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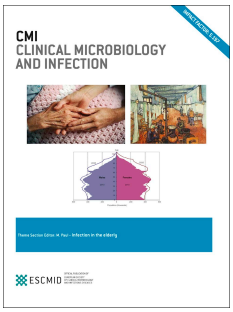

Clinical management of severe infections caused by carbapenem-resistant Gram-negative bacteria: a worldwide cross-sectional survey addressing the use of antibiotic combinations

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Abstract

Objectives: optimal treatment of carbapenem-resistant Gram-negative (CR-GNB) infections is uncertain due to the lack of good-quality evidence and the limited effectiveness of available antibiotics. The aim of this survey was to investigate clinicians' prescribing strategies for treating CR-GNB infections worldwide.

Methods: a 36-items-questionnaire was developed addressing the following aspects of antibiotic prescribing: respondent's background, diagnostic and therapeutic availability, preferred antibiotic strategies and rationale for selecting combination therapy. Prescribers were recruited following the snowball-sampling approach, and a post-stratification correction with inverse proportional weights was used to adjust the sample's representativeness.

Results: 1012 respondents from 95 countries participated in the survey. Overall, 298 (30%) of respondents had local guidelines for treating CR-GNB at their facility and 702 (71%) had access to Infectious Diseases consultation, with significant discrepancies according to country economic status: 85% (390/502) in High-Income-Countries vs 59% (194/283) in Upper-Medium-Income-Countries and 30% (118/196) in Lower-Middle-Income-Countries/Lower-Income-Countries). Targeted regimens varied widely, ranging from 40 regimens for CR-*Acinetobacter spp*. to more than 100 regimens for CR-Enterobacteriaceae. Although the majority of respondents acknowledged the lack of evidence behind this choice, dual combination was the preferred treatment scheme and carbapenem-polymyxin was the most prescribed regimen, irrespective of pathogen and infection source. Respondents noticeably disagreed around the meaning of 'combination therapy' with 20% (150/783) indicating the simple addition of multiple compounds, 42% (321/783) requiring the presence of *in vitro* activity and 38% (290/783) of *in vitro*-synergism**.**

Conclusions: management of CR-GNB infections is far from being standardized. Strategic public health focussed randomised controlled trials are urgently required to inform evidence-based treatment guidelines.

Introduction

In 2017, the World Health Organization (WHO) prioritized carbapenem-resistant Gram-negative bacteria (CR-GNB) *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and Enterobacteriaceae as species of critical importance for research and development of new and effective antibiotics. (1) Only a few new antibiotics with the potential to treat those bacteria have come to the market, and fewer still are in the later stages of their clinical development.(2) However, none of these new compounds have been tested in large randomized clinical trials enrolling patients with CR-GNB infections before their approval. Robust evidence of their effectiveness and superiority to conventional and available antibiotics still needs to be established.(2) Existing studies on the treatment of CR-GNB infections are

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mostly observational and limited by small sample sizes and the lack of adjustment for major confounders.(3-5) The few available guidance documents, although recognizing the low quality of the evidence, suggest that combination therapy might be superior to monotherapy when dealing severe infections. (6, 7) However, due to the very limited evidence, it is difficult to provide precise recommendations as to the specific antibiotic combinations that should be adopted for treating the possible clinical scenarios. In an era where the rational use of the few available antibiotics is of utmost importance, clinicians treating severe infections caused by CR-GNB have to make decisions on which antibiotics to use on a daily basis without the support of evidence-based recommendations and heterogeneous access to diagnostic and therapeutic resources.(8)

The main goal of this study was to conduct a cross-sectional survey to assess antibiotic prescribing patterns among clinicians worldwide with a particular focus on the use of combination therapy.

Methods

Target population and sampling

The target population of the survey was clinicians managing patients with severe infections caused by CR-GNB in their current practice (a minimum of 5 cases of any CR-GNB infection per year was set as a limit to participate in the survey). Participants were sampled from the target population in accordance with the 'snowball sampling' approach, which relies essentially on two key phases: *i)* the recruitment of a core sample of individuals having similar characteristics to the population target (a core-expert group of 99 prescribers selected from surveillance networks and scientific societies) and *ii)* the referral process**,** in which this group nominates, through various transmission routes, other individuals who meet the eligibility criteria.(9-11) The objective was to involve at least one representative from all the countries where diagnostic capabilities for detecting carbapenem-resistance are in place (the full process is detailed in Table S1a-S2).

Survey development, validation and distribution

The survey content was developed and validated in accordance with current guidelines on surveys in medical research.(12-16) The final questionnaire consisted of 36 open-ended, single and multiple-choice items addressing four major aspects of antibiotic prescribing: respondent's background, diagnostic and therapeutic availability, preferred antibiotic strategies and rationale for selecting combination therapy. The questionnaire was validated by experts from different geographic areas and disseminated via a *Survey Monkey* link (https://it.surveymonkey.com) during a 10 week period (the final questionnaire and details of the development and validation process are detailed in Fig S1 and Table S1b).

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Statistical analysis

Anonymous data were automatically entered by the survey software into an electronic database. Both complete and incomplete questionnaires were included for analysis. Results were expressed as frequency of responses for each question or as median with interquartile range (IQR), when appropriate. The number of total responses for each question item was used as denominator. Responses were computed overall or stratified by four subgroups of interest: WHO region; income category (in accordance with the 2019 World Bank Classification); patients' age (neonates: 0-1 month, children: >1 month- 14 years, adults: > 14 years); respondents' antibiotic prescribing frequency (low rate prescribers: from 1 to 4 cases per year; medium rate prescribers: from 5 to 20 cases per year, high rate prescribers: more than 20 cases per year). Between groups comparisons were computed using Chi-square and a two-sided p value <0·05 was regarded as significant. Data were analysed using STATA 15 (Statacorp LP, College Station, US). Figures were created using Python 3.7.3 and Matplotlib package v. 3.2.1.

To address the imbalance due to the non-probabilistic sampling method, a post-stratification correction was applied for pre-selected question items according to the respondent's country and hospital. In the post-stratification analysis, the weights were adjusted so that the totals in each group are equal to the known population totals.(17, 18)

Official submission to the Ethics Committee was deemed unnecessary because the participation into the survey was voluntary and anonymous.

Results

Respondents' characteristics

The survey was disseminated during a 10 week- period, from April 15th until June 28th 2019. In total 1012 respondents from 95 countries and 687 hospitals returned the questionnaire with an average completion rate of 86%. The distribution of respondents according to the four main categories is shown in Table 1. The majority of respondents were specialized in Infectious Diseases (548; 54%), were employed in tertiary level hospitals (810; 81%) and in teaching or university affiliated hospitals (859; 85%). The distribution of respondents by country and specialty is displayed in Table S3 and Figure S2.

Local prevalence of carbapenem resistance in GNB was reported with high variability among countries and among hospitals within the same country and, in some cases even within the same region. (Table S4). Overall, 20% (193/974) of respondents did not have data on local phenotypic drug resistance rates; the genotypic mechanism of resistance was not known by 32% (299/974) of respondents. Relative to CR-*Klebsiella pneumoniae*, the production

of serine-carbapenemases was the most frequent resistance mechanism in the American Region (93/203; 46%), while the production of metallo-beta-lactamases was the most common resistance mechanism in South East Asia (39/90; 43%) and Western Pacific Regions (34/77; 44%) (Table S5).

Availability of diagnostics, therapeutics, and treatment guidelines

Availability of antibiotics was heterogeneous across countries and, often, also within the same country. Gentamicin, trimethoprim-sulfamethoxazole (TMP-SMX), rifampin, amikacin, and carbapenems were available in more than 95% of the surveyed countries, regardless of the income. Carbapenems were placed under restrictive policies in 78% (32/41) of High-Income-Countries; in 89% (25/28) of Upper-Middle-Income-Countries and in 61% (16/26) of Lower-Middle-Income-Countries/Lower-Income-Countries. Colistin was available in 83% (79/94) of the surveyed countries, with restrictive policies in place in 90% (37/41) of HIC, 91% (25/28) of Upper-Middle-Income-Countries and 77% (20/26) of Lower-Middle-Income-Countries/Lower-Income-Countries. Among the drugs that most recently entered the market, ceftazidime/avibactam was available in 33% (32/94) of countries (26/41, 63% High-Income-Countries; 4/28, 14% Upper-Middle-Income-Countries and 2/26, 8% Lower-Middle-Income-Countries/Lower-Income-Countries). Less than 10 respondents had access to the most recently approved antibiotic compounds (meropenem/vaborbactam, eravacycline and plazomicin). Availability of antibiotics by country and income is detailed in Figures S3a-c.

Only 30% (298/981) of respondents reported that local guidelines for treating CR-GNB were available, with no significant difference according to income category (Table S6). Active Infectious Diseases consultation services were significantly more common among respondents from High-Income-Countries (390/582, 85%) compared to respondents from Upper-Middle-Income-Countries (194/283, 59%) and Lower-Middle-Income-Countries/Lower-Income-Countries (118/196, 30%) ($p < 0{\cdot}01$).

As for diagnostic resources, 77% (767/908) of respondents had access to standard susceptibility testing at a local level with no differences according to the income status. More complex diagnostics (MALDI-TOF and NAAT) were significantly more accessible in High-Income-Countries compared to Upper-Middle-Income-Countries and Lower-Middle-Income-Countries/Lower-Income-Countries (Table 2). As a direct consequence of this variability, the timing of diagnosis was considerably longer in low-resourced settings, with 23% (110/473) of respondents from those countries receiving blood cultures more than 72 hours after sampling, compared to only 7% (37/500) in High-Income-Countries (Table 3).

Prescribing strategies

Colistin and tigecycline were preferably prescribed in combination by 73% (492/671) and 71% (330/647) of respondents, followed by combination fosfomycin (53%; 244/463), ceftazidime/avibactam (45%; 145/333), polymyxin B (35%; 104/297) and gentamicin (34%; 264/770) (Table 4).

As for prescribing strategies, carbapenem loading dose and extended infusion were adopted more frequently by high rate prescribers compared to clinicians that dealt with CR-GNB infections less frequently. Similarly, higher dose tigecycline and loading dose of polymyxins and tigecycline, were significantly more frequent in the high rate prescribers group compared with the others ($p < 0{\cdot}01$ for all comparisons; Supplementary Table S7).

The decision to start an empiric coverage for CR-GNB was significantly more common in prescribers from High-Income-Countries and directly associated with patients' clinical severity. Local epidemiological data and/or individual risk factors played less of a role in driving the decision to start empiric coverage (Figure 1).

As for targeted therapy, the preferred strategy was the combination of two antibiotics (between 35% and 45% of respondents depending on sepsis sources or bacterial species). The use of single-antibiotic therapy was second in preference, especially for CR *Acinetobacter spp.* And CR *Pseudomonas spp.* (23-37% and 26-35% of respondents, respectively, depending on the sepsis source). A combination of three antibiotics was regarded as the preferred strategy by a lower number of respondents (15-20% depending on sepsis sources or pathogen type). Full results on preferred therapeutic choices are displayed in Tables S8-S10.

When considering the components in the targeted combination regimens, respondents selected an extremely wide spectrum of distinct combinations. The number of regimens ranged from 40 regimens in CR *Acinetobacter spp*. To more than 100 regimens in CR Enterobacteriaceae. Overall, the combination "carbapenem *plus* a polymyxin" was the most prescribed option for treating sepsis, irrespective of bacterial species or sepsis source (full results on targeted treatment are presented in Figures S4a-c and Tables S11-S13).

Only 80 responses were available regarding treatment options in children and neonates; similar to the adult population, the most commonly prescribed treatment among children was "carbapenem *plus* polymyxin". Full data on pediatric population are available in the supplementary material (Table S14-S16).

The concept of 'combination therapy'

The main reasons leading to the prescription of combination treatment were to improve clinical efficacy (570/707; 81% of respondents) and to reduce resistance development (364/707; 51%) (Figure S5). According to 80% of respondents (611/783), 'combination therapy' must include antibiotics which retain some degree of *in vitro* activity (321/783; 42% of respondents) or be synergic (290/783; 38% of respondents). Twenty percent of respondents

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(150/783) conceived 'combination therapy' as the simple association of two or more antibiotic compounds, regardless their potential *in vitro* activity (Table S17).

Type of evidence supporting the use of combination therapy included: experts' recommendations (62%; 486/777), evidence from randomized controlled trials (37%; 285/777), evidence from *in vitro* studies (36%; 277/777), controlled observational studies (34%; 264/777) and personal experience (29%; 224/777) (Figure S6).

Discussion

Our results showed that the treatment of CR-GNB infections is far from being standardized and clinicians over the world use a wide range of antibiotic strategies and combinations depending on clinical severity, local availability and clinical experience. Of interest, empiric coverage for CR-GNB was driven mostly by the severity of the clinical scenario and more commonly prescribed in High-Income-Countries compared to lower resourced settings. As for targeted treatment, the majority of respondents opted for a double-antibiotic combination (most commonly polymyxin plus carbapenem) despite the lack of evidence supporting this indication.

Access to rapid diagnostics and recently approved antibiotics was inversely correlated with country economic status. Gentamicin, amikacin and TMP-SMX were the most accessible compounds worldwide, while new BL/BLIs and also older antibiotics such as colistin and polymyxin B were available in less than 50% of the surveyed countries. Our results confirmed that not only high-priced newer drugs are very rarely accessible, but also off-patent drugs can encounter supply shortages since manufacturing costs are not compensated by the low sale-price.(19) A survey conducted by the European Society of Clinical Microbiology and Infectious Diseases (ESCMID) revealed that there was a reduction in access to 'old antibiotics' in the United States, Europe and Australia from 2011 to 2015.(20) Similar data collected in Lower-Middle-Income-Countries found that access to 'old antibiotics' was very limited even in countries with high rates of antibiotic resistance.(21)

Up to 80% of respondents from High-Income-Countries favoured empirical coverage for CR-GNB in presence of severe clinical condition and epidemiological risk factors. Conversely, confronted with the same clinical scenario, only half of respondents from Lower-Middle-Income-Countries/Lower-Income-Countries opted for empirical coverage of CR-GNB. The main reason of this significant discrepancy probably resides in the lack of viable therapeutic options in those countries, in line with the most recent findings revealing that early coverage with colistin does not provide any benefit on survival in presence of severe CR-GNB infections.(22)

As for targeted treatment, despite the overall preference for dual antibiotic therapy, a notable portion of prescribers still opt for monotherapy when dealing with microbiologically documented CR-GNB infections. The choice of

monotherapy could either reflect the actual lack of evidence supporting specific combinations or the absence of other viable options due to concomitant resistance, drug toxicity or local unavailability.

Despite the relatively low percentage of paediatricians and neonatologists contributing to the survey (8.5%), a significant heterogeneity of prescribing patterns was identified also in this patients' population. A similar lack of standardization has been already observed in two global point prevalence surveys, where almost 200 different antibiotic regimens were used for treating sepsis in children and neonates.(23),(24)

Overall, 80% of prescribers agreed that the main aim of combination therapy is to improve therapeutic efficacy, while 50% supported the use of combination for reducing resistance development or promoting microbiological eradication when compared to monotherapy. The majority of prescribers seemed to recognize that the use of combination therapy for treating CR-GNB infections comes from "expert" recommendations and that the supporting evidence is very poor and of low quality, being composed almost exclusively of observational and *in vitro* studies. Interestingly, approximately one third of respondents believed that the use of combination therapy is supported by RCTs, although valid examples in the literature are scarce.(25) A even much higher rate of prescribers sharing this same misconception have been also observed in a similar survey on management of CR-GNB infections in Europe and US in 2017. In this study, up to 55% of respondents declared that combination therapy is supported by a strong level of evidence.(26)

Finally, it is notable that the concept of 'combination therapy' had a different meaning among respondents, with 42% indicating 'combination of *in vitro* active drugs', 38% indicating 'combination of *in vitro* synergistic drugs' and 20% indicating 'combination of two or more drugs, regardless the *in vitro* activity'. Disagreement among respondents clearly reflects the lack of a standardized definition for 'combination therapy' also in clinical studies, with the result that there can be a misinterpretation and poor generalizability of study results.(27)

Although the referral process allowed the rapid recruitment of respondents from areas of the world that are usually difficult to access, the use of a non-probabilistic sampling method remains a main limitation of this study. Our sampling process started from surveillance networks in order to track and filter hospitals and countries having the minimum standard needed for diagnosing CR-GNB infections. Therefore, we may have missed countries and hospitals in which microbiological diagnosis is made with an acceptable degree of standardization, but without active surveillance systems, particularly in LMIC/LIC and non-English speaking countries. Additionally, it should be considered that individuals embedded in a network have greater probabilities of being identified and accessed

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than others, with risk of over-representing certain prescribers. For this reason, a post-stratification correction with inverse proportional weighting was applied to mitigate the risk of oversampled countries and hospitals.

In conclusion, we recorded a huge variability in the management of severe CR-GNB infections among over one-thousand clinicians worldwide. Unequal access to diagnostic and therapeutic resources and the unavailability of evidence-based recommendations were two strong determinants contributing to this heterogeneity. Additionally, the lack of a universally accepted definition of 'combination therapy' might have further impaired the confidence in results from available clinical studies. These results demonstrate the urgent need for public health focussed strategic randomised controlled trials with the involvement of Low and Low-Middle-Income-Countries. International guidelines will be able to inform decision-making only when results from adequately conducted RCTs will be available.

Role of the funding source

GARDP supported the entire project, GARDP secondee (LJVP) and employees contributed to study design, data interpretation, and writing of the manuscript. All authors had full access to data and had final responsibility for the decision to submit for publication.

Contributors

ET and LJVP conceived the idea for this project. EC, AS, SE, FF, LJVP and ET designed the study. AS, EC, AG contributed to the data analysis and synthesis. AS and EC wrote the paper. All authors contributed to the survey development, pilot phase, revision of the paper and approval of the final version for submission. All authors had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Declaration of interests

AS, EC, AG, GLH, ER, CT, AR, HZ, CG, AJB and ET have no competing interests to be declared. SE, FF and LJVP are employed by GARDP. PNAH declares research grants outside the submitted work from Sandoz, Shionogi and MSD and speakers' fees from Pfizer.

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Table 1: Number of respondents stratified by the four subgroups of interest

WHO region	**Respondents, n (%)**
Africa	64 (6·0)
Americas	205 (20·5)
Eastern Mediterranean	116 (11·5)
Europe	444 (44·0)
South East Asia	95 (9·3)
Western Pacific	88 (8·7)
Total	**1012 (100)**
Patients' age	**Respondents, n (%)**
Adults	867 (85·6)
Pediatric population	145 (14·3)
- Children	- 110 (10·9)
- Neonates	- 35 (3·5)
Total	**1012 (100)**
Income category	**Respondents, n (%)**
High income countries	512 (50·6)
Upper-Middle income countries	296 (29·2)
Lower -Middle income/Low income countries	204 (20·1)
Total	**1012 (100)**
Prescribing frequency*	**Respondents, n (%)**
Low rate prescribers	257 (25·4)
Medium rate prescribers	416 (41·1)
High rate prescribers	283 (28·0)
Not specified	56 (5·5)
Total	**1012 (100)**
*low rate prescribers: from 1 to 4 cases per year; medium rate prescribers: from 5 to 20 cases per year, high rate prescribers: more than 20 cases per year	

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Table 2: Availability of diagnostic tools for detecting CR-GNB in blood cultures

Diagnostic tool **% (N)**	**HIC** **45·8 (N 469)**	**UMIC** **26·3 (N 268)**	**LMIC/LIC** **27·9 (N 171)**	**Overall** **N 908**	**P value**
Standard AST	75·2 (373)	82·6 (238)	76·3 (156)	77·5 (767)	NS
MALDI-TOF	58·8 (277)	17·7 (61)	2·8 (15)	32·4 (353)	<0·001
Rapid phenotypic test from blood isolates	32·3 (142)	21·1 (61)	1·5 (15)	20·8 (218)	<0·001
NAAT - **in all CR-GNB strains** - **only in selected cases**	47·2 (217) 26·6 (157) 20·6 (60)	15·4 (45) 6·4 (16) 9·1 (29)	9·6 (21) 5·8 (11) 3·7 (10)	28·4 (283) 15·5 (184) 12·9 (99)	<0·001 <0·001 0·008
Internal testing facilities NOT available	5·3 (34)	14·0 (38)	21·7 (25)	10· 6 (97)	<0·001

Frequencies of positive responses are presented as percentages of the total of responses from each income category after adopting post-stratification correction by hospital and country; n: number of respondents. AST: Antimicrobial susceptibility test; NAAT: nucleic acid amplification testing; NS: non-significant; HIC: High income countries, UMI: Upper-Middle income countries; Lower -Middle income/Low income countries

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5 **Table 3: Time needed by laboratories to inform on the positivity of blood cultures**

Time to positive blood cultures	**Income category % (n) of country**			P value
	HIC 51·5 (N 500)	**UMI 27·2 (N 282)**	**LMI/LIC 25·3 (N 191)**	
Within 36 hours	41·2 (172)	21·6 (70)	20·8 (51)	0·01
Within 48 hours*	73·2 (349)	40·0 (139)	42·5 (93)	<0·001
Within 72 hours*	80·1 (463)	52·0 (224)	59·8 (139)	<0·001
Within 96 hours*	99·1 (494)	91·8 (260)	80·4 (174)	<0·001
More than 96 hours	0·9 (6)	8·2 (22)	19·6 (17)	<0·001
Frequencies of positive responses are presented as cumulative percentages within each time interval using the total of responses from each income category as a denominator and applying post-stratification correction by hospital and country; HIC: High Income countries, UMI: Upper-Middle income countries; Lower -Middle income/Low income countries				

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7 **Table 4: Antibiotic compounds always prescribed in combination by respondents**

Prescribing frequency	I prescribe combination very rarely	Meropenem /vaborbactam	Ceftazidime/ avibactam	Ceftolozane/ tazobactam	Plazomicin	Eravacycline	Aztreonam
	N (%)	C/A (%)	C/A (%)	C/A (%)	C/A (%)	C/A (%)	C/A (%)
High rate prescriber	11/255 (4.3)	0/4 (0)	39/86 (45.3)	26/93 (28.0)	1/3 (33.3)	0/2	28/100 (28.0
Medium rate prescriber	29/321 (9.0)	7/19 (36.8)	72/146 (49.3)	47/151 (31.1)	0/3 (0.0)	0/4	37/139 (26.6)
Low rate prescriber	68/209 (32.5)	4/23 (17.4)	34/101 (33.7)	21/100 (21.0)	2/6 (33.3)	2/6 (33.3)	24/117 (20.5)
Overall	108/785 (13.7)	11/46 (23.9)	145/333 (45.3)	94/344 (27.3)	3/12 (25)	2/12 (16.7)	89/356 (25)
P value	<0.001	NP	0.047	NP	NP	NP	NP
Prescribing frequency	Gentamicin	Tobramycin	Amikacin	Tigecycline	Polymyxin B	Colistin	Fosfomycin (IV)
	C/A (%)	C/A (%)	C/A (%)	C/A (%)	C/A (%)	C/A (%)	C/A (%)
High rate prescriber	81/250 (32.4)	17/132 (12.9)	119/248 (48.0)	132/228 (57.9)	45/99 (45.5)	191/230 (83.0)	98/162 (60.5)
Medium rate prescriber	109/315 (34.6)	26/176 (14.8)	173/307 (56.4)	61/263 (23.2)	41/121 (33.9)	212/281 (75.4)	105/188 (55.9)
Low rate prescriber	74/205 (36.1)	37/137 (27.0)	102/187 (54.5)	137/156 (87.8)	18/77 (23.4)	89/160 (55.6)	41/113 (36.3)
Overall	264/770 (34.2)	80/445 (17.9)	394/742 (53)	330/647 (70.6)	104/297 (35)	492/671 (73)	244/463 (52.7)
P value	NP	0.004	NP	<0.001	0.009	<0.001	<0.001

Legend: C: always in combination; A: number of respondents with available agent; NP: not performed (less than five respondents contributed to the analysis)

The results are presented as proportions and stratified by prescribing frequency. As denominator, only the number of respondents declaring the availability of the antibiotic compounds were considered. The statistical significance was computed only if more than five respondents contributed to the analysis.

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10 **Figure 1**: **Percentage of respondents who are likely to cover empirically for CR-GNB according to different**

11 **clinical, epidemiological/microbiological factors and stratified by country-income**

12

(%) OF RESPONDENTS			CLINICAL FACTORS			
			Clinically stable/ No risk factor for immunodepression	Clinically stable/ Risk factors for immunodepression	Worsening clinical conditions (empirical therapy not covering CR-GNB)	Septic shock
EPIDEMIOLOGICAL/MICROBIOLOGICAL FACTORS	Known colonization in ANY site	HIC	8·1	32·7	80·6	70·2
		UMIC	4·3	26·4	66·6	63·4
		LMIC/LIC	2·3	35·5	50·1	43·7
		p value	NS	NS	0·003	0·02
	The Infection originates from a known colonized site	HIC	28·0	55·0	83·1	67·9
		UMIC	14·8	46·9	74·1	62·8
		LMIC/LIC	26·9	36·0	40·6	42·6
		p value	NS	NS	< 0·001	0·03
	Recent admission in a highly-endemic hospital (<90 days)	HIC	7·6	64·3	67·2	66·8
		UMIC	6·3	29·8	65·7	62·7
		LMIC/LIC	6·0	38·7	49·1	36·4
		p value	NS	NS	NS	0·005
	Recent travel in a highly-endemic country (<90 days)	HIC	4·7	26·2	58·7	57·1
		UMIC	4·6	18·3	62·1	58·7
		LMIC/LIC	9·3	18·2	43·7	31·1
		p value	NS	NS	NS	0·01
	Recent exposure to carbapenem (<90 days)	HIC	5·9	23·0	56·0	55·3
		UMIC	5·4	27·2	66·4	50·1
		LMIC/LIC	3·9	15·8	44·0	61·3
		p value	NS	NS	NS	NS
	Preliminary identification highly suggestive of CR-GNB	HIC	25·6	60·5	81·0	70·5
		UMIC	24·8	45·9	81·2	70·9
		LMIC/LIC	13·2	46·7	58·0	41·0
		p value	NS	NS	0·006	0·003
	Positive rapid susceptibility tests i.e. NAAT, carba-NP*	HIC	54·6	68·3	63·5	62·7
		UMIC	30·9	53·6	67·4	65·5
		LMIC/LIC	0·0	30·4	69·5	54·3
		p value	NS	NS	NS	NS

Abbreviations: HIC: high income countries; UMIC: upper-middle income countries; LMIC: lower-middle income countries; LIC: low income countries; NAAT: nucleic acid amplification testing; NS: not statistically significant.
*Number of respondents for denominator are 215 (only the respondents declaring that their labs can perform rapid tests for CR-GNB).
The results are presented as weighted proportions after adopting post-stratification correction according to hospital and country. The likelihood of empiric coverage for CR-GNB is divided into four thresholds and graphically represented according to this color scale: < 15% | 15-30% | 31-50% | > 50%

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