Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Antimicrobial Resistance in Ukraine and Neighboring Poland Before and During Russia's Full-Scale Invasion of Ukraine: A Comparative Analysis of Public Surveillance Data, 2019-2025

Shrreya Jain

sdzhein.3m19@knmu.edu.ua

Kharkiv National Medical University

Research Article

Keywords: antimicrobial resistance, carbapenem-resistant enterobacterales, klebsiella pneumoniae, acinetobacter, armed conflict, ukraine, poland, antimicrobial surveillance

Posted Date: November 12th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11461079/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Introduction

Russia's full-scale invasion of Ukraine in February 2022 brought large numbers of war injuries, overcrowded hospitals and transfers of patients across borders, all of which favor the spread of antimicrobial resistance (AMR). Highly resistant Gram-negative bacteria have been reported in war-injured patients inside and outside Ukraine, but national trends before and during the war have not been compared with those of a neighboring country. This study compared AMR in invasive bacterial isolates in Ukraine and Poland before and during the full-scale war.

Materials and methods

This retrospective study used publicly available, aggregated surveillance data from the World Health Organization (WHO) Regional Office for Europe, the European Antimicrobial Resistance Surveillance Network and the WHO Global Antimicrobial Resistance and Use Surveillance System. Five pathogen-antibiotic combinations were analyzed: carbapenem-resistant *Klebsiella pneumoniae*, *K. pneumoniae* with combined resistance, carbapenem-resistant *Acinetobacter* species, multidrug-resistant *Pseudomonas aeruginosa* and methicillin-resistant *Staphylococcus aureus*. The percentage of resistant isolates in the pre-war period (2019–2021) was compared with the war period (2022–2023) using risk ratios (RR) with 95% confidence intervals (CI), the Cochran-Armitage test for trend and a difference-in-differences analysis. National policy indicators were taken from the Tracking Antimicrobial Resistance Country Self-assessment Survey.

Results

Carbapenem resistance in *K. pneumoniae* rose from 61.0% to 71.3% in Ukraine (RR 1.17, 95% CI: 1.07–1.27) and from 12.5% to 17.5% in Poland (RR 1.41, 95% CI: 1.25–1.58). In Poland, most of this increase occurred in 2021, before the invasion, and resistance reached 24.3% in 2025. Carbapenem resistance in *Acinetobacter* species increased in Ukraine (74.2% to 83.0%) but not in Poland (79.1% to 78.1%), and the change was significantly greater in Ukraine (ratio of odds ratios 1.80, 95% CI: 1.17–2.77). In 2023, Ukraine reported the highest carbapenem resistance of all reporting countries in the WHO European Region for both *K. pneumoniae* (70.1% for meropenem) and *Escherichia coli* (10.7%), although it tested about a quarter as many bloodstream isolates per million population as Poland. Both countries reported laws on prescription-only sale of antibiotics and similar self-assessed capacity for infection prevention and control.

Conclusions

Ukraine entered the full-scale war with very high carbapenem resistance, which rose further during the war, most clearly in *Acinetobacter* species. In Poland, the increase in carbapenem-resistant *K. pneumoniae* began before the invasion and continued afterwards. Expanding surveillance and low blood culture rates in Ukraine limit causal conclusions. Stronger infection control, enforcement of prescription-only antibiotic sales and coordinated cross-border surveillance are needed in both countries.

Introduction

Antimicrobial resistance (AMR) is one of the leading threats to global health. In 2019 alone, bacterial AMR was directly responsible for an estimated 1.27 million deaths worldwide, and carbapenem-resistant Gram-negative bacteria were among the pathogens causing the greatest burden [1]. Armed conflict creates nearly ideal conditions for these organisms to spread. Contaminated blast and gunshot wounds, long hospital stays, overcrowded intensive care units (ICUs), shortages of staff and supplies and heavy empirical use of broad-spectrum antibiotics all select for resistant bacteria. This pattern has been documented repeatedly, from *Acinetobacter baumannii* infections in soldiers injured in Iraq and Afghanistan [2] to multidrug-resistant bacteria in patients injured in the Syrian war [3].

Ukraine has been affected by armed conflict since 2014. Even before the full-scale invasion, bacteria isolated from war injuries in military hospitals in eastern Ukraine between 2014 and 2020 showed high rates of resistance to carbapenems and other last-line antibiotics [4]. After Russia's full-scale invasion on February 24, 2022, the number of injured patients grew sharply, and several reports described highly resistant Gram-negative bacteria in Ukrainian hospitals. Ljungquist et al. (2023) described Gram-negative isolates from war victims that were resistant to nearly all antibiotics tested [5]. A point prevalence survey in three regional hospitals in late 2022 found that 60% of patients with a healthcare-associated infection had a carbapenem-resistant organism [6]. Extensively drug-resistant Gram-negative bacteria were also reported in severe infections of conflict wounds [7] and in war wounds treated in Dnipro, where genomic analysis identified several carbapenemase genes [8].

The consequences of this were quickly seen outside Ukraine. Germany reported a marked increase in New Delhi metallo-beta-lactamase (NDM)-producing *Klebsiella pneumoniae* associated with the war in 2022 [9], and the Netherlands detected multidrug-resistant organisms in patients arriving from Ukraine [10]. Poland, which shares a border of about 535 km with Ukraine, received more refugees than any other country, as well as many medically evacuated patients. Biedrzycka et al. (2025) analyzed 65 carbapenemase-producing Enterobacterales isolates recovered in 36 Polish medical centers from patients arriving from Ukraine between March 2022 and February 2023. *K. pneumoniae* was the most common species (50 isolates belonging to 15 sequence types), and many of the lineages were related to organisms circulating in Russia and other parts of Eastern Europe [11].

Despite this growing body of work, most published studies describe single hospitals, small groups of patients or short periods. Surveillance of AMR in post-Soviet countries has historically been fragmented, with limited laboratory capacity and low participation in international networks [12]. The closest study to

the present one, by Uren et al. (2025), compared a cumulative antibiogram from one hospital network in Lviv with national data from neighboring countries, but it covered only one year and could not describe trends over time [13]. To our knowledge, no study has compared national AMR trends in Ukraine with those of a neighboring European Union country across the periods before and during the full-scale war.

The aim of this study was to compare the percentage of resistant invasive isolates of key bacterial pathogens in Ukraine and Poland before (2019–2021) and during (2022 onwards) the full-scale war, to place Ukraine within the wider European context, and to compare the national AMR policy indicators reported by both countries.

Materials & Methods

Study Design

This was a retrospective comparative study of publicly available, aggregated national surveillance data. The study compared Ukraine with Poland, its largest neighbor in the European Union (EU), across a pre-war period (2019–2021) and a war period (2022 onwards). Romania, Slovakia and Hungary, the other EU countries bordering Ukraine, were included for context. The data contained no information on individual patients, so ethical approval and informed consent were not required.

Data Sources

Data for Ukraine were taken from the country profile in the World Health Organization (WHO) Regional Office for Europe report on AMR surveillance in the WHO European Region, which presents data reported to the Central Asian and European Surveillance of Antimicrobial Resistance (CAESAR) network for 2019–2023 [14]. For each pathogen-antibiotic combination, the report gives the number of invasive isolates tested and the percentage that were resistant. The same profile was used to describe the population coverage of Ukrainian surveillance, the number of reporting laboratories, the share of isolates from ICUs and the blood culture rate.

Data for Poland, Romania, Slovakia and Hungary were downloaded from the European Centre for Disease Prevention and Control (ECDC) Surveillance Atlas of Infectious Diseases, which presents data reported to the European Antimicrobial Resistance Surveillance Network (EARS-Net) [15]. For each combination, two indicators were exported for 2019–2025: the number of resistant isolates and the percentage of resistant isolates. Values for 2025 were the latest available in the Atlas at the time of download in October 2026. Population coverage and the blood culture rate for Poland were taken from the ECDC annual epidemiological report for 2024 [16].

The WHO Global Antimicrobial Resistance and Use Surveillance System (GLASS) dashboard [17] was used for three purposes: to check the derived Ukrainian counts against exact counts, to obtain Ukrainian data on colistin resistance, and to compare Ukraine and Poland with all countries of the WHO European

Region in 2023 for individual antibiotics and for the number of bloodstream isolates tested per million population.

National AMR policy indicators for 2020–2025 were taken from the Tracking Antimicrobial Resistance Country Self-assessment Survey (TrACSS) [18]. In TrACSS, each country rates its own capacity on a scale from A (no capacity) to E (sustained capacity) or answers yes or no. Values were read from the regional comparison view and checked against the Trend View country profiles for Ukraine and Poland.

Pathogens and Antibiotics

Five pathogen-antibiotic combinations were selected because they are reported in the same way by CAESAR and EARS-Net and are among the most relevant to hospital-acquired infections and war wounds: (1) *K. pneumoniae* resistant to carbapenems (imipenem or meropenem); (2) *K. pneumoniae* with combined resistance to third-generation cephalosporins, fluoroquinolones and aminoglycosides; (3) *Acinetobacter* species resistant to carbapenems; (4) *Pseudomonas aeruginosa* with combined resistance to at least three of piperacillin-tazobactam, ceftazidime, fluoroquinolones, aminoglycosides and carbapenems; and (5) methicillin-resistant *Staphylococcus aureus* (MRSA). Only invasive isolates (from blood or cerebrospinal fluid) were included.

Study Periods and Counts

The pre-war period was defined as 2019–2021 and the war period as 2022–2023, the latest years with published country-level data for Ukraine. For the EU countries, a sensitivity analysis extended the war period to 2022–2025. Data for 2018 were excluded because Ukrainian surveillance covered less than 1% of the population that year. For *P. aeruginosa*, the Ukrainian pre-war period included only 2020–2021, because fewer than 20 isolates were tested in 2019.

The WHO report gives percentages rounded to whole numbers, so the number of resistant Ukrainian isolates was calculated as the number tested multiplied by the percentage resistant, rounded to the nearest whole isolate. These derived counts matched the exact GLASS counts for carbapenem-resistant *K. pneumoniae* (502 of 688) and *Acinetobacter* species (219 of 267) in 2023. For the EU countries, the number of isolates tested was calculated as the number of resistant isolates divided by the percentage resistant.

Statistical Analysis

For each country and combination, resistant and tested isolates were pooled within each period. The change between periods was expressed as a risk ratio (RR) with a 95% confidence interval (CI) calculated on the log scale, and tested with Pearson's chi-square test. A linear trend across years was assessed with the Cochran-Armitage test, where a positive z value indicates an increase. To test whether resistance changed more in Ukraine than in Poland, a difference-in-differences analysis was performed

as the ratio of the war-versus-pre-war odds ratios (OR) of the two countries, with a 95% CI calculated by the Woolf method. This is equivalent to the country-by-period interaction term in a saturated logistic regression model. For the European comparison, countries with at least 10 isolates tested for a given antibiotic in GLASS for 2023 were ranked from highest to lowest percentage of resistance. A p value below 0.05 was considered statistically significant. Analyses were performed in Python version 3.13 (Python Software Foundation, Wilmington, Delaware, USA) using the pandas and SciPy libraries.

Results

Surveillance Coverage

Ukrainian AMR surveillance expanded rapidly during the study period. Estimated population coverage increased from 1% in 2019 to 10% in 2021 and 45% in 2023, and the number of laboratories reporting *K. pneumoniae* increased from six to 63 [14]. Between 58% and 69% of Ukrainian *K. pneumoniae* isolates came from ICUs, and the median blood culture rate remained at three to four blood culture sets per 1,000 patient-days in every year. Isolate representativeness was rated as low by WHO in all years, and only 24% of Ukrainian laboratories took part in external quality assessment in 2023 [14]. In comparison, Polish surveillance covered an estimated 20% of the population, with a mean blood culture rate of 57.7 sets per 1,000 patient-days in 2024 [16]. In GLASS data for 2023, Ukraine reported 50.3 bloodstream isolates per million population, compared with 187.7 in Poland and a median of 129.7 across all reporting countries [17].

Carbapenem-Resistant K. pneumoniae

Carbapenem resistance in *K. pneumoniae* was very high in Ukraine throughout the study period and increased from 61.0% in the pre-war period to 71.3% in the war period (RR 1.17, 95% CI: 1.07–1.27; $p < 0.001$), with a significant linear trend (Table 1). The annual percentage rose from 54% in 2020 to 64% in 2021, 69% in 2022 and 73% in 2023 (Fig. 1). In Poland, resistance increased from 12.5% to 17.5% (RR 1.41, 95% CI: 1.25–1.58; $p < 0.001$). However, most of the Polish increase took place in 2021, before the invasion, when resistance rose from 8.2% to 19.5%. It then remained between 16.8% and 18.8% from 2022 to 2024 and reached 24.3% in 2025. When the war period was extended to 2022–2025, Polish resistance was 19.9% (RR 1.60, 95% CI: 1.45–1.76). In relative terms, the change did not differ significantly between the two countries (ratio of odds ratios 1.06, 95% CI: 0.81–1.40; $p = 0.654$) (Table 2).

Among the other EU neighbors of Ukraine, the clearest change at the time of the invasion was seen in Hungary, where carbapenem resistance in *K. pneumoniae* rose from 0.9% in 2021 to 5.3% in 2022 and 10.5% in 2025. The pooled percentage increased from 0.9% to 5.6% (RR 6.54, 95% CI: 4.20-10.19; $p < 0.001$). Smaller increases were observed in Slovakia (8.6% to 13.9%; RR 1.62, 95% CI: 1.25–2.10) and Romania (45.5% to 50.8%; RR 1.12, 95% CI: 1.04–1.20).

Other Pathogens

Carbapenem resistance in *Acinetobacter* species rose in Ukraine from 74.2% to 83.0% (RR 1.12, 95% CI: 1.03–1.22; p = 0.006) but did not change in Poland (79.1% to 78.1%; p = 0.526). This was the largest difference between the two countries, with a ratio of odds ratios of 1.80 (95% CI: 1.17–2.77; p = 0.007). Combined resistance in *K. pneumoniae* also changed differently in the two countries, rising slightly in Ukraine (70.3% to 75.0%) and falling slightly in Poland (49.0% to 46.0%), with a ratio of odds ratios of 1.43 (95% CI: 1.07–1.89; p = 0.014). Combined resistance in *P. aeruginosa* remained about three times higher in Ukraine than in Poland (69.7% versus 21.4% in the war period) but did not change significantly in either country. The proportion of MRSA decreased in both countries, from 22.5% to 16.0% in Ukraine and from 15.2% to 13.6% in Poland.

Table 1

Resistant invasive isolates in Ukraine and Poland before (2019–2021) and during (2022–2023) the full-scale war. R: resistant isolates; n: isolates tested; RR: risk ratio of the war period compared with the pre-war period; CI: confidence interval; MRSA: methicillin-resistant *Staphylococcus aureus*. Combined resistance in *K. pneumoniae*: resistance to third-generation cephalosporins, fluoroquinolones and aminoglycosides; in *P. aeruginosa*: resistance to at least three of piperacillin-tazobactam, ceftazidime, fluoroquinolones, aminoglycosides and carbapenems. The p value is from Pearson's chi-square test; the trend p value is from the Cochran-Armitage test across 2019–2023. The Ukrainian pre-war period for *P. aeruginosa* covers 2020–2021. Ukrainian data are from the WHO Regional Office for Europe [14]; Polish data are from the ECDC Surveillance Atlas of Infectious Diseases [15].

Pathogen and resistance	Country	Pre-war, R/n (%)	War, R/n (%)	RR (95% CI)	p value	Trend p value
K. pneumoniae, carbapenems	Ukraine	241/395 (61.0)	848/1,189 (71.3)	1.17 (1.07–1.27)	< 0.001	< 0.001
	Poland	456/3,658 (12.5)	509/2,904 (17.5)	1.41 (1.25–1.58)	< 0.001	< 0.001
K. pneumoniae, combined resistance	Ukraine	256/364 (70.3)	791/1,055 (75.0)	1.07 (0.99–1.15)	0.082	0.046
	Poland	1,693/3,457 (49.0)	1,216/2,645 (46.0)	0.94 (0.89–0.99)	0.020	0.802
Acinetobacter species, carbapenems	Ukraine	173/233 (74.2)	390/470 (83.0)	1.12 (1.03–1.22)	0.006	0.033
	Poland	1,199/1,515 (79.1)	715/916 (78.1)	0.99 (0.94–1.03)	0.526	0.051
P. aeruginosa, combined resistance	Ukraine	55/75 (73.3)	122/175 (69.7)	0.95 (0.80–1.12)	0.564	0.791
	Poland	219/875 (25.0)	136/635 (21.4)	0.86 (0.71–1.03)	0.102	0.222
MRSA	Ukraine	73/324 (22.5)	142/887 (16.0)	0.71 (0.55–0.91)	0.009	0.600
	Poland	745/4,910 (15.2)	537/3,953 (13.6)	0.90 (0.81–0.99)	0.035	0.256

Table 2

Difference-in-differences comparison of the change in resistance in Ukraine and Poland. OR: odds ratio; CI: confidence interval; MRSA: methicillin-resistant *Staphylococcus aureus*. A ratio of ORs above one means that resistance increased more, or decreased less, in Ukraine than in Poland between the pre-war (2019–2021) and war (2022–2023) periods. The 95% CI was calculated by the Woolf method.

Pathogen and resistance	OR, war vs pre-war, Ukraine	OR, war vs pre-war, Poland	Ratio of ORs (95% CI)	p value
Acinetobacter species, carbapenems	1.69	0.94	1.80 (1.17–2.77)	0.007
K. pneumoniae, combined resistance	1.26	0.89	1.43 (1.07–1.89)	0.014
K. pneumoniae, carbapenems	1.59	1.49	1.06 (0.81–1.40)	0.654
P. aeruginosa, combined resistance	0.84	0.82	1.03 (0.53–1.97)	0.940
MRSA	0.66	0.88	0.75 (0.53–1.05)	0.089

Ukraine in the European Context

In GLASS data for 2023, Ukraine reported the highest percentage of carbapenem resistance in *K. pneumoniae* of all countries in the WHO European Region for each carbapenem tested (Table 3). The values were, however, close to those of other countries in Eastern Europe. For meropenem, Ukraine (70.1%) was followed by the Republic of Moldova (68.3%) and Georgia (64.0%), and for imipenem by the Russian Federation (71.8%) and Greece (70.5%). The difference was much larger for *Escherichia coli*, in which carbapenem resistance is still rare in most of Europe. Ukraine reported 10.7% resistance to meropenem, three times the next highest value (3.3% in Türkiye), against a regional median of less than 0.1%. Colistin resistance in Ukrainian *K. pneumoniae* was 9.3% (19 of 204 isolates tested), equal to the regional median, and 2.4% (two of 82) in *Acinetobacter* species. Only about 30% of Ukrainian isolates of these species were tested for colistin.

Table 3

Resistance in bloodstream isolates in Ukraine and Poland compared with all reporting countries of the WHO European Region, 2023. WHO: World Health Organization; IQR: interquartile range; R: resistant isolates; n: isolates tested. Rank 1 is the highest percentage of resistance in the region. Only countries with at least 10 isolates tested for the given antibiotic are included. Data are from the WHO Global Antimicrobial Resistance and Use Surveillance System dashboard [17].

Pathogen and antibiotic	Countries	Regional median, % (IQR)	Ukraine, % (R/n)	Ukraine rank	Poland, % (R/n)
K. pneumoniae, meropenem	31	2.4 (0.8–32.7)	70.1 (479/683)	1	6.6 (14/213)
K. pneumoniae, imipenem	26	7.8 (1.3–37.4)	72.4 (326/450)	1	20.0 (271/1,356)
K. pneumoniae, ertapenem	23	7.9 (2.3–38.8)	82.0 (155/189)	1	10.9 (49/448)
K. pneumoniae, colistin	19	9.3 (4.1–14.7)	9.3 (19/204)	10	10.6 (58/546)
E. coli, meropenem	31	0.05 (0.0-0.3)	10.7 (21/197)	1	0.0 (0/415)
E. coli, imipenem	29	0.2 (0.0-0.8)	7.2 (10/139)	1	0.2 (6/2,544)
E. coli, ertapenem	25	0.6 (0.2–1.2)	30.2 (16/53)	1	1.2 (11/889)
E. coli, third-generation cephalosporins	31	16.5 (10.9–33.7)	52.9 (54/102)	5	20.1 (480/2,384)

National Policy Indicators

In TrACSS, Ukraine reported progress with a national action plan on AMR (level C) from 2022 to 2025, while Poland reported no national action plan (level A from 2022 to 2024 and no current plan in 2025) (Table 4). Both countries reported laws on prescription and sale of antimicrobials for human use in every year from 2021, while Ukraine answered no to this question in 2020. Ukraine rated its national AMR surveillance in humans lower than Poland in every year it answered (B or C versus D), but rated its monitoring of antimicrobial use higher in 2025 (E versus D). Both countries rated infection prevention and control at the lowest level (A) in most years before 2025 and at level C in 2025. Ukraine reported starting an integrated surveillance system for AMR in 2022 but not from 2023 onwards.

Table 4

Self-assessed national AMR policy indicators in Poland and Ukraine, 2020, 2022 and 2025. AMR: antimicrobial resistance; AWaRe: Access, Watch, Reserve classification of antibiotics; NA: question not asked in that survey year; NR: not reported. Levels range from A (no capacity) to E (sustained capacity). In 2025, optimizing antimicrobial use refers to hospitals; both countries rated primary care at level B. Data are from the Tracking Antimicrobial Resistance Country Self-assessment Survey [18].

Indicator	Poland 2020	Poland 2022	Poland 2025	Ukraine 2020	Ukraine 2022	Ukraine 2025
National action plan on AMR	NA	A	No current plan	NA	C	C
Laws on prescription and sale of antimicrobials for human use	Yes	Yes	Yes	No	Yes	Yes
National surveillance of AMR in humans	D	D	D	NR	B	C
National monitoring of antimicrobial use in humans	B	B	D	B	A	E
Infection prevention and control in health care	A	A	C	NR	B	C
Optimizing antimicrobial use in human health	C	C	C	NR	C	C
AWaRe classification in the national essential medicines list	A	B	B	NR	B	B
Raising awareness and understanding of AMR	C	B	C	B	C	B
Integrated surveillance system for AMR started	NA	No	No	NA	Yes	No

Discussion

This study shows that Ukraine entered the full-scale war with carbapenem resistance in *K. pneumoniae* already above 60%, and that resistance continued to rise during the war, reaching 73% in 2023. By 2023, Ukraine reported the highest carbapenem resistance in both *K. pneumoniae* and *E. coli* in the WHO European Region. The clearest difference between Ukraine and Poland was in *Acinetobacter* species, in which carbapenem resistance increased in Ukraine but remained stable in Poland. In Poland, carbapenem resistance in *K. pneumoniae* also increased, but most of this increase happened in 2021, before the invasion.

Ukraine and the Eastern European Pattern

Although Ukraine ranked first in Europe for carbapenem resistance in *K. pneumoniae*, its values were close to those of the Republic of Moldova, Georgia and the Russian Federation. This suggests that the war intensified a problem that was already shared across the former Soviet Union rather than creating a new one. Post-Soviet countries have long had high antibiotic consumption [19] and weak, fragmented AMR surveillance [12]. Ukraine introduced electronic prescriptions for systemic antibiotics in 2022, and early studies have examined how this changed pharmacy sales [20]. Notably, Ukraine answered no to having laws on prescription and sale of antimicrobials in TrACSS in 2020 and yes from 2021, which means that the legal basis for prescription-only sale is very recent and its enforcement is still developing.

The situation in *E. coli* is of particular concern. Carbapenem resistance in *E. coli* is still below 1% in most European countries, but Ukraine reported 10.7% for meropenem and 30.2% for ertapenem. Carbapenemase genes are usually carried on plasmids that can move between species of Enterobacterales, and Biedrzycka et al. (2025) described the spread of plasmids carrying both resistance and virulence genes among isolates from Ukrainian patients [11]. Resistance in *E. coli*, which is a common cause of community-acquired infections, may therefore be an early sign that carbapenem resistance is moving beyond hospitals.

War-Related Drivers

The rise in carbapenem-resistant *Acinetobacter* species in Ukraine, with no change in Poland, fits well with what is known about war injuries. *Acinetobacter* has been the typical pathogen of wound infections in modern conflicts [2,3], and it was frequently isolated from war-injured patients in Ukraine both before [4] and after the full-scale invasion [5,7,8]. Patients with severe injuries often go through several hospitals during evacuation, receive broad-spectrum antibiotics at each stage and spend long periods in ICUs. Overcrowding, staff shortages and damaged infrastructure make infection prevention and control harder to maintain, and in 2022 a point prevalence survey in three Ukrainian regional hospitals found that most healthcare-associated infections were caused by carbapenem-resistant organisms [6].

Poland: A Rise That Began Before the War

The Polish data show that a rise in resistance near a conflict zone cannot automatically be attributed to the war. Carbapenem resistance in Polish *K. pneumoniae* more than doubled in 2021, during the COVID-19 pandemic, when the number of confirmed NDM-producing Enterobacterales in Poland almost doubled compared with 2019 [21]. Resistance then remained stable from 2022 to 2024, despite the arrival of patients from Ukraine. The further increase to 24.3% in 2025 may partly reflect the import of Ukrainian clones, which have been documented in Poland, Germany and the Netherlands [9–11], but national aggregated data cannot separate imported from locally acquired infections. Hungary, where carbapenem resistance in *K. pneumoniae* rose more than fivefold between 2021 and 2022, showed the change most closely timed to the invasion, but the same limitation applies.

The Effect of Surveillance Expansion

The most important limitation in interpreting the Ukrainian data is that surveillance itself changed during the study period. Population coverage increased from 1% to 45%, the number of reporting laboratories increased about tenfold, and most isolates came from ICUs [14]. Blood culture rates in Ukraine remained around three sets per 1,000 patient-days, compared with 57.7 in Poland [14,16], and the number of bloodstream isolates per million population was about a quarter of that in Poland [17]. The ECDC review of Ukrainian surveillance in 2025 noted that microbiology capacity at the district level is scarce and that most surveillance data are still collected on paper [22]. When blood cultures are taken only from the most severely ill patients, the percentage of resistant isolates is likely to be overestimated. On the other hand, the inclusion of many new regional hospitals would be expected to lower the percentage of resistance, as was probably the case for MRSA, which fell from 31% in 2021 to 16% in 2023. The fact that carbapenem resistance in *K. pneumoniae* and *Acinetobacter* species continued to rise while the network expanded suggests that at least part of the increase is real.

Policy Indicators

The TrACSS results show little relation between self-assessed policy and measured resistance. Ukraine reported a developed national action plan from 2022, even though its national AMR strategy was formally approved only in 2024 [23], while Poland, with much lower resistance, reported no national action plan at all. Both countries rated infection prevention and control at the lowest level for most of the study period, which is a concern given the central role of infection control in limiting the spread of carbapenem-resistant bacteria. The improvement in Ukraine's rating to level C in 2025 coincides with mandatory minimum requirements for infection prevention and control in all healthcare facilities introduced in 2024 [23], although Poland reported the same change without a comparable reform, so a change in the wording of the 2025 survey may also contribute.

Limitations

This study has several limitations. First, it is based on aggregated national data, so it cannot account for patient characteristics, type of infection or hospital setting, and associations at the national level may not apply to individual patients. Second, the Ukrainian and Polish data come from two different surveillance networks; although both use the same definitions and European Committee on Antimicrobial Susceptibility Testing (EUCAST) breakpoints, their laboratory practices and coverage differ. Third, the number of resistant Ukrainian isolates was derived from rounded percentages, although these values matched the exact GLASS counts where they could be checked. Fourth, the pre-war period overlaps with the COVID-19 pandemic, which affected antibiotic use and infection control in both countries. Fifth, country-level Ukrainian data for 2024 had not yet been published at the time of analysis, as only an executive summary of the 2024 European data was available [24], and surveillance does not cover the temporarily occupied territories of Ukraine [22]. Finally, the TrACSS indicators are self-reported and not independently verified.

Implications

Despite these limitations, the findings point to several practical needs. Ukraine needs continued investment in microbiology laboratories, higher blood culture rates and routine screening of patients transferred between hospitals. Enforcement of prescription-only sale of antibiotics and antimicrobial stewardship programs are needed to reduce selection pressure. For Poland and other neighboring countries, screening of patients transferred from Ukrainian hospitals and shared genomic surveillance would help to detect imported clones early. Future studies should use isolate-level or hospital-level data to separate the effect of the war from the effect of expanding surveillance, and should extend the analysis to 2024 and later years once data become available.

Conclusions

Ukraine entered the full-scale war with some of the highest levels of carbapenem resistance in Europe, and resistance continued to rise during the war, most clearly in *Acinetobacter* species, the pathogen most closely linked to war wounds. Carbapenem resistance has also appeared in *E. coli* at levels far above the rest of Europe, which suggests that resistance is spreading beyond the hospital setting. In neighboring Poland, the rise in carbapenem-resistant *K. pneumoniae* started before the invasion and should not be attributed to the war alone, although resistance has continued to grow since then.

These findings must be interpreted with caution because Ukrainian surveillance expanded rapidly and still relies on few blood cultures from mostly critically ill patients. Strengthening laboratory capacity, infection prevention and control and enforcement of prescription-only antibiotic sales in Ukraine, together with coordinated screening and genomic surveillance across the border, will be essential to limit the spread of resistant bacteria in the region during and after the war.

Declarations

Funding:

No funding was received for conducting this study

Author Contribution

S.J. conceived and designed the study, extracted and curated the national surveillance data, performed the statistical analyses in Python, prepared Figure 1 and Tables 1–4, and wrote the main manuscript text. S.J. reviewed and approved the final submitted manuscript. If your target journal prefers the formal CRediT (Contributor Roles Taxonomy) format with initials:Author ContributionsS.J.: Conceptualization, methodology, software, formal analysis, data curation, visualization, writing – original draft preparation, and writing – review & editing.

Data Availability

The datasets analyzed during the current study are publicly available open-access surveillance data. Ukrainian national surveillance data were obtained from the World Health Organization (WHO) Regional Office for Europe CAESAR report and the WHO Global Antimicrobial Resistance and Use Surveillance System (GLASS) dashboard. Data for Poland, Romania, Slovakia, and Hungary were obtained from the European Centre for Disease Prevention and Control (ECDC) Surveillance Atlas of Infectious Diseases (EARS-Net). Country policy indicators were derived from the Tracking Antimicrobial Resistance Country Self-assessment Survey (TrACSS) database. All data sources and their respective online repositories are fully detailed and cited within the manuscript references. Specific Repository URLs : WHO CAESAR / AMR Surveillance in the WHO European Region: https://www.who.int/europe/publications/i/item/9789289062817 ECDC Surveillance Atlas of Infectious Diseases: https://atlas.ecdc.europa.eu/public/index.aspx WHO GLASS Dashboard: https://worldhealthorg.shinyapps.io/glass-dashboard/ TrACSS Database: https://amrcountryprogress.org/

References

1. Murray CJ, Ikuta KS, Sharara F, et al. Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. Lancet. 2022;399:629–55. 10.1016/S0140-6736(21)02724-0.
2. O'Shea MK. Acinetobacter in modern warfare. Int J Antimicrob Agents. 2012;39:363–75. 10.1016/j.ijantimicag.2012.01.018.
3. Teicher CL, Ronat JB, Fakhri RM, Basel M, Labar AS, Herard P, Murphy RA. Antimicrobial drug-resistant bacteria isolated from Syrian war-injured patients, August 2011-March 2013. Emerg Infect Dis. 2014;20:1949–51. 10.3201/eid2011.140835.
4. Kondratiuk V, Jones BT, Kovalchuk V, Kovalenko I, Ganiuk V, Kondratiuk O, Frantsishko A. Phenotypic and genotypic characterization of antibiotic resistance in military hospital-associated bacteria from war injuries in the Eastern Ukraine conflict between 2014 and 2020. J Hosp Infect. 2021;112:69–76. 10.1016/j.jhin.2021.03.020.
5. Ljungquist O, Nazarchuk O, Kahlmeter G, et al. Highly multidrug-resistant Gram-negative bacterial infections in war victims in Ukraine, 2022. Lancet Infect Dis. 2023;23:784–6. 10.1016/S1473-3099(23)00291-8.
6. Kuzin I, Matskov O, Bondar R, et al. Notes from the field: responding to the wartime spread of antimicrobial-resistant organisms - Ukraine, 2022. MMWR Morb Mortal Wkly Rep. 2023;72:1333–4. 10.15585/mmwr.mm7249a5.
7. Pallett SJ, Morkowska A, Woolley SD, et al. Evolving antimicrobial resistance of extensively drug-resistant Gram-negative severe infections associated with conflict wounds in Ukraine: an observational study. Lancet Reg Health Eur. 2025;52:101274. 10.1016/j.lanepe.2025.101274.
8. Stepanskyi D, Ishchenko O, Luo T, Lebreton F, Bennett JW, Kovalenko I, McGann P. Phenotypic and genomic analysis of bacteria from war wounds in Dnipro, Ukraine. JAC Antimicrob Resist. 2024;6:dlae090. 10.1093/jacamr/dlae090.

9. Sandfort M, Hans JB, Fischer MA, et al. Increase in NDM-1 and NDM-1/OXA-48-producing Klebsiella pneumoniae in Germany associated with the war in Ukraine, 2022. Euro Surveill. 2022;27:2200926. 10.2807/1560-7917.ES.2022.27.50.2200926.
10. Zwittink RD, Wielders CC, Notermans DW, et al. Multidrug-resistant organisms in patients from Ukraine in the Netherlands, March to August 2022. Euro Surveill. 2022;27:2200896. 10.2807/1560-7917.ES.2022.27.50.2200896.
11. Biedrzycka M, Izdebski R, Hryniewicz W, Gniadkowski M, Żabicka D. Carbapenemase-producing Enterobacterales from patients arriving from Ukraine in Poland, March 2022-February 2023. Infect Dis Ther. 2025;14:401–19. 10.1007/s40121-024-01097-9.
12. Zhazykhbayeva D, Bayesheva D, Kosherova Z, Semenova Y. Antimicrobial resistance surveillance in post-Soviet countries: a systematic review. Antibiot (Basel). 2024;13:1129. 10.3390/antibiotics13121129.
13. Uren HD, Aliieva N, Matolinets N, Berrey BH, Holcomb JB, Voitovych O, Herych H. Conflict zone medical evacuations catalyzing antimicrobial resistance spread and threatening regional health: a retrospective comparative observational study. J Trauma Acute Care Surg. 2025;99:S45–54. 10.1097/TA.0000000000004729.
14. World Health Organization Regional Office for Europe. Antimicrobial Resistance Surveillance in the WHO European Region 2024: Data 2023. WHO Regional Office for Europe, Copenhagen; 2026. https://www.who.int/europe/publications/i/item/9789289062817.
15. Surveillance Atlas of Infectious Diseases: antimicrobial resistance. (2026). Accessed: October 21, 2026: https://atlas.ecdc.europa.eu/public/index.aspx
16. European Centre for Disease Prevention and Control, EEA (EARS-Net): Annual Epidemiological Report for 2024. European Centre for Disease Prevention and Control, Stockholm. : Antimicrobial Resistance in the EU/ 2025. https://www.ecdc.europa.eu/sites/default/files/documents/antimicrobial-resistance-eu-annual-epidemiological-report-2024.pdf
17. Global Antimicrobial Resistance and Use Surveillance System (GLASS) dashboard. (2025). Accessed: October 21, 2026: https://worldhealthorg.shinyapps.io/glass-dashboard/
18. Global Database for Tracking Antimicrobial Resistance (AMR) Country Self-Assessment Survey (TrACSS). (2025). Accessed: October 22, 2026: https://amrcountryprogress.org/
19. Robertson J, Iwamoto K, Hoxha I, et al. Antimicrobial medicines consumption in Eastern Europe and Central Asia - an updated cross-national study and assessment of quantitative metrics for policy action. Front Pharmacol. 2019;9:1156. 10.3389/fphar.2018.01156.
20. Kotvitska AA, Volkova AV, Korzh IV, Sevriukov OV, Nozdrina AA. Study of the impact of e-prescription implementation on the sale of antibacterial drugs for systemic use from pharmacies on the example of chloramphenicol. Farmatsevtychnyi Chasopys. 2024;2:51–60. 10.11603/2312-0967.2024.2.14749.

21. Janc J, Słabisz N, Woźniak A, Łysenko L, Chabowski M, Leśnik P. Infection with the multidrug-resistant Klebsiella pneumoniae New Delhi metallo-B-lactamase strain in patients with COVID-19: Nec Hercules contra plures? Front Cell Infect Microbiol. 2024;14:1297312. 10.3389/fcimb.2024.1297312.
22. European Centre for Disease Prevention and Control. ECDC Country Review of Surveillance of Communicable Diseases in Ukraine. Stockholm: European Centre for Disease Prevention and Control; 2026. 10.2900/1501639.
23. World Health Organization Regional Office for Europe: WHO Country Office in Ukraine Annual Report 2024. WHO Regional Office for Europe, Copenhagen. 2025. https://www.who.int/europe/publications/i/item/WHO-EURO-2025-11954-51726-79169
24. WHO Regional Office for Europe, European Centre for Disease Prevention and Control. Surveillance of Antimicrobial Resistance in Europe, 2024 Data: Executive Summary. WHO Regional Office for Europe, Copenhagen; 2025. https://www.who.int/europe/publications/i/item/9789289062619.

Figures

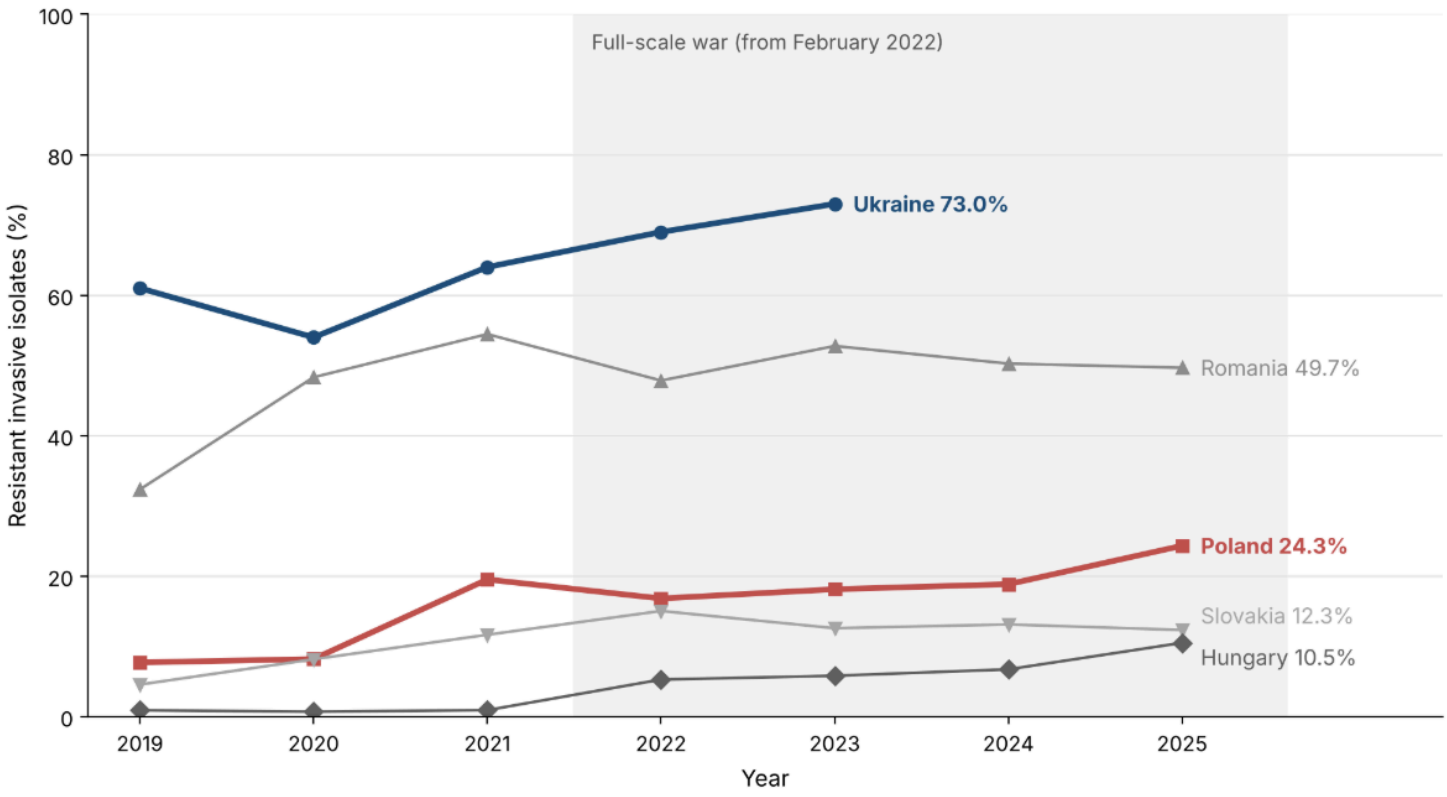


Figure 1

Percentage of invasive Klebsiella pneumoniae isolates resistant to carbapenems in Ukraine and its European Union neighbors, 2019-2025. The shaded area marks the period of the full-scale war. Country-level data for Ukraine were available up to 2023. Ukrainian data are from the World Health Organization

Regional Office for Europe [14]; data for Poland, Romania, Slovakia and Hungary are from the European Centre for Disease Prevention and Control Surveillance Atlas of Infectious Diseases [15].