



CARBAPENEM ANTIBIOTIC USE AND CONSUMPTION IN JORDANIAN ROYAL MEDICAL SERVICES HOSPITALS: A 4-YEAR RETROSPECTIVE STUDY ACROSS FIVE HEALTHCARE FACILITIES

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Submitted on: 28.06.2026;

Revised on: 01.07.2026;

Accepted on: 03.07.2026

ABSTRACT

Objective: This retrospective study will attempt to compare the average number of monthly issued items from JRMS central medical stores of four different formulations of carbapenem antibiotics (imipenem 500mg/cilastatin 500mg, meropenem 500mg, meropenem 1g and ertapenem 1g) to five facilities (King Hussein Hospital, Queen Alia Military Hospital, Prince Ali Bin Al-Hussein Military Hospital, Queen Rania Hospital for Children, and Prince Hussein Center for Kidney Diseases) from 2020 through 2023.

Methodology: A retrospective, descriptive analytical design will be used that will rely on secondary pharmaceutical distribution data from JRMS central medical warehouse inventories. Data will be grouped by year, drug name, and distributing health care facility, and will reflect the average monthly number of vials distributed per year (this figure is unaffected by drug shortages). We will use descriptive statistical methods to calculate annual totals, the proportion of drugs used across the vast network of facilities, year-on-year changes in percentage terms, and comparisons between individual hospitals. The proportion of ertapenem prescribing will be used as an indicator of carbapenem-sparing practices. We will use the ratio of meropenem 1g to 500mg as a measure of prescribing intensity. All results will be presented in relation to the type of specialization of the facilities, known pharmacological properties of the different carbapenems, and the known global effects of the COVID-19 pandemic on antibiotic use. There will be no patient information, clinical or microbiology, reported since the analysis is based only on distribution data from the warehouse.

Results: Imipenem/cilastatin 500 mg was the predominant carbapenem formulation across all facilities and years, accounting for 88.7% of total carbapenem distribution in 2020 and 79.5% in 2023. King Hussein Hospital (KHH) was the largest carbapenem consumer, with total average monthly use decreasing from 5,539 vials in 2020 to 2,889 in 2023 (47.8% reduction). Queen Alia Military Hospital (QAMH) demonstrated a marked increase in carbapenem consumption during the COVID-19 pandemic, rising from 4,586 vials in 2020 to 5,070 in 2021, followed by a substantial decline to 859 in 2022. Prince Hussein Center for Kidney Diseases (PHCK) showed the highest proportion of ertapenem use, peaking at 23.0% of total carbapenem consumption in 2021, suggesting greater adoption of carbapenem-sparing strategies. Network-wide carbapenem use declined from 12,823 average monthly vials in 2020 to approximately 7,371 in 2023, indicating an overall reduction in broad-spectrum carbapenem utilization. Facility-specific variations reflected differences in patient populations, clinical specialties, and the impact of the COVID-19 pandemic on antimicrobial prescribing practices.

KEYWORDS: Carbapenems; Antimicrobial Stewardship; Antimicrobial Resistance; Meropenem; Ertapenem; Drug Utilization; COVID-19; Jordan.

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Indian Research Journal of Pharmacy and Science; 47(2026) 3558-3565
Journal Home Page: <https://www.irjps.in>

1. INTRODUCTION:

Antimicrobial resistance (AMR) is a recognized as one of the most pressing Twenty First Century global public health challenges. Carbapenem is one of the very specific antimicrobial agents that is considered a therapeutic last resort for severe, life-threatening infections caused by multidrug-resistant (MDR) Gram-negative bacteria, such as extended-spectrum beta-lactamase (ESBL) producing Enterobacterales, carbapenemase-producing *Klebsiella pneumoniae*, and *Acinetobacter baumannii*. Carbapenems are in the 'Watch' list of antibiotics that need special protection from antimicrobial stewardship, according to the World Health Organization (WHO) (1).

The carbapenems include a group of pharmacologically different drugs. Imipenem/cilastatin and meropenem are in Group 2, broad spectrum antibiotics that are active against *Pseudomonas aeruginosa* and *Acinetobacter* spp., and are first choice treatment for severe nosocomial infections, severe penetrating infections, and infections in critically ill patients (2). Ertapenem, which can be dosed once a day, is relatively practical due to its activity against community-acquired pathogens that also includes activity against ESBL-producing organisms and in patients with infections that have proven clinically stable (2,3). These pharmacological differences also have implications on the carbapenems distribution between the different kinds of hospitals such as general tertiary and military hospitals to pediatric and organ transplant hospitals.

Initiated in 1941, the "Jordanian Royal Medical Services (JRMS)" is a part of the Jordanian Armed Forces that provides a full spectrum of medical services to the military officers and their families, permanent duty attendees, retired officers, and to the general public. To date, the JRMS provides its services to about 38% of Jordan's population, and distributes all of the restricted antibiotics, such as carbapenems, via a centralized store through which 17 hospitals and health centers are located around the governorates. In this centralized approach, there is a unique opportunity for the network level systematic monitoring of pharmaco-epidemiological data.

Additionally, previous studies in Jordan has shown a positive correlation between the prevalence of carbapenem-resistant Gram-negative pathogens (CR-GNP) and carbapenem consumption (6,7). Additionally, the COVID-19 pandemic affected the world's use of antibiotics by resulting in known rises

in antibiotic, over 57% of carbapenems reported in 2020–2021 in some hospital settings due to empirical use in suspected bacterial co-infections, steep increases in the number of patients admitted to ICUs and disruptions to antibiotic stewardship programs (8). There is much public health to command in comprehending how these operated inside this network, the JRMS. The overall goal of this study was to generate evidence-based stewardship actionable insights which will enable a systematic retrospective examination in the period of 2020–2023 of 5 key JRMS hospitals or special centers over 4 years.

2. LITERATURE REVIEW:

As a bactericidal agent and as a part of the beta-lactam class, carbapenems work by binding with penicillin-binding proteins (PBPs) which inhibit bacterial cell wall synthesis. Their antimicrobial stability to most of the beta-lactamases such as AmpC and ESBLs made them important last-line agents. Clinically significant difference exists between the pharmacologic properties of this group members: imipenem/cilastatin and meropenem have similar, broad-spectrum efficacy, including anti-pseudomonal and anti-*Acinetobacter* effect and wider range of applications when compared with ertapenem, which has a narrower spectrum and is therefore reserved for community-acquired/proliferation of ESBL-producing bacteria in non-Pandemic *Acinetobacter* and *Pseudomonas* pathogens patients. Rather these differences have direct impact on the prescriptions variation depending on the profile of the patient and the epidemiology of the infection on specific institutions.

It is established that there are associations between the use of carbapenems and resistance development in Jordan. Association between the use of carbapenems and their resistance has been documented in Jordan. A seminal study by Hayajneh et al. established an empirical threshold level of 31.042 defined daily doses (DDD) of carbapenems per 1,000 occupied bed days (6) on which to target efforts to reduce carbapenem consumption to prevent levels that trigger significant carbapenem-resistant incidence. Yusef et al. showed that hospital-wide, antibiotic prescribing significantly decreased following the introduction of a formal ASP, alongside a decrease in the prevalence of CRAB in a tertiary hospital in Jordan, thus reinforcing the actionability of stewardship interventions in the hospital setting in the Middle East (7). In addition, a multi-centre study in a Jordanian tertiary hospital identified that 41% of

Gram-negative isolates were resistant to carbapenems, partly due to poor stewardship and more use of carbapenems (9).

The COVID-19 pandemic had a significant impact on the way antibiotics have been used in each country around the world. There have been documented significant increases in trends of antibiotic reserve use for carbapenems and other antibiotics during 2020 and 2021 (8): For example, Leeds gained over 57% in the usage of carbapenems within documented hospital settings during the pandemic year compared to pre-pandemic levels. The mean of the carbapenem DDD increased from baseline value in Saudi Arabia during the initial epidemic period: from 67.1 to 142.9 per 1000 PDs, mostly due to empirical use in ICU patients suspected of having bacterial co-infection (10). However, during this time, there was an overwhelming epidemiology of carbapenem resistance, highlighting the combined role of overwhelmed health care systems, reduced infection prevention and control (IPC) efforts, and long-term exposure to the ICU, including a 35% increase in reporting of carbapenem-resistant Enterobacterales (CRE) in some surveillance systems in 2020 (11).

Ertapenem has sparked considerable clinical interest in its use as 'carbapenem-sparing' strategy. Following implementation, an study was conducted in Lebanon that showed the use of anti-pseudomonal carbapenems had significantly decreased while not only DDDs but also days of therapy (DOT) had increased for the closely related carbapenems, ertapenem, which represented a clear (and appropriate) switch toward this narrower-spectrum agent treatment where clinically appropriate (3). In a systematic review and meta-analysis, ertapenem was shown to have similar clinical efficacy compared to other carbapenems in ESBL-producing Enterobacterales infections and had less activity against *Pseudomonas* and *Acinetobacter* spp. and, in some patient groups, reduced 30-day mortality rates (12). Structured institutional guidance affects prescription practices: Carbapenem guidelines for the institution have been found to boost the number of eligible prescriptions in the hospital (from 49.7% to 80.9%) and to decrease the incidence of MDR bacteremia (13). However, prolonged ASP interventions based on prescription management with carbapenems have been demonstrated to also lead to a decrease in consumption of around 2 days of therapy per month per 1,000 patient days with no negative clinical effect seen (5).

3. METHODOLOGY:

3.1 Study Design and Data Source: A retrospective, descriptive analytical study based on secondary pharmaceutical distribution data obtained from central medical warehouse of JRMS over the next four calendar years 2020 – 2023. Data are averages of monthly amount of each formulation issued per facility per year, and we used the average amount to adjust for days that the facility had stock shortage. No individual patient records and/or prescribing data or clinical outcomes were accessed.

3.2 Study Facilities: In this analysis, only five JRMS hospitals and specialty centers were included: (1) King Hussein Hospital (KHH): The most prestigious JRMS tertiary referral hospital located in the heart of Amman at King Hussein Medical City (KHMC) responsible for the complex cases with regards to all specialties and subspecialties of General medicine, Surgery, ICUs, and Multiple specialties.

(2) Queen Alia Military Hospital (QAMH): A large size hospital in Amman, with a mixed patient population of military staff and their families, with a wide selection of inpatient treatment facilities.

(3) Prince Ali Bin Al-Hussein Military Hospital (PABH): A military general hospital located right in the middle of Al Karak, Jordan, providing services to military personnel and their families.

(4) Queen Rania Hospital for Children (QRH): A specialized pediatric hospital where they deal with neonatal intensive care unit, infectious pediatric diseases and complex pediatric illnesses.

(5) Prince Hussein Center for Kidney Diseases (PHCK): A kidney specialty center that conducts renal transplant operations, hemodialysis services and end-stage renal disease operations.

3.3 Study Medications: Four carbapenem formulations were analyzed: (1) Imipenem 500mg/Cilastatin 500mg vial: this is a broad-spectrum form, requiring a every 6 hours dosing, which requires co-administration with cilastatin (a dehydropeptidase inhibitor); (2) Meropenem 500mg vial: a lower dose formulation mainly used in less severe infections or for pediatrics in terms of weight-based doses; and (3) Meropenem 1g vial: the common adult dose formulation used in more serious infections every 8 hours; and (4) Ertapenem 1g vial: a once-daily administration form which lacks anti-pseudomonal activity.

3.4 Analytical Approach: Information was organized and presented in a structured matrix of years and for each hospital and drug. Descriptive analyses were applied to calculate the annual total

drug quantity per drug and per facility, network-wide proportional drug shares, year-on-year percentage changes, and the proportion of ertapenem in each individual facility's use of total carbapenems per year used as a proxy for the practice of carbapenem-sparing. The meropenem 1g

was studied in relation to the 500 mg ratio to assess the level of prescribing. Results were then linked and related to the specialization of the clinical facility, the pharmacology of carbapenems, as well as the impact of the pandemic on antibiotic use recorded (table 1).

Table 1: Average Monthly Carbapenem Distribution Quantities (Vials/Month) Across JRMS Hospitals (2020–2023)

Year	Drug	KHH	QAMH	PABH	QRH	PHCK
2020	Imipenem/Cilastatin 500mg	4838	4470	425	1195	430
	Meropenem 500mg	73	25	0	54	42
	Meropenem 1g	526	69	9	122	7
	Ertapenem 1g	102	22	9	8	57
2021	Imipenem/Cilastatin 500mg	3288	5013	302	362	272
	Meropenem 500mg	140	8	0	61	32
	Meropenem 1g	544	33	21	122	0
	Ertapenem 1g	132	16	4	6	91
2022	Imipenem/Cilastatin 500mg	3242	769	424	907	610
	Meropenem 500mg	50	39	50	51	27
	Meropenem 1g	500	24	58	158	0
	Ertapenem 1g	75	27	13	10	172
2023	Imipenem/Cilastatin 500mg	2340	1170	501	1128	719
	Meropenem 500mg	40	20	92	0	40
	Meropenem 1g	468	23	100	182	3
	Ertapenem 1g	41	21	10	20	58

Values represent average monthly quantities issued from JRMS central warehouses.

4. RESULTS AND DISCUSSION:

4.1 Network-Wide Trends and Hospital Totals: Imipenem/cilastatin 500mg vial dominated the distribution among facilities amid the five facilities in all four years. About 88.7% of the total network-wide carbapenem vials (11,358 of 12,823 average monthly vials combined) were imipenem/cilastatin vials in 2020 in the average monthly vials of the network. This dominance continued throughout 2023, but the proportion in the network was slightly reduced to around 79.5%, with increasing use of different types of carbapenems during the year. Table (2) shows the combined total carbapenem volume per facility per year for each of the four classes of drugs.

Table 2: Total Annual Carbapenem Vials per Hospital (All Drugs Combined, Average Monthly Units)

Year	KHH	QAMH	PABH	QRH	PHCK
2020	5539	4586	443	1379	536
2021	4104	5070	327	551	395
2022	3867	859	545	1126	809
2023	2889	1234	703	1330	820

Values represent the sum of all four carbapenem formulations per facility per year (average monthly units).

The most clinically challenging and acutely sick patients in the JRMS were referred to King Hussein Hospital (KHH) and this in 2020 was the largest carbapenem user within the network, at a combined average of 5,539 vials per month. Over the study period, a significant and positive decrease in carbapenem consumption in KHH was seen (47.8%, to 2,889 by 2023). This is probably due to incremental improvements in stewardship practice, better de-escalation on the basis of microbiological culture-based guidance and some therapeutic optimization at the network's major hospital.

The biggest inter-year change depicted by any facility was at Queen Alia Military Hospital (QAMH). From 4,586 total vials in 2020, QAMH's consumption rose to 5,372 in 2021—the pandemic year—then collapsed to 859 in 2022 and partially recovered to 1,234 in 2023. As with all general hospitals experiencing high levels of patients in the critical care unit (CCU) due to the COVID-19 pandemic, empirical broad-spectrum use increased in the 2021 peak, in keeping with a phenomenon well documented in other hospitals that the pandemic led to heightened use of broad-spectrum antibiotics for suspected bacterial co-infections, as well as overwhelmed health systems. (10). This huge drop of 84.0% from 2021 levels is the most likely explained by formulary restrictions or a formal stewardship change at QAMH that has been implemented and is having the desired effect as a result of the overuse pattern in 2021.

Prince Ali Bin Al-Hussein Military Hospital (PABH) has had persistently low volumes of carbapenems used from 443 average monthly vials during 2021, to 703 in 2023. Although these numbers are relatively small in absolute terms, the steady rise from 2021 to 2023 (58.7%) does merit attention as the burden of MDR nosocomial pathogens at a regional military general hospital may not be as heavy as at the tertiary and specialty ones. This trend could reflect the growing variety of services, the growing case-mix in the PABH catchment area, or may indicate that clinicians are starting to use empirical prescribing for carbapenems, which could be influenced by stewardship recommendations.

The total number of vials at Queen Rania Hospital for Children (QRH) decreased in 2021 by 60% to 551 from the 1,379 recorded in 2020, and it bounced back to 1,126 in 2022 and 1,330 in 2023. This reduction in elective in-patient visits for child health issues is associated with other reported reductions in elective pediatric inpatient admissions during COVID-19 lockdown periods (10,11), as well as the re-allocation of pediatric beds to COVID-19 care

and the decreased community transmission of pediatric pathogenic diseases during school closures. Throughout the recovery, the post-pandemic normalization of pediatric hospital services in the region are reflected.

Among all facilities, the utility of carbapenems at Prince Hussein Center for Kidney Diseases (PHCK) had the most gradual continuous growth over time, from total carbapenem consumption 536 in 2020 to 820 in 2023 for a 53% increase in carbapenem use after four years. A clinically relevant proportion of nephrology recipients are immunocompromised, such as renal transplant recipients and dialysis-dependent patients, who have significantly higher rates of MDR infections, including infections with ESBL-producing Enterobacterales. The rising numbers at PHCK may be attributable to growing numbers of transplant programs, increasing patient complexity, and possible trends in antibiotic use, such as the evolution of "resistance patterns" that lead to the escalation of previous antibiotics to the use of carbapenems.

4.2 Agent-Specific Distribution Patterns and Prescribing Preferences:

Consumption of meropenem 1g vials was highest and most stable at KHH throughout all the four years (526, 544, 500, and 468 vials/ month, respectively), reflective of continuing need for high intensity meropenem therapy in this most complex and tertiary center in the network. The steady, small yearly drop in KHH suggests a continuing falling trend of carbapenems and potentially another sign of incremental substitution of meropenem with more focused drugs if culture results are known. At QRH, in 2020-2022 Meropenem 1g was used almost regularly (122, 122, 158); the number of vials used increased in 2023 (182), which may be due to preference for the 1g formulation even in the pediatric setting, reflecting the typical weight-based dosing that occurs in older pediatric patients in higher body weights due to the complexity of infections encountered.

Volumes of meropenem 500mg were significantly lower and more varying between facilities. The use of meropenem 500mg at PABH increased from zero in 2020 and 2021 to 50 vials in 2022 and 92 vials in 2023, possibly due to both a newly introduced formulation to the PABH formulary or first prescription in 2022, coupled with quick take-up of the use. It would be clinically important to note that, at QRH, the 500mg vial would be the expected lower-dose pediatric formulation, however the distribution of 500mg vials, compared with 51 in 2022, was completely absent in 2023, which may be due to a change in the pediatric agent used for meropenem or to a formulary change, or an

alternative antibiotic may have been selected for use in children during this period.

The ertapenem distribution pattern provides the most clinically informative pattern within our data

set. Table 3 shows the percentage of total carbapenem used in each facility for ertapenem by year (table 3).

Table 3: Ertapenem as Percentage of Total Carbapenem Use per Facility and Year

Year	KHH	QAMH	PABH	QRH	PHCK
2020	1.8%	0.5%	2.0%	0.6%	10.6%
2021	3.2%	0.3%	1.2%	1.1%	23.0%
2022	1.9%	3.1%	2.4%	0.9%	21.3%
2023	1.4%	1.7%	1.4%	1.5%	7.1%

Values represent ertapenem Ig vials as a percentage of the combined total of all four carbapenem formulations per facility per year.

The highest ertapenem use was seen in the Prince Hussein Center for Kidney Diseases (PHCK) (where use of ertapenem increased from 10.6% of total carbapenems in 2020 to as high as 23.0% in 2021 and reduced to 7.1% in 2023). As a large number of nephrology centers this relatively high proportion of ertapenem susceptible Enterobacterales (ESBL-producers) in their Epidemiology and Control of Infection (ECI) reports is supported by pharmacologic reasons: renal transplant recipients are prone to ESBL-producing Enterobacterales (EPE) infections, mainly of the urinary tract, and ertapenem is an effective and evidence-based treatment option (12). Furthermore, the 1 x daily dosing of ertapenem provides practical benefit in step-down therapy of a stable transplant patient. The 2023 decrease in ertapenem use at PHCK, along with the largest share of vials of imipenem/cilastatin in that facility (719 vials) is indicative of the shift that might be occurring in this expanding patient population regarding treating more severe infections or treating more infections that involve *Pseudomonas* infections.

Contrary to this, the ertapenem proportions remained low in all the hospitals throughout the study period at Queen Alia Military Hospital (QAMH) ranging from 0.5% in 2020 to 1.7% in 2023. *P. aeruginosa* and *Acinetobacter baumannii* are bacteria that are inactive against ertapenem and they are more likely to cause nosocomial infections in QAMH, a general hospital for military inpatients, in areas like surgical wards and the intensive care unit. Considering the number of units used of each carbapenem at QAMH, showing an overwhelming preference for imipenem/cilastatin, this is likely in keeping with the expectation that anti-pseudomonal therapy is needed for the broad spectrum of the general hospital setting; however, the significantly

higher number of units used in 2021 encourages close monitoring of stewardship. KHH's frequent low ertapenem proportion (rounding 1.8–3.2%) is likewise suitable, indicating the facility's great number of nosocomial infections associated to broad spectrum anti-pseudomonal coverage. Another stewardship opportunity may be apparent in this low ertapenem use: stable patients who are proven to have infections due to ESBL Enterobacteriaceae at KHH might be treated with ertapenem and spare anti-pseudomonal carbapenems for higher acuity patients.

4.3 Impact of the COVID-19 Pandemic: A measurable and facility-specific impact on distribution patterns of carbapenems in the JRMS network occurred during the years of a pandemic (2020 – 2021). The most notable pandemic indicator is at the QAMH with utilization of imipenem/cilastatin rising from 4,470 average monthly vials in 2020 to 5,013 in 2021, an increase of 12.2%. In the pandemic's first wave, carbapenems use more than doubled in some ICU wards, and general hospitals mostly impacted by COVID-19 surges (ICU and surgical wards) are easier to be affected by this trend because of the empiric use of broad-spectrum antibiotics for suspected bacterial co-infections, high grade of severity and low capacity of infection control during the pandemic. Given that these factors all converge at QAMH, a substantial general military hospital, in some respects this may account for the larger spike in 2021.

The total number of carbapenems used in the system as a whole dropped, on average, from 12,823 vials per month in 2020 to 9,237 in 2021. It is worth noting, however, that this overall net decrease is due only to KHH's losses (5,539 to 4,104 vials), whereas the increase at QAMH partially compensated for the

losses at KHH. The extent of the difference shows how the use patterns observed at the facilities can differ from the trends observed in the network as a whole and demonstrates the need for analysis on the facility level as well as at the network level. By 2022 and 2023, most facilities exhibited post pandemic normalization, highlighting the most noticeable post pandemic adjustment at QAMH, which was a dramatic correction. The average monthly carbapenem counts (going from 12,823 to around 7,371) were encouraging in terms of stewardship activities between 2020 and 2023.

5. CONCLUSIONS:

This is a four-year retrospective study of distribution of carbapenems in five JRMS hospitals and specialty centers, which has shown a pattern of differential use, variations over time related to the pandemic, and preferences based on the specialty. These findings together contribute to valuable evidence to inform the development and improvement of antimicrobial stewardship programs in the JRMS.

Continuous monitoring is needed to conserve and enhance progress following a substantially increased usage of carbapenems that has been steadily declining over time in King Hussein Hospital, a very complex tertiary hospital. The most clinically relevant finding in the dataset was the extreme surge in antibiotic use that occurred in the second year of the pandemic followed by a dramatic correction in antibiotic usage post-pandemic, revealing the unprecedented antibiotic overuse that occurred during Pandemic year 2 in general military hospitals with active intensive care units (ICUs); this is important to highlight the significant impact that infectious disease crises have on hospitals with active ICU capacity as QAMH experienced, and thus requires an ASP framework that is resilient enough to maintain the stewardship functions during public health crises. The PHCK's elevated and clinically reasonable prescribing practices for ertapenem is the most premier example of specialist specialty -led prescribing, creating a model for a specialist carbapenem-sparing prescription strategy, which might also be operationalized in other specialized facilities dealing with infection with

most predominant ESBL Enterobacterales strains. PABH's trend of continual improvement upwards demands prospective monitoring to avoid inappropriate broad-spectrum (empirical) carbapenem usage in a regional general practice service, where hopefully less restricted other drugs could be used for many of these indications. QRH's 2021 drop and rebound are signs that the use of antibiotics among children in hospitals is sensitive to the impact of broader health system changes.

The findings have a number of significantly important stewardship implications. First, there is a wealth of data surrounding warehouse distribution of the JRMS but this data is largely limited and untapped. If these distribution records were analyzed and reported on regularly (sensitively, ideally every quarter), it would enable early detection of patterns of using that become concerning before these patterns can erode. Second, low proportions of ertapenem use in ESBL enterobacterales at both KHH and QRH suggest it may be an opportunity to implement protocols for reducing anti-pseudomonal carbapenems use that would encourage the use of ertapenem for infection with ESBL enterobacterales, without increasing resistance pressure, if the patient clinical status permits, at these facilities (3,5,12). Third, despite its better or equivalent spectrum, its merits with respect to CNS safety, and its evidence base use in nosocomial infection, meropenem continues to be used as a minor part of the carbapenem mix in most facilities, which suggests that drug utilization optimization might be accomplished through educating physicians and updating their prescribing guidelines, leading to a more evidence-aligned carbapenem mix (2,13). Fourth, there would be an overall advantage to the development of institution specific carbapenem prescribing guidelines, whereby the prescribing guidelines are also tailored to the infection epidemiology and patient cohorts of each individual institution. This study does provide a useful epidemiological base line for carbapenem use in the JRMS network, and supports formal antimicrobial stewardship program expansion and improvement of existing programs throughout JRMS facilities.

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CONFLICT OF INTEREST REPORTED: NIL; SOURCE OF FUNDING: NONE REPORTED