-Lactamase, and 9% were carbapenem-resistant.	
Homenta et al. [23]	Molecular epidemiology of clinical *CRAB-calcoaceticus* complex isolates in tertiary care hospitals in Java and Sulawesi Islands, Indonesia	A total of 73 CRAB-cc isolates were collected.	Phenotypic and molecular detection of CRAB-*calcoaceticus* complex (CRAB-cc). CRAB-cc isolates were predominantly recovered from lower respiratory tract specimens (57.5%), followed by pus (16.4%), blood (15.1%), and urine (10.9%).	*bla*OXA-23 was most prevalent.
Arsyad et al. [24]	Identification of carbapenemase-encoding genes in sinks of the general hospital in Makassar City, Indonesia	A cross-sectional observational study analyzed 63 sink swab samples collected from 19 general hospitals in Makassar, Indonesia.	Carbapenemase contamination was detected in 52.6% of hospital sinks, with the highest rates in emergency rooms (15%), ICUs (21%), and inpatient wards (29%).	Imipenem-resistant *Pseudomonas* carbapenemase was identified as the most prevalent type. In addition, *Enterobacter* spp. and *Klebsiella* spp. accounted for 37.1% of Gram-negative bacteria isolated from sink samples. This group showed the greatest diversity of resistance determinants, with all four carbapenemase genes (bla_{IMP}, bla_{VIM}, bla_{OXA}, and bla_{NDM}) detected.

Table 4. The five most cited documents

Document title	Authors	Source	Year	Citations
Detection of carbapenemase-encoding genes in Enterobacteriaceae, *Pseudomonas aeruginosa*, and *Acinetobacter baumanii* isolated from patients at the ICU, Cipto Mangunkusumo Hospital in 2011	Karuniawati et al. [15]	Acta Médica Indonesiana, 45(2), pp. 101–106	2013	57
Epidemiology and characterization of CNPA in a large ICU in Jakarta, Indonesia	Saharman et al. [16]	International Journal of Antimicrobial Agents, 54(5), pp. 655–660	2019	24
Clinical impact of endemic NDM-producing *Klebsiella pneumoniae* in ICUs of the national referral hospital in Jakarta, Indonesia	Saharman et al. [17]	Antimicrobial Resistance and Infection Control, 9(1), 61	2020	15
Antimicrobial susceptibility and molecular species identification of clinical carbapenem-resistant bacteria	Inggraini et al. [19]	Biodiversitas, 22(2), pp. 555–562	2021	6
Clinical and bacteriological profile of culture-negative and culture-proven neonatal sepsis in Palembang, Indonesia	Karmila et al. [21]	Journal of Infection in Developing Countries, 16(12), pp. 1887–1896	2022	4

The general characteristics and key findings of the 11 articles that met the inclusion criteria for this scoping review are systematically organized (Table 3). These parameters include the author(s), publication year, geographic location, target pathogens, molecular mechanisms of resistance, and a summary of the main outcomes. The analysis shows that the five most cited documents were published between 2013 and 2022 (Table 4). Karuniawati et al. (2013) is the most influential study, with 57 citations, underscoring its key role in characterizing carbapenemase-encoding genes among Gram-negative bacilli in the ICU at RSUPN Dr. Cipto Mangunkusumo, Jakarta [15]. Saharman et al. (2019; 2020) rank second and third, with 24 and 15 citations, respectively, reporting on carbapenem-resistant. *aeruginosa* and NNDM-producing*K. pneumoniae* in Indonesian ICUs [16,17]. Inggraini et al. (2021) and Karmila et al. (2022) broaden the scope of Indonesian antimicrobial resistance research by focusing, respectively, on carbapenem-resistant bacteria in teaching hospital settings and on neonatal sepsis [19,21]. Their citation counts continue to rise due to their recent publication dates.

DISCUSSION

The bibliometric analysis shows that research on AMR in Indonesia, largely conducted at tertiary hospitals on the island of Java, remains relatively limited in volume. However, activity has increased significantly since 2019. This rise likely reflects the implementation of the National AMR Action Plan (NAP-AMR) and increased international collaboration. Nevertheless, these findings offer a snapshot of research activity at specific academic centers and do not yet fully reflect the broader national context. The most prolific authors are Karuniawati and Saharman, each with five publications, and affiliated institutions are concentrated in Jakarta (Universitas Indonesia, RSUPN Dr. Cipto Mangunkusumo) and Surabaya (Universitas Airlangga, Dr. Soetomo Academic Hospital). The data highlight a continued geographic concentration of AMR research capacity.

The VOSviewer keyword overlay analysis further illustrates a temporal shift in research focus: early publications (2013–2019) primarily focused on phenotypic and prevalence aspects, whereas studies after 2020 increasingly target specific molecular markers, especially bla_{OXA} and bla_{NDM}, aligning with the growing laboratory capacity observed across the country. Notably, the keyword co-occurrence network highlights imipenem (n=9, TLS=144) and meropenem (n=6, TLS=111) as the most frequently co-occurring carbapenem agents, underscoring the importance of carbapenem susceptibility testing as the primary benchmark for resistance in Indonesia's broader AMR research landscape.

In line with global trends, CRAB has become the most significant nosocomial threat in Indonesia and currently ranks at the top of the WHO's list of critical pathogens. Its biological resilience enables it to persist on dry hospital surfaces, even under nutrient-poor conditions, thereby facilitating its spread via contaminated equipment and healthcare personnel [25]. Recent data from Universitas Airlangga Hospital in Surabaya indicate that CRAB frequently coexists with *K. pneumoniae* (23.1%) and *P. aeruginosa* (3.8%) in polymicrobial settings, creating complex treatment challenges because resistance to ceftazidime and

piperacillin–tazobactam exceeds 96% [14]. Likewise, *P. aeruginosa* remains a significant challenge in ICUs.

Long-term data from the national referral hospital (RSCM) indicate that carbapenem resistance in *A. baumannii* reached 50.5% as early as 2011, and environmental contamination rates for non-susceptible *P. aeruginosa* reached 75% [15,16]. Three main mechanisms drive the emergence of these phenotypes: beta-lactamase production, changes in penicillin-binding proteins (PBPs), and efflux pump over-expression [26,27]. Our bibliometric analysis highlights a shift toward molecular characterization of carbapenemase-encoding genes, with $bla_{\text{NDM-1}}$, bla_{IMP}, and bla_{VIM} most frequently reported in the published documents. These genes are often carried on mobile genetic elements (plasmids), enabling horizontal gene transfer across species [28]. Misuse and overuse of carbapenems, often used as last-line therapy, have unintentionally selected for these resistant strains, with hospital-wide resistance rates reaching 10.7% in recent multicenter surveys [29].

These pathogens are associated with a fourfold increase in mortality risk compared with non-MDRO infections [20]. This burden is most evident in neonatal sepsis, where the risk of death in developing countries such as Indonesia is 34 times higher than in developed nations [30,31]. In both pediatric and adult ICUs, secondary infections with carbapenem-resistant *K. pneumoniae* or *E. coli* prolong mechanical ventilation and extend hospital stays, further straining the healthcare system [32]. The emergence of MDROs in these settings is increasingly linked to human mobility and poor antibiotic prescribing practices, highlighting the need for stronger stewardship [23].

A key finding of this scoping review is that the hospital environment serves as a persistent reservoir for Antimicrobial Resistant Genes (ARGs). Gordon et al. systematically reviewed publications from the past twenty years. The review concluded that more than 30 studies have identified carbapenem-resistant organisms in hospital water systems, primarily in sinks and drains [33]. The presence of these bacteria in hospital waste indicates that community water sources are contaminated with resistance genes, which can eventually re-enter the human population through the food supply or environmental contact [22]. This One Health cycle—where ARGs originate in the environment, increase in hospitals, and return to the community—underscores the limitations of interventions focused solely on hospitals [34].

Although the volume of research on *Acinetobacter baumannii* and carbapenem resistance in Indonesia has grown, a deeper critique of study designs reveals significant methodological heterogeneity that undermines the robustness of the findings. A substantial proportion of the included studies are single-center, retrospective reports or cross-sectional surveys with relatively small sample sizes. The geographic distribution of studies is heavily concentrated in tertiary hospitals in Java. While these provide valuable local insights, they may not fully capture nationwide molecular epidemiology or the diversity of resistance clones across Indonesia.

Diagnostic methods vary considerably. Some studies use advanced automated systems (e.g., VITEK® 2) and molecular confirmation of carbapenemase genes via PCR (e.g., bla_{OXA}), whereas others rely solely on manual disk diffusion or broth microdilution. This lack of standardized diagnostic criteria across centers can lead to discrepancies in reported resistance rates. Furthermore, longitudinal, multicenter genomic surveillance using whole-genome sequencing (WGS), the current gold standard for tracking high-risk clones, is scarce. Consequently, the current evidence base primarily reflects snapshots of resistance rather than a comprehensive, real-time map of the national resistome.

This study has several limitations to consider when interpreting its findings. First, the bibliometric analysis was limited to Scopus and PubMed, which may underestimate studies published in Indonesian-language journals or in gray literature not indexed in these databases. Second, the scoping review identified only 11 eligible studies, reflecting the limited published primary data on carbapenem-resistant WHO critical priority pathogens in Indonesia rather than a flaw in the search strategy. Additionally, future research should focus on 1) prospective multicenter surveillance studies at secondary-level hospitals across all Indonesian provinces; 2) the application of WGS to characterize dominant carbapenem-resistant clones and elucidate transmission networks; and 3) health-economic modeling of the AMR burden on the Jaminan Kesehatan Nasional system to inform policy development for ongoing AMR efforts.

CONCLUSION

This bibliometric analysis and scoping review reveal an increasing yet geographically concentrated research landscape on carbapenem resistance in Indonesia. Java-based institutions primarily drive the literature and focus heavily on the molecular characterization of carbapenemase-encoding genes. While the scoping review identifies a high burden of resistance in reported cohorts—such as high rates of CRAB, CRPA, and bla_{NDM}-positive *K. pneumoniae* in specific tertiary and intensive care settings—these

figures are derived from heterogeneous, often single-center studies. Consequently, they should be viewed as indicators of clinical severity in specialized settings rather than as representative national prevalence rates. This study serves as an exploratory baseline, highlighting the urgent need for integrated infection control and a more unified national approach to mitigating the "Critical Priority" threats identified by the WHO.

Acknowledgement
Not applicable.

Author contributions
Conceptualization: A.R.; Methodology: A.R., D.A.U., and A.I.; Investigation: A.R.; Data curation: A.R. and D.A.U.; Formal analysis: A.R. and D.S.; Writing—original draft: A.R., D.A.U., and A.I.; Writing—review & editing: all authors; Supervision: D.S.; Funding acquisition: none. All authors have read and agreed to the published version of the manuscript.

Funding
This study received no specific funding.

Data availability
The data supporting this study's findings are publicly available.

Ethical considerations
As this study is a bibliometric analysis and scoping review, it did not involve human subjects, animal models, or the collection of sensitive personal data. We retrieved all analyzed data from publicly available academic databases. Consequently, this study was exempt from Institutional Review Board (IRB) approval or formal ethical clearance.

Conflict of Interest
The author declares no conflict of interest in this study.

Use of artificial intelligence (AI)
Portions of this article were edited using Gemini and Grammarly. The article selection process was performed using Rayyan.ai. The authors reviewed and validated all AI-assisted content. The authors are solely responsible for the final product.

REFERENCES

1. Tacconelli E, Carrara E, Savoldi A, Harbarth S, Mendelson M, Monnet DL, et al. Discovery, research, and development of new antibiotics: the WHO priority list of antibiotic-resistant bacteria and tuberculosis. The Lancet Infectious Diseases. 2018; 18(3):318–27.
2. Sati H, Carrara E, Savoldi A, Hansen P, Garlasco J, Campagnaro E, et al. The WHO bacterial priority pathogens list 2024: a prioritization study to guide research, development, and public health strategies against antimicrobial resistance. The Lancet Infectious Diseases. 2025;25(9):1033–43.
3. Dharmayanti NLPI, Kusala MKJ, Nuradji H, Nurjanah D. Antimicrobial resistance in Indonesia: a comprehensive one health analysis and strategic roadmap for mitigation. International Journal of One Health. 2025;11(1):34–53.
4. Siahaan S, Herman MJ, Fitri N. Antimicrobial resistance situation in Indonesia: a challenge of multisector and global coordination. Journal of Tropical Medicine. 2022;2022(1):2783300.
5. Gidey K, Gidey MT, Hailu BY, Gebreamlak ZB, Niriayo YL. Clinical and economic burden of healthcare-associated infections: A prospective cohort study. PLoS ONE. 2023;18(2):e0282141.
6. Institute for Health Metrics and Evaluation (IHME). The burden of antimicrobial resistance (AMR) in Indonesia. Seattle: University of Washington; 2022. Available from: [Website]
7. Parathon H, Kuntaman K, Widiastoety TH, Muliawan BT, Karuniawati A, Qibtiyah M, et al. Progress towards antimicrobial resistance containment and control on Indonesia. BMJ. 2017;358: j3808.
8. Perhimpunan Dokter Spesialis Mikrobiologi Klinik Indonesia (PAMKI). Buku SINAR-PAMKI 2025: Data resistensi antibiotik Indonesia tahun 2024. Jakarta: PAMKI; 2025. Available from: [Website]
9. Chowdhury F, Bhuiya S, Abdul Aleem M, Shuvo TA, Mamun GMdS, Kumar Ghosh P, et al. Decade-long trends in antibiotic prescriptions according to WHO AWaRe classification among patients with severe acute respiratory infection at tertiary hospitals in Bangladesh (2011–2020). Antibiotics. 2025;14(2):199.
10. Limato R, Nelwan EJ, Mudia M, Alamanda M, Manurung ER, Mauleti IY, et al. Perceptions, views, and practices regarding antibiotic prescribing and stewardship among hospital physicians in Jakarta, Indonesia: a questionnaire-based survey. BMJ Open. 2022;12(5):e054768.
11. Religioni U, Barrios-Rodríguez R, Requena P, Borowska M, Ostrowski J. Enhancing therapy adherence: impact on clinical outcomes, healthcare costs, and patient quality of life. Medicina. 2025; 61(1):153.
12. Kadariswantiningsih IN, Rampengan DD, Ramadhan RN, Idrisova A, Idrisov B, Empitu MA. Antibiotic resistance in Indonesia: A systematic review and meta‐analysis of extended-spectrum beta-lactamase-producing bacteria (2008–2024). Tropical Medicine and International Health. 2025; 30(4):246–59.
13. Sugianli AK, Ginting F, Parwati I, De Jong MD, Van Leth F, Schultsz C. Antimicrobial resistance among

uropathogens in the Asia-Pacific region: a systematic review. JAC-Antimicrobial Resistance. 2021;3(1):dlab003.
14. Rosyid AN, Endraswari PD, Setiawan F, Puspitasari Y, Asmarawati TP, Rachman BE, et al. Demystify carbapenem-resistant *Acinetobacter baumannii* pneumonia burden: 2-year cohort study. Annals of African Medicine. 2025;24(4):909–15.
15. Karuniawati A, Saharman YR, Lestari DC. Detection of carbapenemase encoding genes in Enterobacteriaceae, *Pseudomonas aeruginosa*, and *Acinetobacter baumannii* isolated from patients at intensive care unit of Cipto Mangunkusumo Hospital in 2011. Acta Medica Indonesiana. 2013; 45(2):101–6.
16. Saharman YR, Pelegrin AC, Karuniawati A, Sedono R, Aditianingsih D, Goessens WHF, et al. Epidemiology and characterisation of carbapenem-non-susceptible *Pseudomonas aeruginosa* in a large intensive care unit in Jakarta, Indonesia. International Journal of Antimicrobial Agents. 2019; 54(5):655–60.
17. Saharman YR, Karuniawati A, Sedono R, Aditianingsih D, Goessens WHF, Klaassen CHW, et al. Clinical impact of endemic NDM-producing *Klebsiella pneumoniae* in intensive care units of the national referral hospital in Jakarta, Indonesia. Antimicrobial Resistance and Infection Control. 2020;9(1):61.
18. Endraputra PN, Kuntaman K, Wasito EB, Shirakawa T, Raharjo D, Setyarini W. Profile variation of *bla* genes among non-lactose fermenting Gram-negative bacilli between clinical and environmental isolates of Dr. Soetomo Hospital, Surabaya, Indonesia. Biodiversitas: Journal of Biological Diversity. 2021; 22(11).
19. Inggraini M, Nurfajriah S, Priyanto JA, Ilsan NA. Antimicrobial susceptibility and molecular species identification of clinical carbapenem-resistant bacteria. Biodiversitas: Journal of Biological Diversity. 2021;22(2).
20. Sumardika IW, Cokro F, Suranadi IW, Pinatih KJP. Multidrug-resistant organism infections correlate with increased mortality in COVID-19 patients: a retrospective, observational cohort study. Bali Journal of Anesthesiology. 2022;6(4):231–4.
21. Karmila A, Barchia I, Ramandati A, Zhang L. Clinical and bacteriological profile of culture-negative and culture-proven neonatal sepsis in Palembang, Indonesia. The Journal of Infection in Developing Countries. 2022;16(12):1887–96.
22. Endraswari P, Mertaniasih NM, Setiawan F, Paramita AL. Epidemiology of *Escherichia coli* as a critical pathogen of bloodstream infection patients in a tertiary referral hospital. Indonesian Journal of Tropical Infectious Disease. 2022;10(3):205–13.
23. Homenta H, Julyadharma J, Susianti H, Noorhamdani N, Santosaningsih D. Molecular epidemiology of clinical carbapenem-resistant *Acinetobacter baumannii-calcoaceticus* complex isolates in tertiary care hospitals in Java and Sulawesi Islands, Indonesia. Tropical Medicine and Infectious Disease. 2022;7(10):277.
24. Arsyad ZS, Pertiwi YD, Ramadhan AR, Syamsuri F, Rasita YD, Tenriesa L, et al. Identification of carbapenemase gene in sinks of the general hospital in Makassar City, Indonesia. Archives of Clinical Infectious Diseases. 2025;20(4):e161604.
25. Nowak P, Paluchowska P. *Acinetobacter baumannii*: biology and drug resistance — role of carbapenemases. Folia Histochemica et Cytobiologica. 2016;54(2), 61–74.
26. Oliver A, Arca-Suárez J, Gomis-Font MA, González-Pinto L, López-Causapé C. Emerging resistance mechanisms to newer β-lactams in *Pseudomonas aeruginosa.* Clinical Microbiology and Infection. 2025;31(11):1790–6.
27. Türkyılmaz O, Darcan C. Molecular basis of ampicillin resistance: combinatorial mechanisms and future strategies. World Journal of Microbiology and Biotechnology. 2026;42(2):79.
28. Weingarten RA, Johnson RC, Conlan S, Ramsburg AM, Dekker JP, Lau AF, et al. Genomic analysis of hospital plumbing reveals diverse reservoir of bacterial plasmids conferring carbapenem resistance. Bonomo RA, Editor. mBio. 2018;9(1): e02011-17.
29. Kuntaman K, Shigemura K, Osawa K, Kitagawa K, Sato K, Yamada N, et al. Occurrence and characterization of carbapenem-resistant Gram-negative bacilli: A collaborative study of antibiotic-resistant bacteria between Indonesia and Japan. International Journal of Urology. 2018;25(11):966 –72.
30. Putri ND, Dickson BF, Adrizain R, Kartina L, Baker J, Sukarja D, et al. Epidemiology of sepsis in hospitalized neonates in Indonesia: high burden of multidrug-resistant infections reveals poor coverage provided by recommended antibiotic regimens. BMJ Global Health. 2025;10(4):e016272.
31. Wen SCH, Ezure Y, Rolley L, Spurling G, Lau CL, Riaz S, et al. Gram-negative neonatal sepsis in low- and lower-middle-income countries and WHO empirical antibiotic recommendations: A systematic review and meta-analysis. PLoS Medicine. 2021;18(9): e1003787.
32. Langford BJ, So M, Raybardhan S, Leung V, Westwood D, MacFadden DR, et al. Bacterial

co-infection and secondary infection in patients with COVID-19: a living rapid review and meta-analysis. Clinical Microbiology and Infection. 2020;26(12):1622–9.
33. Gordon AEK, Mathers AJ, Cheong EYL, Gottlieb T, Kotay S, Walker AS, et al. The hospital water environment as a reservoir for carbapenem-resistant organisms causing hospital-acquired infections—a systematic review of the literature. Clinical Infectious Disease. 2017;64 (10):1435–44.
34. Fouz N, Pangesti KNA, Yasir M, Al-Malki AL, Azhar EI, Hill-Cawthorne GA, et al. The contribution of wastewater to the transmission of antimicrobial resistance in the environment: implications of mass gathering settings. Tropical Medicine and Infectious Disease. 2020;5(1):33.