Journal of Global Antimicrobial Resistance 25 (2021) 209–221

Contents lists available at ScienceDirect

Journal of Global Antimicrobial Resistance

journal homepage: www.elsevier.com/locate/jgar

Review

Prevalence and molecular epidemiology of carbapenem-resistant Gram-negative bacilli and their resistance determinants in the Eastern Mediterranean Region over the last decade

Ahmad Sleiman[a,b,c,1], Antoine G. Abou Fayad[a,b,c,1,*], Hanin Banna[a,b,c], Ghassan M. Matar[a,b,c,*]

[a] Department of Experimental Pathology, Immunology and Microbiology, Faculty of Medicine, American University of Beirut, Beirut, Lebanon
[b] Center for Infectious Diseases Research, American University of Beirut, Beirut, Lebanon
[c] World Health Organization (WHO) Collaborating Center for Reference and Research on Bacterial Pathogens, Beirut, Lebanon

ARTICLE INFO

Article history:
Received 7 September 2020
Revised 5 January 2021
Accepted 28 February 2021
Available online 1 April 2021

Editor: S. Stefani

Keywords:
Carbapenem resistance
Enterobacteriaceae
Acinetobacter baumannii
Pseudomonas aeruginosa

ABSTRACT

Carbapenem resistance in Enterobacteriaceae, *Acinetobacter baumannii* and *Pseudomonas aeruginosa* is increasing worldwide, which has led the World Health Organization (WHO) to list these bacteria in the critical priority pathogens group. Infections by such pathogens pose a serious threat to hospitalised patients and are associated with clinical and economic consequences. What worsens the case is the weak pipeline of available antimicrobial agents to treat such infections and the absence of new drugs. The aim of this review was to shed light on all studies tackling carbapenem resistance in Enterobacteriaceae, *A. baumannii* and *P. aeruginosa* in the Eastern Mediterranean region, with indication for each country, description of studies timeline, prevalence of carbapenem resistance, and carbapenem resistance-encoding genes detected in these countries.

1. Introduction

Antimicrobial resistance in Gram-negative bacilli has been increasing worldwide in the last decade, accompanied by a lack of available functional antimicrobial agents and the absence of novel ones. Such resistance is associated with significant clinical and economic consequences, including longer hospital stay, higher antimicrobial and hospital costs, and increased mortality rates [1,2].

In the World Health Organization's (WHO's) Global Priority Pathogens List, carbapenem-resistant *Acinetobacter baumannii* (CRAB), carbapenem-resistant *Pseudomonas aeruginosa* (CRPA) and carbapenem-resistant Enterobacteriaceae (CRE) were listed in the critical priority pathogens group. This indicates the urgent need to develop novel antimicrobials to combat the spread of resistance and to overcome the severity of nosocomial infections, knowing that they are causative agents in one-third of acute-care nosocomial infections. CRAB is the most prevalent carbapenem-resistant organism worldwide associated with hospital-acquired infections, followed by CRPA [1,3]. Moreover, increased mortality has been associated with carbapenem-resistant Gram-negative bacteria compared with carbapenem-susceptible isolates [1].

Among the CRE, carbapenem-resistant *Klebsiella pneumoniae* is the most prevalent species, in which expression of carbapenemase genes such as $bla_{\text{OXA-48}}$, bla_{NDM} and others determines its resistance, in addition to resistance mechanisms due to other β-lactamases, outer membrane impermeability and efflux pumps [4]. Carbapenem resistance in *A. baumannii* reported coexisting mechanisms, with the major mechanism being expression of β-lactamases especially carbapenemases encoded by $bla_{\text{OXA-51}}$ and $bla_{\text{OXA-23}}$ that are unique to *A. baumannii*, in addition to permeability and target modifications [5]. On the other hand, carbapenem resistance in *P. aeruginosa* is mainly due to permeability modification, in addition to the contribution of carbapenemases and overexpression of efflux pumps [6]. In 2018, Moghnieh et al. published a review discussing third-generation cephalosporin-

* Co-corresponding authors. Mailing address: DTS Building, Second Floor, Room 215-B, American University of Beirut, Beirut, Lebanon. Tel.: +961 1 350 000 ext. 4938 (A.G. Abou Fayad); DTS Building, Second Floor, Room 229, American University of Beirut, Beirut, Lebanon. Tel.: +961 1 350 000 ext. 5128 (G.M. Matar).
E-mail addresses: aa328@aub.edu.lb (A.G.A. Fayad), gmatar@aub.edu.lb (G.M. Matar).
[1] These two authors should be considered joint first authors.

https://doi.org/10.1016/j.jgar.2021.02.033

Fig. 1. Geographic distribution of the countries listed in the Eastern Mediterranean region [193].

resistant Enterobacteriaceae, CRE, CRPA, CRAB, fluoroquinolone-resistant *Salmonella* spp., methicillin-resistant *Staphylococcus aureus* (MRSA) and penicillin-non-susceptible *Streptococcus pneumoniae* in the countries of the Arab League [7]. However, in the current review our aim is to highlight carbapenem resistance in Enterobacteriaceae, *A. baumannii* and *P. aeruginosa* in the Eastern Mediterranean Region (Fig. 1), including a full description of the studies timeline, prevalence of carbapenem resistance, and the molecular epidemiology of resistance-encoding genes in each country.

2. Methodology

A systematic literature review was performed using the PubMed, Scopus and Google Scholar databases to identify studies and articles discussing carbapenem resistance in Enterobacteriaceae, *A. baumannii* and *P. aeruginosa* in the Eastern Mediterranean Region. Moreover, the selection criteria of literature were based on selecting articles published in peer-reviewed journals between January 2010 and August 2020.

3. Carbapenem-resistant Enterobacteriaceae

3.1. Lebanon

The year 2008 witnessed the isolation of the first β-lactamase-mediated carbapenem resistance in Enterobacteriaceae in Lebanon, where a *K. pneumoniae* harbouring the $bla_{\text{OXA-48}}$ gene was isolated [8]. In 2012, 102 (1.2%) of 8717 Enterobacteriaceae isolates were carbapenem-resistant, and 31 (70.5%) of the 44 tested isolates harboured the $bla_{\text{OXA-48}}$ gene [9]. Furthermore, in a study in 2014 aimed at determining the prevalence of intestinal carriage of carbapenem-resistant bacteria in cancer patients receiving chemotherapy at a hospital in Tripoli, 9 (22.0%) of the 41 patients tested were carriers of CRE [10]. In another study, of 130 isolates (76 *Escherichia coli* and 54 *K. pneumoniae*) collected between 2008–2014 at a tertiary-care centre, 36% harboured the $bla_{\text{OXA-48}}$ gene and 24% harboured the $bla_{\text{NDM-1}}$ gene. Moreover, the prevalence of CRE at this centre increased from 0% in 2008 to 1% in *E. coli* and 4% in *K. pneumoniae* [11]. A CRE prevalence of 3% was detected between 2015–2016 in a study analysing antibiotic susceptibility data from 13 hospitals [12]. Over the period 2015–2017, a total of 6103 Gram-negative isolates were recovered from two hospitals located in the north of the country. Antimicrobial susceptibility testing results showed that the prevalence of CRE increased from 1.7% in 2015 to 1.71% in 2016 and 5.19% in 2017 [13]. Moreover, several studies were performed at the molecular level on either one or a small group of CRE isolates and the data have shown a wide variety of carbapenem resistance genes detected in these isolates, including $bla_{\text{OXA-181}}$ [14], $bla_{\text{NDM-5}}$ [15] and $bla_{\text{NDM-7}}$ [16].

3.2. Egypt

In 2013, a study at Cairo University Hospital aimed to characterise carbapenem resistance genes among Gram-negative bacilli isolated from patients in the intensive care unit (ICU). Of the 111 Enterobacteriaceae isolates, 14 (12.6%) were CRE, of which 9 (64.3%) harboured the $bla_{\text{OXA-48}}$ gene and 4 (28.6%) harboured the $bla_{\text{NDM-1}}$ gene [17]. In the same year, 12 isolates (11.3%) were reported as CRE among 106 Enterobacteriaceae isolates recovered from retail chicken meat samples, and the bla_{NDM} gene was harboured by all 12 isolates [18]. In a study performed between 2013–2015, 42 (19.5%) of 215 Gram-negative bacteria collected from patients admitted to the department of general surgery at Sohag University Hospital were CRE [19]. Moreover, between 2014–2016, a total of 171 Enterobacteriaceae isolates were obtained from the bacteriology unit of a cancer centre and a worrying 113 isolates (66.1%) were recorded as CRE. Genotypic testing of 32 isolates revealed the presence of $bla_{\text{OXA-48}}$, bla_{NDM}, bla_{VIM} and bla_{KPC} genes [20]. Between September 2015 and February 2016, a study was performed aiming to evaluate faecal colonisation by CRE in children admitted to Cairo University paediatric ICUs, which led to the collection of 413 Enterobacteriaceae isolates. Of these isolates, 100 (24.2%) were CRE, and the $bla_{\text{OXA-48}}$ gene was detected in 33% of these isolates while 27% were shown to harbour the $bla_{\text{NDM-1}}$

gene [21]. Moreover, 135 Enterobacteriaceae isolates were recovered from patients admitted to several cancer institutes in Cairo between 2016–2017. In total, 93 (68.9%) of these isolates were CRE and genotypic analysis revealed that bla_{NDM} was the most prevalent gene, followed by bla_{OXA-48}, bla_{OXA-23} and bla_{KPC} [22]. In 2017, 30 (30.0%) of 100 Enterobacteriaceae isolates collected from patients admitted to Egypt Children's Hospital were CRE. The most dominant gene in these 30 CRE isolates was bla_{VIM} (90%), followed by bla_{NDM-1} (23.3%) and bla_{KPC} (10%) [23]. An epidemiological study was performed to determine the prevalence of CRE between 2011–2017 in ICUs of Egyptian hospitals reporting to the national healthcare-associated infections surveillance system. In this period, 871 (54.5%) of the 1598 Enterobacteriaceae isolates reported were CRE [24]. Furthermore, several studies were performed that led to the identification of the following genes: $bla_{OXA-163}$ [25]; $bla_{OXA-181}$ [26]; bla_{NDM-5} [26,27]; bla_{VIM-2} [28]; bla_{VIM-4} [29]; and bla_{IMP-4} [28].

3.3. Saudi Arabia

In 2012, a total of 1870 Enterobacteriaceae isolates were recovered from patients in King Khaled General Hospital, 82 (4.4%) of which were CRE [30]. Between 2012–2015, a study was performed at Al-Noor Specialist Hospital in Makkah City to determine the prevalence of carbapenem resistance among Gram-negative bacteria. In total, 2159 Enterobacteriaceae isolates were collected, of which 515 (23.9%) were CRE. Furthermore, the yearly detailed prevalence of CRE was 144 (18.9%) in 2013, 184 (26.9%) in 2014 and 187 (26.2%) in 2015 [31]. In 2015, 15 (5.8%) of 260 *K. pneumoniae* isolates collected from five different hospitals in Makkah were CRE [32]. In 2017, 26 (21.7%) of 120 Enterobacteriaceae isolates recovered from four tertiary-care hospitals in Makkah were CRE. Moreover, genotypic testing results led to the detection of bla_{OXA-48}, bla_{NDM-1} and bla_{KPC} genes distributed among the isolates [33]. Furthermore, the bla_{VIM} [34] and bla_{VIM-4} [35] genes were detected in other studies.

3.4. Tunisia

Between 2012–2014, a total of 1095 *K. pneumoniae* isolates were obtained from Sahloul Hospital. Of these isolates, 240 (21.9%) were CRE and the bla_{OXA-48} gene was the most commonly detected in these isolates, followed by bla_{NDM-1} and $bla_{OXA-204}$ [36]. Moreover, over the same period, 342 (15.8%) of 2160 *K. pneumoniae* isolates tested were CRE [37]. Between 2015–2016, a total of 220 *K. pneumoniae* isolates were recovered from Tahar Sfar University Hospital, of which 29 (13.2%) were CRE, and genotypic testing revealed that bla_{OXA-48} was the most prevalent gene, followed by bla_{NDM-1} and $bla_{OXA-204}$ [38]. Furthermore, several other carbapenem resistance genes were detected in other studies in Enterobacteriaceae, including bla_{VIM} [39], bla_{VIM-1} [40], bla_{VIM-2} [41], bla_{VIM-4} [42], bla_{KPC} [39], bla_{KPC-2} [43,44], bla_{KPC-3} [44,45], bla_{IMP-1} [46], bla_{IMP-8} [47], bla_{IMP-10} [47] and bla_{IMP-13} [47].

3.5. Iran

Between 2012–2013, 49 (43.8%) of 112 *K. pneumoniae* isolates recovered in a hospital were CRE, and 6 (12.2%) of these isolates harboured the bla_{NDM-1} gene [48]. In 2014, a total of 307 Enterobacteriaceae isolates were collected from five different hospitals and 27 (8.8%) of these were CRE. Moreover, genotypic testing results revealed that bla_{OXA-48} was the most commonly encountered gene, followed by bla_{NDM-1}, bla_{KPC-2} and bla_{KPC-3} [49]. Between 2015–2016, a total of 992 *K. pneumoniae* isolates were recovered from patients admitted to Tehran Imam Khomeini Hospital, of which 100 (10.1%) were CRE, and genotypic testing results revealed that bla_{OXA-48} gene was the most prevalent gene, followed by bla_{NDM} [50]. Over the same period, 11 (6.5%) of 170 *K. pneumoniae* isolates collected from three teaching hospitals were CRE, and bla_{NDM-1} was the only detected gene in 4 of the CRE isolates [51]. Between 2015–2017, 37 (21.1%) of 175 *K. pneumoniae* isolates collected from four different hospitals were CRE, and bla_{NDM-1} was the only detected gene in these isolates [52]. Furthermore, several studies were performed that led to the identification of $bla_{OXA-181}$ [53], bla_{NDM-7} [53,54], bla_{VIM} [55], bla_{VIM-1} [56] and bla_{IMP} [55] genes.

3.6. United Arab Emirates

Between 2011–2012, 4 (1.7%) of 230 Enterobacteriaceae isolates collected from a hospital in Abu Dhabi were CRE and all were demonstrated to harbour the bla_{OXA-48} gene [57]. Over the same period, 13 (6.4%) of 202 *K. pneumoniae* isolates collected from Al-Qassimi Hospital were CRE, and bla_{NDM-1} was the most commonly detected gene in these isolates, followed by bla_{OXA-48} [58]. Between 2015–2016, a total of 13 025 Enterobacteriaceae isolates were recovered from five hospitals in Dubai, of which 599 (4.6%) were CRE. Among the isolates selected for genotypic testing, bla_{OXA-48} was the most prevalent gene, followed by bla_{NDM} [59]. Moreover, $bla_{OXA-181}$ [60], bla_{NDM-5} [60], bla_{NDM-7} [61], bla_{VIM-4} [62] and bla_{KPC} [63] genes were detected in other studies.

3.7. Qatar

In 2017, a total of 201 extended-spectrum β-lactamase (ESBL)-producing Enterobacteriaceae isolates were recovered from children hospitalised with lower urinary tract infection at the Pediatric Emergency Center of Hamad Medical Corporation, Doha. Of these isolates, 2.5% were resistant to both ertapenem and meropenem and 10% were resistant to imipenem [64].

3.8. Iraq

In 2018, a total of 57 Enterobacteriaceae isolates were recovered from specimens of infected burns or wounds from three different hospitals located in Baghdad, of which 8 (14.0%) were CRE, and the bla_{IMP} gene was harboured by 7 isolates [65]. In the same year, 11 (22.0%) of 50 *K. pneumoniae* isolates recovered from hospitalised patients in hospitals in Al-Anbar City were CRE. Genotypic testing on six CRE isolates revealed that the bla_{OXA-48} and bla_{VIM} genes were equally detected in these isolates, followed by bla_{KPC} [66]. Moreover, bla_{OXA-23} [67], bla_{NDM-1} [68], bla_{IMP-1} [67] and bla_{VIM-2} [69] were detected in other studies in Enterobacteriaceae isolates.

3.9. Kuwait

Between 2011–2013, 66 (4.9%) of 1335 Enterobacteriaceae isolates collected from nine hospitals were CRE, and only 11 harboured the bla_{OXA-48} gene [70]. In 2014, a total of 764 Enterobacteriaceae isolates were recovered from patients from four different hospitals, of which 61 (8.0%) were CRE, and bla_{NDM-1} was the most commonly detected gene, followed by bla_{OXA-48} and bla_{KPC} [71]. Furthermore, the bla_{VIM-4} gene [72,73] was detected in two studies in Enterobacteriaceae isolates.

3.10. Libya

Between 2013–2014, 55 (6.8%) of 813 Enterobacteriaceae isolates recovered from patients admitted to Tripoli Children Hospital were CRE [74]. Between 2014–2015, 14 (29.2%) of 48 multidrug-resistant Enterobacteriaceae isolates were CRE, with bla_{OXA-48} being the most prevalent gene, followed by bla_{NDM} [75].

3.11. Morocco

Between 2010–2011, a total of 1174 uropathogenic *E. coli* isolates were collected from laboratories distributed over six Moroccan cities. There results revealed that 5 isolates (0.4%) were CRE, and bla_{OXA-48} and bla_{IMP-1} were harboured in 2 isolates separately [76]. In 2011, 11 (6.6%) of 166 *K. pneumoniae* isolates collected from Ibn Rochd University Hospital Center were CRE, with bla_{OXA-48} being the most prevalent gene, followed by bla_{NDM-1} [77]. In a retrospective study between 2010–2012, 6 (7.3%) of 82 urinary ESBL-producing *K. pneumoniae* isolates were CRE [78].

3.12. Oman

In 2012, 31 (24.0%) of 129 Enterobacteriaceae isolates recovered from a hospital in Muscat were CRE [79]. In 2014, 1 (0.2%) of 645 Enterobacteriaceae isolates recovered from Al-Buraimi Hospital was CRE [80]. Moreover, the bla_{OXA-48} [81], $bla_{OXA-181}$ [81] and bla_{NDM-1} [81,82] genes were detected in other studies.

3.13. Jordan

Between 2012–2013, 7 (2.4%) of 296 *K. pneumoniae* isolated recovered from patients at a hospital in Amman were CRE, with bla_{OXA-48} being the most prevalent gene, followed by bla_{NDM} [83]. In another study, 23 (23.0%) of 100 *E. coli* isolates recovered from patients from a hospital in Jordan were CRE [84]. Between 2013–2014, 28 (1.0%) of 2759 Enterobacteriaceae collected from five different hospitals in Amman were CRE, with bla_{NDM-1} being the most prevalent gene, followed by bla_{OXA-48} and bla_{VIM-4} [85]. Over the same period, 18 (24.0%) of 75 *K pneumoniae* isolates recovered from patients admitted to three hospitals in Jordan were CRE, and the bla_{KPC} gene was harboured by 10 isolates [86].

3.14. Yemen

Several studies were performed that led to the identification of several carbapenem resistance genes, including bla_{OXA-48} [87], $bla_{OXA-181}$ [87], $bla_{OXA-232}$ [87], bla_{NDM} [88], bla_{NDM-1} [87] and bla_{NDM-5} [87].

3.15. Sudan

Between 2015–2016, 67 (45.9%) of 146 Enterobacteriaceae isolates collected from several hospital in Khartoum were CRE, with bla_{VIM} being the most commonly detected gene, followed by bla_{IMP} and bla_{NDM} [89]. During the same period, 17 (10.5%) of 162 Enterobacteriaceae isolates collected from several hospitals in Khartoum were CRE [90]. In 2016, 73 (51.0%) of 143 Enterobacteriaceae isolates collected from several hospitals in Khartoum were CRE, with bla_{OXA-48} being the most commonly encountered gene, followed by bla_{IMP} [91]. Moreover, bla_{OXA-24} [92], bla_{OXA-51} [92], bla_{OXA-58} [92], bla_{NDM-1} [92] and bla_{KPC} [93,94] were detected in other studies.

3.16. Palestine

In 2012, 35 (44.3%) of 79 Enterobacteriaceae isolates were CRE, with bla_{SPM} being the most prevalent gene, followed by bla_{IMP} and bla_{SIM} [95]. In 2013, 9 (9.4%) of 96 Enterobacteriaceae isolates collected from three hospitals in Gaza were CRE, with bla_{VIM-4} being the most prevalent gene, followed by bla_{VIM-28} [96]. Between 2016–2017, a study was done in Gaza aimed at determining carbapenem resistance in poultry. The results revealed that 44 (35.5%) of 124 recovered Enterobacteriaceae isolates were CRE [97]. Over the same period, 30 (13.3%) of 226 Enterobacteriaceae isolates were CRE [98]. Moreover, bla_{KPC-2} and bla_{GES-23} [99] genes were detected in Enterobacteriaceae in another study.

3.17. Syria

Between 2013–2014, 30 (6.5%) of 459 Syrian patients admitted to four hospitals in Israel were carriers of CRE, and bla_{NDM} was the most prevalent gene in the 32 CRE isolates recovered, followed by bla_{OXA-48} [100]. Between 2013–2016, 10 (9.3%) of 107 wounded Syrian children treated at Galilee Medical Center in Israel were CRE carriers, with bla_{NDM} being the most prevalent gene, followed by bla_{OXA-48} [101].

3.18. Bahrain

Between 2012–2017, all CRE isolates recovered from a hospital in Bahrain were collected and it was concluded that the prevalence of CRE continued to increase from 2012 to reach its peak in 2015 and then started decreasing until 2017 [102].

3.19. Pakistan

Between 2012–2014, 2 (1.4%) of 148 uropathogenic *E. coli* collected from a hospital in Pakistan were CRE [103]. Between 2015–2017, 171 (44.8%) of 382 Enterobacteriaceae isolates collected from a hospital in Pakistan were CRE, and genotypic testing revealed that bla_{VIM} and bla_{IMP-1} were harboured in some of these isolates [104]. Moreover, bla_{NDM-1} [105–107] and bla_{IMP} [106] genes were detected in other studies.

3.20. Afghanistan

Between 2009–2015, 141 (3.4%) of 4090 Enterobacteriaceae isolates recovered from wounded military personnel in wars, including the war in Afghanistan, were CRE. Furthermore, the first bla_{NDM-1} gene in *K. pneumoniae* in Afghanistan was reported [108].

3.21. Djibouti

No data were available for this country.

3.22. Somalia

No data were available for this country.

A summary of the distribution of carbapenem resistance genes detected in CRE isolates from countries in the Eastern Mediterranean Region is given in Table 1.

4. Carbapenem-resistant Acinetobacter baumannii (CRAB)

4.1. Lebanon

Between 2011–2013, 2755 (82%) of 3409 *A. baumannii* isolates obtained from 16 different Lebanese hospitals were CRAB [109]. In addition, between 2013–2015, 91 (76.5%) of 119 *A. baumannii* isolates collected from seven Lebanese hospitals were CRAB, and the $bla_{OXA-23-like}$ gene was detected in all CRAB isolates [110]. Between 2015–2016, 3197 (87.0%) of 3675 *A. baumannii* isolates collected from 13 Lebanese hospitals were CRAB, with bla_{OXA-23} being the predominantly detected gene [12]. Moreover, $bla_{OXA-24-like}$ [110–112], $bla_{OXA-58-like}$ [110] and $bla_{OXA-143-like}$ [110] were detected in other studies.

4.2. Egypt

Between 2014–2016, 268 (95.7%) of 280 *A. baumannii* isolates recovered from Mansoura University Hospitals were CRAB, of which 266 were metallo-β-lactamase-producers with bla_{IMP} being most frequently detected, followed by bla_{GIM} and bla_{SIM}

Table 1
Distribution of carbapenem resistance genes detected in carbapenem-resistant Enterobacteriaceae (CRE) isolates from countries located in the Eastern Mediterranean Region

Country	Resistance genes	Total no. of CRE isolates [a]
Lebanon	NDM-1 (11.6%), NDM-5 (2%), NDM-7 (0.4%), OXA-48 (48%), OXA-181 (0.8%)	250
Egypt	IMP-4 (5%), KPC (2.3%), NDM (37.2%), NDM-1 (15.1%), NDM-5 (0.7%), OXA-23 (14.1%), OXA-48 (38.3%), OXA-136 (0.3%), OXA-181 (0.3%), VIM (14.8%), VIM-2 (5%), VIM-4 (0.7%)	298
Saudi Arabia	KPC (10.2%), NDM (2.2%), NDM-1 (29.6%), OXA-48 (72.6%), VIM (0.5%), VIM-4 (3.8%)	186
Tunisia	IMP-1 (2.3%), IMP-8 (1.5%), IMP-10 (2.1%), IMP-13 (0.5%), KPC (5.1%), KPC-2 (0.5%), KPC-3 (0.5%), NDM-1 (11%), OXA-48 (61.8%), OXA-204 (5.4%), VIM (5.1%), VIM-1 (1.8%), VIM-2 (0.8%), VIM-4 (5.1%)	390
Iran	IMP (0.5%), KPC-2 (1%), KPC-3 (0.3%), NDM (8.2%), NDM-1 (21.2%), NDM-7 (2.3%), OXA-48 (37.8%), OXA-181 (0.3%), VIM (0.5%), VIM-1 (1.3%)	392
Unites Arab Emirates	KPC-2 (1.1%), NDM (25.7%), NDM-1 (14.5%), NDM-4 (0.6%), NDM-5 (7.3%), NDM-7 (1.1%), OXA-48 (44.1%), OXA-181 (8.4%), VIM-4 (0.6%)	179
Qatar	– [b]	–
Iraq	IMP (31.4%), KPC (2.9%), NDM-1 (2.9%), OXA-23 (5.7%), OXA-48 (14.3%), VIM (14.3%), VIM-2 (37.1%)	35
Kuwait	KPC (4.7%), NDM-1 (16.1%), OXA-48 (13.4%), VIM-4 (12.8%)	149
Libya	NDM (28.6%), OXA-48 (71.4%)	14
Morocco	IMP-1 (6.25%), NDM-1 (12.5%), OXA-48 (62.5%)	16
Oman	NDM-1 (58.3%), OXA-48 (20.8%), OXA-181 (4.2%)	24
Jordan	KPC (13.2%), NDM (2.6%), NDM-1 (26.3%), OXA-48 (18.4%), VIM-4 (1.3%)	76
Yemen	NDM (27%), NDM-1 (45.9%), NDM-5 (8.1%), OXA-48 (13.5%), OXA-181 (10.8%), ad OXA-232 (2.7%)	37
Sudan	IMP (17.9%), KPC (12.6%), NDM (5.3%), NDM-1 (2.4%), OXA-24 (0.5%), OXA-48 (7.2%), OXA-51 (1.9%), OXA-58 (0.5%), VIM (20.8%)	207
Palestine	GES-23 (3.3%), IMP (19.6%), KPC-2 (4.3%), SIM (1.1%), SPM (73.9%), VIM-4 (6.5%), VIM-28 (3.3%)	92
Syria	NDM (61.9%), OXA-48 (38.1%)	42
Bahrain	–	–
Pakistan	IMP (1.1%), NDM-1 (61.2%), VIM (10.4%)	183
Afghanistan	NDM-1 (100%)	1
Djibouti	–	–
Somalia	–	–

[a] Includes only CRE isolates tested genotypically from the articles included in the review.
[b] – Indicates no information is available.

[113]. Moreover, *bla*$_{OXA-23}$ [114–117], *bla*$_{OXA-24}$ [114], *bla*$_{OXA-51-like}$ [114–117], *bla*$_{OXA-64}$ [117], *bla*$_{OXA-65}$ [117], *bla*$_{OXA-66}$ [117], *bla*$_{OXA-69}$ [117], *bla*$_{OXA-71}$ [117], *bla*$_{OXA-78}$ [117], *bla*$_{OXA-94}$ [117], *bla*$_{OXA-89}$ [117], *bla*$_{OXA-58}$ [114,117] and *bla*$_{NDM-2}$ [118] were detected in other studies.

4.3. Saudi Arabia

Several studies were performed that led to the identification of various carbapenem resistance genes in *A. baumannii*, including *bla*$_{OXA-23}$ [119–121], *bla*$_{OXA-24}$ [122], *bla*$_{OXA-40}$ [121], *bla*$_{OXA-51-like}$ [120], *bla*$_{VIM}$ [121] and *bla*$_{SPM}$ [121].

4.4. Tunisia

Between 2013–2015, 242 (98.4%) of 246 *A. baumannii* isolates obtained from a teaching hospital were CRAB, with *bla*$_{OXA-23}$ being the most commonly detected gene, followed by *bla*$_{NDM-1}$ [122]. Moreover, *bla*$_{OXA-51-like}$ [123], *bla*$_{OXA-58}$ [123] and *bla*$_{GES-11}$ [124] genes were detected in other studies.

4.5. Iran

In Iran, a study published in 2012 showed that 62 (62.0%) of 100 *A. baumannii* were imipenem-resistant, with *bla*$_{OXA-51}$ being the most prevalent gene, followed by *bla*$_{OXA-23}$, *bla*$_{OXA-40-like}$ and *bla*$_{OXA-58}$ [125]. Moreover, *bla*$_{IMP}$ [126], *bla*$_{VIM}$ [126], *bla*$_{IMP-55}$ [127], *bla*$_{IMP}$ [128], *bla*$_{OXA-24}$ [129] and *bla*$_{OXA-143-like}$ [130] were detected in other studies.

4.6. United Arab Emirates

In 2008 at Al Ain Emirate Hospital, 86 (67.7%) of 127 *A. baumannii* isolates were CRAB [131]. Moreover, *bla*$_{NDM-2}$ [132], *bla*$_{OXA-23}$ [115,133], *bla*$_{OXA-58}$ [134], *bla*$_{OXA-51-like}$ [115,133] and its variants including *bla*$_{OXA-64}$ [134], *bla*$_{OXA-66}$ [134], *bla*$_{OXA-69}$ [134], *bla*$_{OXA-98}$ [134], *bla*$_{OXA-65}$ [134], *bla*$_{OXA-83}$ [134], *bla*$_{OXA-67}$ [134], *bla*$_{OXA-68}$ [134], *bla*$_{OXA-78}$ [134], *bla*$_{OXA-79}$ [134], *bla*$_{OXA-89}$ [134], *bla*$_{OXA-91}$ [134], *bla*$_{OXA-94}$ [134], *bla*$_{OXA-95}$ [134] and *bla*$_{OXA-208}$ [134] carbapenemase genes were detected in other studies.

4.7. Qatar

Between 2012–2013, 170 (45.7%) of 372 *A. baumannii* isolates obtained from Hamad tertiary hospital were CRAB [135]. Moreover, *bla*$_{OXA-23}$ [136] and *bla*$_{OXA-51}$ [133] carbapenemase genes were detected in other studies.

4.8. Iraq

Between 2012–2013, 101 (84.2%) of 120 *A. baumannii* isolates collected from four different Kurdistan hospitals were CRAB, and *bla*$_{OXA-23-like}$, *bla*$_{OXA-24-like}$ and *bla*$_{OXA-51-like}$ genes were detected in these isolates [137]. Moreover, *bla*$_{IMP}$ [138] and *bla*$_{VIM}$ [138] carbapenemase genes were detected in another study.

4.9. Kuwait

In 2008, 114 (46.2%) of 247 *A. baumannii* isolates collected from government hospitals in Kuwait were CRAB, and the *bla*$_{OXA-69}$ gene was detected in these isolates [139]. In 2008, 40 (42.6%) of 94 *A. baumannii* isolates obtained from Mubarak Al-Kabeer and Al-Adan Hospitals were CRAB, and the *bla*$_{IMP-1}$ and *bla*$_{VIM-2}$ genes were detected in these isolates [140]. Moreover, *bla*$_{OXA-23-type}$ [133], *bla*$_{OXA-51-type}$ [133] including *bla*$_{OXA-66}$ [141], *bla*$_{OXA-64}$ [141], *bla*$_{OXA-71}$ [141] and *bla*$_{OXA-98}$ [141] genes were detected in other studies.

4.10. Libya

Several studies were performed that led to the identification of various carbapenem resistance genes, including *bla*$_{OXA-23}$ [142,143], *bla*$_{-OXA24}$ [143], *bla*$_{OXA-48}$ [143] and *bla*$_{NDM-1}$ [142].

4.11. Morocco

Between 2012–2014, 314 (87.7%) of 358 *A. baumannii* isolates collected from Mohammed V Military Teaching Hospital were CRAB [144]. Moreover, $bla_{\text{OXA-23-like}}$ [145,146], $bla_{\text{OXA-24-like}}$ [146], $bla_{\text{OXA-51-like}}$ [145], $bla_{\text{OXA-58-like}}$ [147], bla_{GES} [145], bla_{NDM} [145] and $bla_{\text{NDM-1}}$ [146] carbapenem resistance genes were detected in several studies.

4.12. Oman

Between 2007–2016, 117 (70.5%) of 166 *A. baumannii* isolates collected from Sultan Qaboos University Hospital were CRAB [148]. In 2015, none of the 94 *A. baumannii* isolates collected from Nizwa Hospital were CRAB [149]. Moreover, $bla_{\text{OXA-23}}$ [133] and $bla_{\text{OXA-51-like}}$ [133] carbapenem resistance genes were detected in another study.

4.13. Jordan

Between 2009–2010, 72 (97.3%) of 74 *A. baumannii* isolates obtained from Jordan University Hospital were CRAB, with $bla_{\text{OXA-51-like}}$ being the most commonly detected gene, followed by $bla_{\text{OXA-23-like}}$ and $bla_{\text{OXA-24-like}}$ [150]. In 2016, all 70 *A. baumannii* isolates obtained from a cancer centre in Amman were CRAB, and bla_{VIM}, bla_{GES}, $bla_{\text{NDM-1}}$, bla_{NDM}, bla_{IMP}, bla_{KPC} and bla_{SPM} genes were detected [151].

4.14. Yemen

Between 2012–2013, 252 (90.0%) of 280 *A. baumannii* isolates obtained from three hospitals of Sana'a were CRAB [152]. Moreover, $bla_{\text{OXA-23-like}}$ [153] and $bla_{\text{OXA-51-like}}$ [153] genes were detected in another study.

4.15. Sudan

Several studies were performed that led to the identification of various carbapenem resistance genes, including bla_{KPC} [93], $bla_{\text{OXA-51}}$ [92] and bla_{OXA23} [92].

4.16. Palestine

Several studies were performed that led to the identification of various carbapenem resistance genes, including bla_{NDM} [154], $bla_{\text{NDM-1}}$ [154], $bla_{\text{NDM-2}}$ [155], $bla_{\text{VIM-2}}$ [155], $bla_{\text{OXA-51}}$ [155], $bla_{\text{VIM-4}}$ [155], $bla_{\text{OXA-23}}$ [154], $bla_{\text{OXA-24}}$ [154], $bla_{\text{OXA-58}}$ [154], $bla_{\text{OXA-66}}$ [155] and $bla_{\text{OXA-70}}$ [155].

4.17. Syria

Between 2011–2013, a study led to the detection of $bla_{\text{OXA-66}}$ [156], $bla_{\text{OXA-94}}$ [156], $bla_{\text{OXA-69}}$ [156], $bla_{\text{OXA-406}}$ [156] and $bla_{\text{NDM-1}}$ [156] carbapenem resistance genes among Syrian refugees.

4.18. Bahrain

Between 2007–2008, 262 (57.7%) of 454 *A. baumannii* isolates collected from Salmaniya Medical Complex were CRAB, and $bla_{\text{OXA-23-like}}$, $bla_{\text{OXA-40-like}}$ and $bla_{\text{OXA-58-like}}$ carbapenem resistance genes were detected in these isolates [157]. Another study led to the detection of the $bla_{\text{OXA-51-type}}$ gene [133].

4.19. Pakistan

Between 2010–2011, 59 (65.5%) of 90 *A. baumannii* isolates collected from three health care facilities in Pakistan were CRAB, and the $bla_{\text{NDM-1}}$ gene was detected in these isolates [158]. In 2016, 135 (98.5%) of 137 *A. baumannii* isolates collected from different tertiary hospitals in Lahore were CRAB, and the $bla_{\text{OXA-23}}$ and $bla_{\text{OXA-51-like}}$ genes were detected in these isolates [159].

4.20. Afghanistan

No data were available for this country.

4.21. Djibouti

No data were available for this country.

4.22. Somalia

No data were available for this country.

A summary of the distribution of carbapenem resistance genes detected in CRAB isolates from countries in the Eastern Mediterranean Region is given in Table 2.

5. Carbapenem-resistant *Pseudomonas aeruginosa* (CRPA)

5.1. Lebanon

Between 2011–2013, 2240 (27%) of 7897 *P. aeruginosa* isolates collected from 16 different hospitals were CRPA [109]. In addition, between 2015–2016, 2701 (30.0%) of 9005 *P. aeruginosa* isolates recovered from 13 participating hospitals were CRPA [12]. Several studies were performed at the country level that led to the identification of various carbapenem resistance genes in *P. aeruginosa*, including $bla_{\text{VIM-2}}$ [160,161], $bla_{\text{IMP-1}}$ [160], $bla_{\text{IMP-2}}$ [160] and $bla_{\text{IMP-15}}$ [161].

5.2. Egypt

Between 2011–2012, 48 (39.3%) of 122 *P. aeruginosa* isolates collected from Kasr El Aini Hospital and National Cancer Institute were imipenem-resistant and 56 (45.9%) were meropenem-resistant [162]. Between 2013–2014, 137 (78.3%) of 175 *P. aeruginosa* isolates recovered from Alexandria University Students' Hospital were CRPA, with bla_{SPM} being the most commonly detected gene, followed by bla_{IMP} [163]. Moreover, between 2013–2014, 39 (26.5%) of 147 *P. aeruginosa* isolates were CRPA [164]. The year 2012 marked the first detection of $bla_{\text{NDM-1}}$ in *P. aeruginosa* in Egypt [165]. Furthermore, several studies were performed that led to the identification of various carbapenem resistance genes, including $bla_{\text{OXA-48-like}}$ [166], $bla_{\text{VIM-1-like}}$ [166], $bla_{\text{VIM-1}}$ [167], $bla_{\text{VIM-2}}$ [166,167], $bla_{\text{VIM-4}}$ [167], $bla_{\text{IMP-1}}$ [167], $bla_{\text{GIM-1}}$ [167], $bla_{\text{SPM-1}}$ [167] and $bla_{\text{SIM-1}}$ [167].

5.3. Saudi Arabia

In 2010, 135 (38.6%) of 350 *P. aeruginosa* isolates collected from Prince Salman Hospital were CRPA, with $bla_{\text{VIM-2}}$ being the most commonly detected gene [168]. Moreover, in the same year, 109 (69.9%) of 156 *P. aeruginosa* isolates were CRPA [169]. Between 2013–2014, 37 (30.6%) of 121 *P. aeruginosa* isolates collected from four tertiary hospitals in Makkah and Jeddah were meropenem-resistant and 23 (19.0%) were imipenem-resistant [170]. Moreover, bla_{VIM} [169], $bla_{\text{VIM-6}}$ [171], $bla_{\text{VIM-11}}$ [171], $bla_{\text{VIM-17}}$ [171] and $bla_{\text{VIM-48}}$ [171] genes were detected in other studies.

Table 2
Distribution of carbapenem resistance genes detected in carbapenem-resistant *Acinetobacter baumannii* (CRAB) isolates from countries located in the Eastern Mediterranean Region

Country	Resistance genes	Total no. of CRAB isolates [a]
Lebanon	NDM-1 (0.13%), OXA-23 (100%), OXA-24 (0.39%), OXA-58 (0.03%), OXA-143 (0.03%)	3064
Egypt	GIM (29.56%), IMP (66.01%), NDM-2 (0.25%), OXA-23 (31.53%), OXA-24 (0.74%), OXA-51-like (28.82%), OXA-58 (1.72%), OXA-64 (1.66%), OXA-65 (3.32%), OXA-66 (0.95%), OXA-69 (0.71%), OXA-71 (0.47%), OXA-78 (0.24%), OXA-89 (0.24%), OXA-94 (0.47%), SIM (32.51%), VIM (0.25%)	406
Saudi Arabia	OXA-23 (97.4%), OXA-40 (24.68%), OXA-51-like (10.39%), SPM (22.08%), VIM (23.38%)	77
Tunisia	NDM-1 (4.2%), OXA-23 (100%), OXA-51-like (9.54%), OXA-58 (0.38%)	262
Iran	IMP (15.79%), IMP-55 (1.66%), OXA-23 (75.62%), OXA-24 (21.33%), OXA-40-like (6.37%), OXA-51 (91.97%), OXA-58 (16.07%), OXA-143-like (3.88%), VIM (13.02%)	361
United Arab Emirates	NDM-2 (0.66%), OXA-23 (79.4%), OXA-24 (1.66%) OXA-51-like (55.48%), OXA-58 (1.01%), OXA-64 (0.67%), OXA-65 (0.67%), OXA-66 (1.35%), OXA-67 (0.34%), OXA-68 (0.34%), OXA-69 (0.67%), OXA-78 (0.34%), OXA-83 (0.67%), OXA-89 (0.34%), OXA-91 (0.34%), OXA-94 (0.34%), OXA-95 (0.34%), OXA-98 (1.01%), OXA-208 (0.34%)	301
Qatar	OXA-23 (100%), OXA-51 (11.11%)	754
Iraq	IMP (13.67%), OXA-23-like (72.6%), OXA-24-like (2.88%), OXA-51-like (86.33%), VIM (3.6%)	139
Kuwait	IMP-1 (4.55%), OXA-23 (25.57%), OXA-51 (4.55%), OXA-64 (6.82%), OXA-66 (17.05%), OXA-69 (90.34%), OXA-71 (1.14%), OXA-98 (9.66%), VIM-1 (0.57%), VIM-2 (10.23%)	176
Libya	NDM-1 (4.55%), OXA-23 (100%), OXA-24 (13.64%), OXA-48 (13.64%)	22
Morocco	GES (16.82%), NDM (4.67%), NDM-1 (25.23%), OXA-23-like (95.33%), OXA-24-like (1.87%), OXA-51-like (100%), OXA-58-like (0.93%)	107
Oman	OXA-23 (100%), OXA-51-like (100%)	4
Jordan	GES (31.15%), IMP (4.92%), KPC (4.92%), NDM (14.75%), NDM-1 (21.31%), OXA-23-like (96.72%), OXA-24-like (18.03%), OXA-51-like (100%), SPM (1.64%), VIM (47.54%)	61
Yemen	OXA-23-like (100%), OXA-51-like (100%)	3
Sudan	KPC (32.26%), OXA-23 (3.23%), OXA-51 (3.23%)	31
Palestine	NDM (4.71%), NDM-2 (1.18%), OXA-23 (67.06%), OXA-24 (11.76%), OXA-51 (1.18%), OXA-58 (2.35%), OXA-66 (15.29%), OXA-70 (1.18%), VIM-2 (3.53%), VIM-4 (1.18%)	85
Syria	NDM-1 (8.57%), OXA-23 (92.86%), OXA-64 (10%), OXA-66 (100%), OXA-69 (28.57%), OXA-70 (1.43%), OXA-71 (1.43%), OXA-94 (7.14%), OXA-104 (1.43%), OXA-120 (2.86%), OXA- 121 (1.43%), OXA-132 (1.43%), OXA-406 (1.43%)	70
Bahrain	OXA-23-like (62.5%), OXA-40-like (62.5%), OXA-51-like (100%), OXA-58-like (12.5%), OXA-72 (62.5%)	8
Pakistan	NDM-1 (0.551%), OXA-23 (69.9%), OXA-51-like (98.47%)	196
Afghanistan	– [b]	–
Djibouti	–	–
Somalia	–	–

[a] Includes only CRAB isolates tested genotypically from the articles included in the review.
[b] – Indicates no information is available.

5.4. Tunisia

Several studies were performed that led to the identification of the $bla_{\text{VIM-2}}$ [172–174] carbapenem resistance gene in *P. aeruginosa* in Tunisia.

5.5. Iran

In Iran in 2013, 161 (63.1%) of 255 *P. aeruginosa* isolates collected from Motahari Hospital were CRPA, and the bla_{VIM} and bla_{IMP} genes were detected in these isolates [175]. Moreover, $bla_{\text{VIM-2}}$ [176], $bla_{\text{IMP-1}}$ [176] and $bla_{\text{NDM-1}}$ [176] were reported in other studies.

5.6. United Arab Emirates

In 2008 at Al Ain Emirate Hospital, 80.4% of 788 *P. aeruginosa* isolates were CRPA [131]. Furthermore, several studies were performed that led to the identification of various carbapenem resistance genes, including $bla_{\text{VIM-2}}$ [177], $bla_{\text{VIM-17}}$ [171], $bla_{\text{VIM-30}}$ [177], $bla_{\text{VIM-31}}$ [177], $bla_{\text{VIM-42}}$ [177], $bla_{\text{VIM-48}}$ [171] and $bla_{\text{GES-5}}$ [177].

5.7. Qatar

A study on *P. aeruginosa* isolates in the Gulf Region led to the identification of several carbapenem resistance genes in Qatar, including $bla_{\text{VIM-2}}$ [171], $bla_{\text{VIM-28}}$ [171], $bla_{\text{VIM-17}}$ [171] and $bla_{\text{VIM-48}}$ [171].

5.8. Iraq

Several studies were performed that led to the identification of various carbapenem resistance genes in *P. aeruginosa* in Iraq, including bla_{IMP} [138,178], bla_{NDM} [179], $bla_{\text{SPM-1}}$ [178] and bla_{VIM} [138].

5.9. Kuwait

Between 2007–2008, 13 (9.6%) of 135 *P. aeruginosa* isolates collected from Al Amiri Hospital were CRPA [180]. Moreover, a study was performed that led to the identification of several carbapenem resistance genes, including bla_{KPC} [181], bla_{VIM} [181] and bla_{IMP} [181].

5.10. Libya

Several studies were performed that led to the identification of the $bla_{\text{VIM-2}}$ [143] gene in CRPA in Libya.

5.11. Morocco

Between 2012–2014, 33 (26.8%) of 123 *P. aeruginosa* isolates recovered from Meknes-Tafilalet region were CRPA, and the $bla_{\text{VIM-2}}$ gene was detected in these isolates [182].

5.12. Oman

Between 2007–2016, 43 (18.6%) of 231 *P. aeruginosa* isolates collected from Sultan Qaboos University Hospital were CRPA, with an increase in resistance to carbapenems noted in the last few years

Table 3
Distribution of carbapenem resistance genes detected in carbapenem-resistant *Pseudomonas aeruginosa* (CRPA) isolates from countries located in the Eastern Mediterranean Region

Country	Resistance genes	Total no. of CRPA isolates [a]
Lebanon	IMP-1 (1.81%), IMP-2 (3.17%), IMP-15 (7.24%), VIM-2 (21.27%)	221
Egypt	GIM-1 (20.97%), IMP (17.74%), IMP-1 (1.61%), NDM-1 (3.23%), OXA-48-like (3.23%), SIM-1 (19.35%), SPM (30.65%), SPM-1 (9.68%), VIM-1-like (11.29%), VIM-2 (9.68%), VIM-4 (6.45%)	62
Saudi Arabia	VIM (4.9%), VIM-2 (67.65%), VIM-6 (1.96%), VIM-2 or VIM-11 (0.98%), VIM-2, VIM-17 or VIM-48 (8.33%)	204
Tunisia	VIM-2 (66.67%)	90
Iran	IMP (1.54%), IMP-1 (0.77%), NDM-1 (0.77%), VIM (1.92%), VIM-2 (0.38%)	260
United Arab Emirates	GES-5 (1.82%), VIM-2 (16.36%), VIM-2, VIM-17 or VIM-48 (1.82%), VIM-30 (5.45%), VIM-31 (3.64%), VIM-42 (3.64%)	55
Qatar	VIM-2, VIM-17 or VIM-48 (85.71%), VIM-28 (28.57%)	7
Iraq	IMP (13%), NDM-1 (2%), SPM-1 (2%), VIM (9%)	100
Kuwait	IMP (33.33%), KPC (91.67%), VIM (41.67%)	12
Libya	VIM-2 (90.48%)	33
Morocco	VIM-2 (100%)	21
Oman	– [b]	–
Jordan	VIM-2 (9.38%)	32
Yemen	–	–
Sudan	IMP (8.64%), KPC (8.64%), NDM (37.04%), NDM-1 (1.23%), OXA-24 (1.23%), OXA-48 (3.7%), OXA-51 (6.17%), OXA-58 (1.23%), OXA-181 (3.7%), VIM (24.69%)	81
Palestine	IMP (16.13%), SPM (3.23%), VIM (32.26%), VIM-2 (9.68%), VIM-4 (3.23%)	31
Syria	–	–
Bahrain	NDM-1 (3.57%), VIM (67.86%), VIM-2 (17.86%)	28
Pakistan	GES-1 (6.67%), GES-2 (6.67%), IMP-1 (6.67%), IMP-13 (6.67%), IMP-15 (6.67%), IMP-19 (6.67%), IMP-29 (6.67%), NDM (26.67%), OXA-18 (6.67%), SPM-1 (6.67%), VIM-1 (6.67%), VIM-2 (13.33%)	15
Afghanistan	–	–
Djibouti	–	–
Somalia	–	–

[a] Includes only CRPA isolates tested genotypically from the articles included in the review.
[b] – Indicates no information is available.

of the study where 22% carbapenem resistance was recorded in blood isolates between 2012–2016 compared with 14% between 2007–2011 [148].

5.13. Jordan

In 2006, 92 (92.0%) of 100 *P. aeruginosa* isolates were CRPA [183]. Moreover, the $bla_{\text{VIM-2}}$ [184] carbapenem resistance gene was detected in another study in *P. aeruginosa*.

5.14. Yemen

In 2017, 39 (20.2%) of 193 *P. aeruginosa* isolates recovered from Sana'a Hospital were CRPA [185]. In 2018, 21 (21.4%) of 98 *P. aeruginosa* isolates collected from Al-Thawrah Hospital were CRPA [186].

5.15. Sudan

Several studies were performed that led to the identification of various carbapenem resistance genes, including bla_{VIM} [89,92], bla_{IMP} [89], bla_{NDM} [89,187], $bla_{\text{OXA-51}}$ [92], $bla_{\text{OXA-48}}$ [92], $bla_{\text{OXA-181}}$ [92], $bla_{\text{OXA-58}}$ [92], $bla_{\text{OXA-24}}$ [92], bla_{KPC} [92,93] and $bla_{\text{NDM-1}}$ [92].

5.16. Palestine

In 2018, none of the 210 *P. aeruginosa* isolates obtained from three hospitals in Gaza were CRPA [188]. Moreover, bla_{VIM} [189], $bla_{\text{VIM-2}}$ [155], $bla_{\text{VIM-4}}$ [155], bla_{IMP} [189] and bla_{SPM} [189] carbapenem resistance genes were detected in several studies carried out in Palestine.

5.17. Syria

Between 2011–2012, 78 (43.9%) of 177 *P. aeruginosa* isolates collected from three key hospitals in Aleppo were CRPA [190].

5.18. Bahrain

Several studies were performed that led to the identification of various carbapenem resistance genes, including $bla_{\text{NDM-1}}$ [191], bla_{VIM} [191] and $bla_{\text{VIM-2}}$ [171].

5.19. Pakistan

There are not enough reports in Pakistan to denote the prevalence of carbapenem resistance and the underlying mechanisms. A study in 2016 at the Kidney Center in Al-Sayed Hospital detected the presence of bla_{NDM} genes in CRPA isolates as well as bla_{VIM}, bla_{IMP}, bla_{GES}, $bla_{\text{SPM-1}}$ and $bla_{\text{OXA-18}}$ [192].

5.20. Afghanistan

No data were available for this country.

5.21. Djibouti

No data were available for this country.

5.22. Somalia

No data were available for this country.

A summary of the distribution of carbapenem resistance genes detected in CRPA isolates from countries in the Eastern Mediterranean Region is given in Table 3.

6. Conclusion

This review of 192 studies reveals the level of spread and the prevalence of carbapenem resistance in the Eastern Mediterranean Region, in addition to the distressing high variety of carbapenem resistance-encoding genes and other resistance determinants encountered. These perturbing data should lead to an emergency plan in each country to handle the spread of such strains to prevent outbreaks and to save lives.

Funding

None.

Competing interests

None declared.

Ethical approval

Not required.

References

[1] Theuretzbacher U. Global antimicrobial resistance in Gram-negative pathogens and clinical need. Curr Opin Microbiol 2017;39:106–12. doi:10.1016/j.mib.2017.10.028.
[2] Kaye KS, Pogue JM. Infections caused by resistant Gram-negative bacteria: epidemiology and management. Pharmacotherapy 2015;35:949–62. doi:10.1002/phar.1636.
[3] World Health Organization (WHO) Prioritization of pathogens to guide discovery, research and development of new antibiotics for drug resistant bacterial infections, including tuberculosis, Geneva, Switzerland: WHO; 2017. WHO/EMP/IAU/2017.12.
[4] Logan LK, Weinstein RA. The epidemiology of carbapenem-resistant Enterobacteriaceae: the impact and evolution of a global menace. J Infect Dis 2017;215(Suppl 1):S28–36. doi:10.1093/infdis/jiw282.
[5] Abbott I, Cerqueira GM, Bhuiyan S, Peleg AY. Carbapenem resistance in *Acinetobacter baumannii*: laboratory challenges, mechanistic insights and therapeutic strategies. Expert Rev Anti Infect Ther 2013:395–409. doi:10.1586/eri.13.21.
[6] Pang Z, Raudonis R, Glick BR, Lin TJ, Cheng Z. Antibiotic resistance in *Pseudomonas aeruginosa*: mechanisms and alternative therapeutic strategies. Biotechnol Adv 2019;37:177–92. doi:10.1016/j.biotechadv.2018.11.013.
[7] Moghnieh RA, Kanafani ZA, Tabaja HZ, Sharara SL, Awad LS, Kanj SS. Epidemiology of common resistant bacterial pathogens in the countries of the Arab League. Lancet Infect Dis 2018;18:e379–94. doi:10.1016/S1473-3099(18)30414-6.
[8] Matar GM, Cuzon G, Araj GF, Naas T, Corkill J, Kattar MM, et al. Oxacillinase-mediated resistance to carbapenems in *Klebsiella pneumoniae* from Lebanon. Clin Microbiol Infect 2008;14:887–8. doi:10.1111/j.1469-0691.2008.02059.x.
[9] Hammoudi D, Moubareck CA, Aires J, Adaime A, Barakat A, Fayad N, et al. Countrywide spread of OXA-48 carbapenemase in Lebanon: surveillance and genetic characterization of carbapenem-non-susceptible Enterobacteriaceae in 10 hospitals over a one-year period. Int J Infect Dis 2014;29:e139–44. doi:10.1016/j.ijid.2014.07.017.
[10] Christophy R, Osman M, Mallat H, Achkar M, Ziedeh A, Moukaddem W, et al. Prevalence, antibiotic susceptibility and characterization of antibiotic resistant genes among carbapenem-resistant Gram-negative bacilli and yeast in intestinal flora of cancer patients in North Lebanon. J Infect Public Health 2017;10:716–20. doi:10.1016/j.jiph.2016.10.009.
[11] Kissoyan KAB, Araj GF, Matar G. Prevalence of carbapenem resistance encoding genes and corresponding MIC_{90} in Enterobacteriaceae at a tertiary medical care center in Lebanon. Int Arab J Antimicrob Agents 2016;6:1–9. doi:10.3823/785.
[12] Moghnieh R, Araj GF, Awad L, Daoud Z, Mokhbat JE, Jisr T, et al. A compilation of antimicrobial susceptibility data from a network of 13 Lebanese hospitals reflecting the national situation during 2015–2016. Antimicrob Resist Infect Control 2019;8:41. doi:10.1186/s13756-019-0487-5.
[13] Hamze M, Osman M, Mallat H, Nasr S, Bou Raad E, Achkar M. Epidemiology and antibiotic susceptibility patterns of carbapenem resistant Gram negative bacteria isolated from two tertiary care hospitals in North Lebanon. Int Arab J Antimicrob Agents 2018;8:2–9. doi:10.3823/823.
[14] Dagher C, Salloum T, Alousi S, Arabaghian H, Araj GF, Tokajian S. Molecular characterization of carbapenem resistant *Escherichia coli* recovered from a tertiary hospital in Lebanon. PLoS One 2018;13:e203323. doi:10.1371/journal.pone.0203323.
[15] Nawfal Dagher T, Azar E, Al-Bayssari C, Chamieh AS, Rolain JM. First Detection of colistin-resistant *Klebsiella pneumoniae* in association with NDM-5 carbapenemase isolated from clinical Lebanese patients. Microb Drug Resist 2019;25:925–30. doi:10.1089/mdr.2018.0383.
[16] Arabaghian H, Salloum T, Alousi S, Panossian B, Araj GF, Tokajian S. Molecular characterization of carbapenem resistant *Klebsiella pneumoniae* and *Klebsiella quasipneumoniae* isolated from Lebanon. Sci Rep 2019;9:531. doi:10.1038/s41598-018-36554-2.
[17] Assem M, Abdalla Wifi M-N, Elsherif R, Saad A, Ismail DK, Hasanin A, et al. Emergence of Gram-negative bacilli with concomitant bla_{NDM-1-} and $bla_{OXA-48-like}$ genes in Egypt. Am J Intern Med 2017;5:1. doi:10.11648/j.ajim.20170501.11.
[18] Abdallah HM, Reuland EA, Wintermans BB, Al Naiemi N, Koek A, Abdelwahab AM, et al. Extended-spectrum β-lactamases and/or carbapenemases-producing Enterobacteriaceae isolated from retail chicken meat in Zagazig, Egypt. PLoS One 2015;10:e0136052. doi:10.1371/journal.pone.0136052.
[19] Fattouh M, Nasr El-din A, Omar MA. Detection of *Klebsiella pneumoniae* carbapenemase (KPC) producing Gram negative superbugs: an emerging cause of multidrug-resistant infections in general surgery department of Sohag University Hospital, Egypt. Int J Curr Microbiol App Sci 2015;4:1–15.
[20] Kamel NA, El-Tayeb WN, El-Ansary MR, Mansour MT, Aboshanab KM. Phenotypic screening and molecular characterization of carbapenemase-producing Gram-negative bacilli recovered from febrile neutropenic pediatric cancer patients in Egypt. PLoS One 2018;13:e0202119. doi:10.1371/journal.pone.0202119.
[21] Ghaith DM, Mohamed ZK, Farahat MG, Aboulkasem Shahin W, Mohamed HO. Colonization of intestinal microbiota with carbapenemase-producing Enterobacteriaceae in paediatric intensive care units in Cairo. Egypt. Arab J Gastroenterol 2019;20:19–22. doi:10.1016/j.ajg.2019.01.002.
[22] Tawfick MM, Alshareef WA, Bendary HA, Elmahalawy H, Abdulall AK. The emergence of carbapenemase bla_{NDM} genotype among carbapenem-resistant Enterobacteriaceae isolates from Egyptian cancer patients. Eur J Clin Microbiol Infect Dis 2020;39:1251–9. doi:10.1007/s10096-020-03839-2.
[23] Hager R, Ahmed S, Salam A, Abo NM, Magd E. Emergence of carbapenem resistant Enterobacteriaceae coharboring New Delhi metallo-β-lactamase (NDM-1) and *Klebsiella pneumoniae* carbapenemase (KPC) isolated from a tertiary hospital in Egypt. IJAMBR 2019;7:86–94. doi:10.33500/ijambr.2019.07.011.
[24] Kotb S, Lyman M, Ismail G, Abd El Fattah M, Girgis SA, Etman A, et al. Epidemiology of carbapenem-resistant Enterobacteriaceae in Egyptian intensive care units using national healthcare-associated infections surveillance data, 2011–2017. Antimicrob Resist Infect Control 2020;9:2. doi:10.1186/s13756-019-0639-7.
[25] Abdelaziz MO, Bonura C, Aleo A, Fasciana T, Mammina C. NDM-1- and OXA-163-producing *Klebsiella pneumoniae* isolates in Cairo, Egypt, 2012. J Glob Antimicrob Resist 2013;1:213–15. doi:10.1016/j.jgar.2013.06.003.
[26] Gamal D, Fernández-Martínez M, El-Defrawy I, Ocampo-Sosa AA, Martínez-Martínez L. First identification of NDM-5 associated with OXA-181 in *Escherichia coli* from Egypt. Emerg Microbes Infect 2016;5:e30. doi:10.1038/emi.2016.24.
[27] Soliman AM, Khalifa HO, Ahmed AM, Shimamoto T, Shimamoto T. Emergence of an NDM-5-producing clinical *Escherichia coli* isolate in Egypt. Int J Infect Dis 2016;48:46–8. doi:10.1016/j.ijid.2016.05.003.
[28] Ghaith DM, Zafer MM, Ismail DK, Al-Agamy MH, Bohol MFF, Al-Qahtani A, et al. First reported nosocomial outbreak of *Serratia marcescens* harboring bla_{IMP-4} and bla_{VIM-2} in a neonatal intensive care unit in Cairo, Egypt. Infect Drug Resist 2018;11:2211–17. doi:10.2147/IDR.S174869.
[29] Dimude JU, Amyes SGB. Molecular characterisation and diversity in *Enterobacter cloacae* from Edinburgh and Egypt carrying $bla_{CTX-M-14}$ and bla_{VIM-4} β-lactamase genes. Int J Antimicrob Agents 2013;41:574–7. doi:10.1016/j.ijantimicag.2013.02.012.
[30] Kandeel A. Prevalence and risk factors of extended-spectrum β-lactamases producing Enterobacteriaceae in a general hospital in Saudi Arabia. J Microbiol Infect Dis 2014;4:50–4. doi:10.5799/ahinjs.02.2014.02.0126.
[31] Faidah HS, Momenah AM, El-Said HM, Barhameen AAA, Ashgar SS, Johargy A, et al. Trends in the annual incidence of carbapenem resistant among Gram negative bacilli in a large teaching hospital in Makah City, Saudi Arabia. J Tuberc Res 2017;05:229–36. doi:10.4236/jtr.2017.54024.
[32] Khan MMA, Faiz A. Frequency of carbapenemase producing *Klebsiella pneumoniae* in Makkah, Saudi Arabia. J Microbiol Infect Dis 2016;6:121–7. doi:10.5799/jmid.vi.328980.
[33] Khan MA, Mohamed AM, Faiz A, Ahmad J. Enterobacterial infection in Saudi Arabia: first record of *Klebsiella pneumoniae* with triple carbapenemase genes resistance. J Infect Dev Ctries 2019;13:334–41. doi:10.3855/jidc.11056.
[34] Al-Zahrani IA, Alasiri BA. The emergence of carbapenem-resistant *Klebsiella pneumoniae* isolates producing OXA-48 and NDM in the Southern (Asir) Province, Saudi Arabia. Saudi Med J 2018;39:23–30. doi:10.15537/smj.2018.1.21094.
[35] Memish ZA, Assiri A, Almasri M, Roshdy H, Hathout H, Kaase M, et al. Molecular characterization of carbapenemase production among Gram-negative bacteria in Saudi Arabia. Microb Drug Resist 2015;21:307–14. doi:10.1089/mdr.2014.0121.
[36] Messaoudi A, Haenni M, Bouallègue O, Saras E, Chatre P, Chaouch C, et al. Dynamics and molecular features of OXA-48-like-producing *Klebsiella pneumoniae* lineages in a Tunisian hospital. J Glob Antimicrob Resist 2020;20:87–93. doi:10.1016/j.jgar.2019.07.005.
[37] Messaoudi A, Mansour W, Jaidane N, Chaouch C, Boujaâfar N, Bouallègue O. Epidemiology of resistance and phenotypic characterization of carbapenem resistance mechanisms in *Klebsiella pneumoniae* isolates at Sahloul University Hospital-Sousse, Tunisia. Afr Health Sci 2019;19:2008–20. doi:10.4314/ahs.v19i2.24.
[38] Mansour W, Haenni M, Saras E, Grami R, Mani Y, Ben Haj Khalifa A, et al. Outbreak of colistin-resistant carbapenemase-producing *Klebsiella pneumoniae* in Tunisia. J Glob Antimicrob Resist 2017;10:88–94. doi:10.1016/j.jgar.2017.03.017.
[39] Battikh H, Harchay C, Dekhili A, Khazar K, Kechrid F, Zribi M, et al. Clonal spread of colistin-resistant *Klebsiella pneumoniae* coproducing KPC and VIM carbapenemases in neonates at a Tunisian university hospital. Microb Drug Resist 2017;23:468–72. doi:10.1089/mdr.2016.0175.
[40] Dziri R, Ayari I, Barguellil F, Ouzari HI, El Asli MS, Klibi N. First report of NDM and VIM coproducing *Klebsiella pneumoniae* in Tunisia and emergence

of novel clones. Microb Drug Resist 2019;25:1282–6. doi:10.1089/mdr.2019.0115.
[41] Dziri O, Alonso CA, Dziri R, Gharsa H, Maraoub A, Torres C, et al. Metallo-β-lactamases and class D carbapenemases in south-east Tunisia: implication of mobile genetic elements in their dissemination. Int J Antimicrob Agents 2018;52:871–7. doi:10.1016/j.ijantimicag.2018.06.002.
[42] Ktari S, Arlet G, Mnif B, Gautier V, Mahjoubi F, Ben Jmeaa M, et al. Emergence of multidrug-resistant *Klebsiella pneumoniae* isolates producing VIM-4 metallo-β-lactamase, CTX-M-15 extended-spectrum β-lactamase, and CMY-4 AmpC β-lactamase in a Tunisian university hospital. Antimicrob Agents Chemother 2006;50:4198–201. doi:10.1128/AAC.00663-06.
[43] Ben Tanfous F, Alonso CA, Achour W, Ruiz-Ripa L, Torres C, Ben Hassen A. First description of KPC-2-producing *Escherichia coli* and ST15 OXA-48-positive *Klebsiella pneumoniae* in Tunisia. Microb Drug Resist 2017;23:365–75. doi:10.1089/mdr.2016.0090.
[44] Ben Yahia H, Chairat S, Gharsa H, Alonso CA, Ben Sallem R, Porres-Osante N, et al. First report of KPC-2 and KPC-3-producing Enterobacteriaceae in wild birds in Africa. Microb Ecol 2020;79:30–7. doi:10.1007/s00248-019-01375-x.
[45] Mani Y, Mansour W, Mammeri H, Denamur E, Saras E, Boujâafar N, et al. KPC-3-producing ST167 *Escherichia coli* from mussels bought at a retail market in Tunisia. J Antimicrob Chemother 2017;72:2403–4. doi:10.1093/jac/dkx124.
[46] Chouchani C, Marrakchi R, Ferchichi L, El Salabi A, Walsh TR. VIM and IMP metallo-β-lactamases and other extended-spectrum β-lactamases in *Escherichia coli* and *Klebsiella pneumoniae* from environmental samples in a Tunisian hospital. APMIS 2011;119:725–32. doi:10.1111/j.1600-0463.2011.02793.x.
[47] Chouchani C, Marrakchi R, Henriques I, Correia A. Occurrence of IMP-8, IMP-10, and IMP-13 metallo-β-lactamases located on class 1 integrons and other extended-spectrum β-lactamases in bacterial isolates from Tunisian rivers. Scand J Infect Dis 2013;45:95–103. doi:10.3109/00365548.2012.717712.
[48] Fazeli H, Norouzi-Barough M, Ahadi AM, Shokri D, Solgi H. Detection of New Delhi metallo-β-lactamase-1 (NDM-1) in carbapenem-resistant *Klebsiella pneumoniae* isolated from a university hospital in Iran. Hippokratia 2015;19:205–9.
[49] Sadeghi MR, Ghotaslou R, Akhi MT, Asgharzadeh M, Hasani A. Molecular characterization of extended-spectrum β-lactamase, plasmid-mediated AmpC cephalosporinase and carbapenemase genes among Enterobacteriaceae isolates in five medical centres of east and West Azerbaijan, Iran. J Med Microbiol 2016;65:1322–31. doi:10.1099/jmm.0.000356.
[50] Jafari Z, Harati AA, Haeili M, Kardan-Yamchi J, Jafari S, Jabalameli F, et al. Molecular epidemiology and drug resistance pattern of carbapenem-resistant *Klebsiella pneumoniae* isolates from Iran. Microb Drug Resist 2019;25:336–43. doi:10.1089/mdr.2017.0404.
[51] Shoja S, Ansari M, Faridi F, Azad M, Davoodian P, Javadpour S, et al. Identification of carbapenem-resistant *Klebsiella pneumoniae* with emphasis on New Delhi metallo-β-lactamase-1 (bla_{NDM-1}) in Bandar Abbas, South of Iran. Microb Drug Resist 2018;24:447–54. doi:10.1089/mdr.2017.0058.
[52] Kiaei S, Moradi M, Hosseini-Nave H, Ziasistani M, Kalantar-Neyestanaki D. Endemic dissemination of different sequence types of carbapenem-resistant *Klebsiella pneumoniae* strains harboring bla_{NDM} and 16S rRNA methylase genes in Kerman hospitals, Iran, from 2015 to 2017. Infect Drug Resist 2019;12:45–54. doi:10.2147/IDR.S186994.
[53] Solgi H, Giske CG, Badmasti F, Aghamohammad S, Havaei SA, Sabeti S, et al. Emergence of carbapenem resistant *Escherichia coli* isolates producing bla_{NDM} and $bla_{OXA-48-like}$ carried on IncA/C and IncL/M plasmids at two Iranian university hospitals. Infect Genet Evol 2017;55:318–23. doi:10.1016/j.meegid.2017.10.003.
[54] Solgi H, Badmasti F, Aminzadeh Z, Giske CG, Pourahmad M, Vaziri F, et al. Molecular characterization of intestinal carriage of carbapenem-resistant Enterobacteriaceae among inpatients at two Iranian university hospitals: first report of co-production of bla_{NDM-7} and bla_{OXA-48}. Eur J Clin Microbiol Infect Dis 2017;36:2127–35. doi:10.1007/s10096-017-3035-3.
[55] Shahcheraghi F, Aslani MM, Mahmoudi H, Karimitabar Z, Solgi H, Bahador A, et al. Molecular study of carbapenemase genes in clinical isolates of Enterobacteriaceae resistant to carbapenems and determining their clonal relationship using pulsed-field gel electrophoresis. J Med Microbiol 2017;66:570–6. doi:10.1099/jmm.0.000467.
[56] Nobari S, Shahcheraghi F, Rahmati Ghezelgeh F, Valizadeh B. Molecular characterization of carbapenem-resistant strains of *Klebsiella pneumoniae* isolated from Iranian patients: first Identification of bla_{KPC} gene in Iran. Microb Drug Resist 2014;20:285–93. doi:10.1089/mdr.2013.0074.
[57] Ahn C, Butt AA, Rivera JI, Yaqoob M, Hag S, Khalil A, et al. OXA-48-producing Enterobacteriaceae causing bacteremia, United Arab Emirates. Int J Infect Dis 2015;30:e36–7. doi:10.1016/j.ijid.2014.11.008.
[58] Dash N, Panigrahi D, Al Zarouni M, Darwish D, Ghazawi A, Sonnevend A, et al. High incidence of New Delhi metallo-β-lactamase-producing *Klebsiella pneumoniae* isolates in Sharjah, United Arab Emirates. Microb Drug Resist 2014;20:52–6. doi:10.1089/mdr.2013.0040.
[59] Moubareck CA, Mouftah SF, Pál T, Ghazawi A, Halat DH, Nabi A, et al. Clonal emergence of *Klebsiella pneumoniae* ST14 co-producing OXA-48-type and NDM carbapenemases with high rate of colistin resistance in Dubai, United Arab Emirates. Int J Antimicrob Agents 2018;52:90–5. doi:10.1016/j.ijantimicag.2018.03.003.
[60] Sonnevend Á, Ghazawi A, Hashmey R, Haidermota A, Girgis S, Alfaresi M, et al. Multihospital occurrence of pan-resistant *Klebsiella pneumoniae* sequence type 147 with an IS*Ecp1*-directed $bla_{OXA-181}$ insertion in the *mgrB* gene in the United Arab Emirates. Antimicrob Agents Chemother 2017;61:e00418-17.
[61] Pál T, Ghazawi A, Darwish D, Villa L, Carattoli A, Hashmey R, et al. Characterization of NDM-7 carbapenemase-producing *Escherichia coli* isolates in the Arabian Peninsula. Microb Drug Resist 2017;23:871–8. doi:10.1089/mdr.2016.0216.
[62] Sonnevend Á, Ghazawi A, Yahfoufi N, Al-Baloushi A, Hashmey R, Mathew M, et al. VIM-4 carbapenemase-producing *Enterobacter cloacae* in the United Arab Emirates. Clin Microbiol Infect 2012;18:E494–6. doi:10.1111/1469-0691.12051.
[63] Moubareck CA, Hammoudi Halat D, Sartawi M, Lawlor K, Sarkis DK, Alatoom A. Assessment of the performance of CHROMagar KPC and Xpert Carba-R assay for the detection of carbapenem-resistant bacteria in rectal swabs: first comparative study from Abu Dhabi, United Arab Emirates. J Glob Antimicrob Resist 2020;20:147–52. doi:10.1016/j.jgar.2019.07.021.
[64] Eltai NO, Al Thani AA, Al-Ansari K, Deshmukh AS, Wehedy E, Al-Hadidi SH, et al. Molecular characterization of extended spectrum β-lactamases Enterobacteriaceae causing lower urinary tract infection among pediatric population. Antimicrob Resist Infect Control 2018;7:90. doi:10.1186/s13756-018-0381-6.
[65] Al-Khafaji ASK, Al-Baayit SFA, Ibraheem OS, Abdul-Ilah HH. Molecular investigation of metallo-β-lactamase encoding gene in nosocomial carbapenem-resistant Enterobacteriaceae in Iraqi Hospitals. In: International Conference on Research in Education and Science. The Eurasia Proceedings of Science, Engineering & Mathematics, 2; 2018. p. 239–43.
[66] Ahmed MM, Al Meani SAL. Occurrence of *Klebsiella pneumoniae* carbapenemase KPC gene in *Klebsiella pneumoniae* isolated from patients in Anbar City of Iraq. Ann Trop Med Public Health 2019;22. doi:10.36295/ASRO.2019.220514.
[67] Aziz RAR, Al-Jubori SS. Genetic elements responsible for extreme drug resistance (XDR) in *Klebsiella pneumoniae* var *pneumoniae* isolated from clinical samples of Iraqi patients. World J Pharm Res 2016;5:1–23. doi:10.20959/wjpr20165-6020.
[68] Poirel L, Fortineau N, Nordmann P. International transfer of NDM-1-producing *Klebsiella pneumoniae* from Iraq to France. Antimicrob Agents Chemother 2011;55:1821–2. doi:10.1128/AAC.01761-10.
[69] Huang XZ, Frye JG, Chahine MA, Glenn LSM, Ake JA, Su W, et al. Characteristics of plasmids in multi-drug-resistant Enterobacteriaceae isolated during prospective surveillance of a newly opened hospital in Iraq. PLoS One 2012;7:e40360. doi:10.1371/journal.pone.0040360.
[70] Jamal WY, Albert MJ, Khodakhast F, Poirel L, Rotimi VO. Emergence of new sequence type OXA-48 carbapenemase-producing Enterobacteriaceae in Kuwait. Microb Drug Resist 2015;21:329–34. doi:10.1089/mdr.2014.0123.
[71] Jamal WY, Albert MJ, Rotimi VO. High prevalence of New Delhi metallo-β-lactamase-1 (NDM-1) producers among carbapenem-resistant Enterobacteriaceae in Kuwait. PLoS One 2016;11:e0152638. doi:10.1371/journal.pone.0152638.
[72] Jamal W, Rotimi VO, Albert MJ, Khodakhast F, Nordmann P, Poirel L. High prevalence of VIM-4 and NDM-1 metallo-β-lactamase among carbapenem-resistant Enterobacteriaceae. J Med Microbiol 2013;62:1239–44. doi:10.1099/jmm.0.059915-0.
[73] Sonnevend Á, Yahfoufi N, Ghazawi A, Jamal W, Rotimi V, Pál T. Contribution of horizontal gene transfer to the emergence of VIM-4 carbapenemase producer Enterobacteriaceae in Kuwait. Infect Drug Resist 2017;10:469–78. doi:10.2147/IDR.S149321.
[74] Zorgani A, Elahmer O, Bashein A, Hawas A, Aljerbi A, Ziglam H, et al. Extended-spectrum β-lactamase- and carbapenemase-producing Enterobacteriaceae among Libyan children. EC Microbiol 2017;3:126–35.
[75] Ahmed M, Aghila E, Elamri S, Baptiste K. Molecular investigation of carbapenemase-producing Enterobacteriaceae isolated from a Tripoli hospital. Libya. Libyan J Med Sci 2017;1:80. doi:10.4103/ljms.ljms_24_17.
[76] Barguigua A, El Otmani F, Talmi M, Zerouali K, Timinouni M. Prevalence and types of extended spectrum β-lactamases among urinary *Escherichia coli* isolates in Moroccan community. Microb Pathog 2013;61–62:16–22. doi:10.1016/j.micpath.2013.04.010.
[77] Barguigua A, Zerouali K, Katfy K, El Otmani F, Timinouni M, Elmdaghri N. Occurrence of OXA-48 and NDM-1 carbapenemase-producing *Klebsiella pneumoniae* in a Moroccan university hospital in Casablanca. Morocco. Infect Genet Evol 2015;31:142–8. doi:10.1016/j.meegid.2015.01.010.
[78] El Bouamri MC, Arsalane L, El Kamouni Y, Zouhair S. Antimicrobial susceptibility of urinary *Klebsiella pneumoniae* and the emergence of carbapenem-resistant strains: a retrospective study from a university hospital in Morocco, North Africa. Afr J Urol 2015;21:36–40. doi:10.1016/j.afju.2014.10.004.
[79] Balkhair A, Al-Farsi YM, Al-Muharrmi Z, Al-Rashdi R, Al-Jabri M, Neilson F, et al. Epidemiology of multi-drug resistant organisms in a teaching hospital in Oman: a one-year hospital-based study. ScientificWorldJournal 2014;2014:157102. doi:10.1155/2014/157102.
[80] Khalid M, Al Naimi MK, Murtaza Saleem HG, Ullah MM, Al Baloshi AYMD. Antibiotics resistance profile of uropathogens isolated from Al Buraimi Hospital, Sultanate of Oman. Glob J Health Sci 2017;10:98. doi:10.5539/gjhs.v10n1p98.
[81] Dortet L, Poirel L, Al Yaqoubi F, Nordmann P. NDM-1, OXA-48 and OXA-181 carbapenemase-producing Enterobacteriaceae in Sultanate of Oman. Clin Microbiol Infect 2012;18:E144–8. doi:10.1111/j.1469-0691.2012.03796.x.
[82] Poirel L, Al Maskari Z, Al Rashdi F, Bernabeu S, Nordmann P. NDM-1-producing *Klebsiella pneumoniae* isolated in the Sultanate of Oman. J Antimicrob Chemother 2011;66:304–6. doi:10.1093/jac/dkq428.

[83] Aqel AA, Giakkoupi P, Alzoubi H, Masalha I, Ellington MJ, Vatopoulos A. Detection of OXA-48-like and NDM carbapenemases producing *Klebsiella pneumoniae* in Jordan: a pilot study. J Infect Public Health 2017;10:150–5. doi:10.1016/j.jiph.2016.02.002.
[84] Muhammad MH, Swedan S. Molecular and phenotypic characterization of carbapenem resistance and extended spectrum β-lactamases among urinary *Escherichia coli* isolates. Int J Sci Technol 2015;5.
[85] Aqel AA, Findlay J, Al-Maayteh M, Al-Kaabneh A, Hopkins KL, Alzoubi H, et al. Characterization of carbapenemase-producing Enterobacteriaceae from patients in Amman. Jordan. Microb Drug Resist 2018;24:1121–7. doi:10.1089/mdr.2017.0238.
[86] Al Mahasneh AAM, Mahafzah AM, Shehabi AA. Low incidence of hypervirulent clinical *Klebsiella pneumoniae* producing carbapenemases among Jordanian hospitalized patients. Int Arab J Antimicrob Agents 2015;5. doi:10.3823/771.
[87] Alsharapy SA, Gharout-Sait A, Muggeo A, Guillard T, Cholley P, Brasme L, et al. Characterization of carbapenem-resistant Enterobacteriaceae clinical isolates in Al Thawra University Hospital, Sana'a, Yemen. Microb Drug Resist 2020;26:211–17. doi:10.1089/mdr.2018.0443.
[88] Gharout-Sait A, Alsharapy SA, Brasme L, Touati A, Kermas R, Bakour S, et al. Enterobacteriaceae isolates carrying the New Delhi metallo-β-lactamase gene in Yemen. J Med Microbiol 2014;63:1316–23. doi:10.1099/jmm.0.073767-0.
[89] Adam MA, Elhag WI. Prevalence of metallo-β-lactamase acquired genes among carbapenems susceptible and resistant Gram-negative clinical isolates using multiplex PCR, Khartoum hospitals, Khartoum Sudan. BMC Infect Dis 2018;18:4–9. doi:10.1186/s12879-018-3581-z.
[90] Mohammed I, Nafi M. Detection of carbapenem-resistant *Escherichia coli, Klebsiella pneumoniae* and *Proteus mirabilis* clinical isolates in Khartoum; Sudan. Lab Med J 2019;3:14–20.
[91] Dahab RA, Ibrahim AM, Altayb HN. Phenotypic and genotypic detection of carbapenemase enzymes producing Gram-negative bacilli isolated from patients in Khartoum State. F1000Res 2017;6:1656. doi:10.12688/f1000research.12432.1.
[92] Abdelhamid Mohamed ME, Abdalla Osman A, El-Shiekh Babiker K, Sirag B, Musa Abdalla A. Phenotypic and genotypic characterization of carbapenems resistant clinical Gram-negative bacteria from Sudan. Edorium J Microbiol 2019;5 100011M08MM2019. doi:10.5348/100011M08MM2019RA.
[93] Elsir MA, Bakheit MA, Satir SB, Elkhalifa AI, Rahim A, Hussein E, et al. Molecular detection of carbapenem resistant gene (bla_{KPC}) among different Gram negative bacteria using loop mediated isothermal amplification (LAMP) assay, Khartoum State. Sudan. IJSRSET 2018;4:51–4.
[94] Satir SB, Elkhalifa AI. Detection of carbapenem resistance genes among selected Gram negative bacteria isolated from patients in Khartoum State. Sudan. Clin Microbiol Open Access 2016;5:6. doi:10.4172/2327-5073.1000266.
[95] Adwan G, Bourinee H, Othman S. Prevalence of metallo-β-lactamases producing *Escherichia coli* isolated from north of Palestine. J Microbiol Antimicrob Agents 2016;2:9–15.
[96] Tayh G, Nagarjuna D, Ben Sallem R, Verma V, Chairat S, Boudabous A, et al. First report of VIM metallo-β-lactamase production in *Escherichia coli* and *Klebsiella pneumoniae* clinical isolates from Gaza Strip. Palestine. Germs 2020;10:18–26. doi:10.18683/germs.2020.1181.
[97] Elmanama AA, Al-Reefi MR, Shamali MA, Hemaid HI. Carbapenems resistance among Gram negative bacteria isolated from poultry samples in Gaza – Palestine. Int Arab J Antimicrob Agents 2019;8:1–9. doi:10.3823/826.
[98] Rida RH, Al Laham NA, Elmanama AA. Carbapenem resistance among clinical and environmental Gram-negative isolates recovered from hospitals in Gaza Strip. Palestine. Germs 2018;8:147–54. doi:10.18683/germs.2018.1142.
[99] Kattan R, Liddawi R, Ghneim R, Sriyani I, Al-Dawodi R, Abu-Diab A, et al. Emergence of *Klebsiella pneumoniae* carbapenemase (bla_{KPC-2}) in members of the Enterobacteriaceae family in Palestine. Int Arab J Antimicrob Agents 2012;2:1–9. doi:10.3823/713.
[100] Lerner A, Solter E, Rachi E, Adler A, Rechnitzer H, Miron D, et al. Detection and characterization of carbapenemase-producing Enterobacteriaceae in wounded Syrian patients admitted to hospitals in northern Israel. Eur J Clin Microbiol Infect Dis 2016;35:149–54. doi:10.1007/s10096-015-2520-9.
[101] Faour Kassem D, Hoffmann Y, Shahar N, Ocampo S, Salomon L, Zonis Z, et al. Multidrug-resistant pathogens in hospitalized Syrian children. Emerg Infect Dis 2017;23:166–8. doi:10.3201/eid2301.161204.
[102] Saeed NK, Alkhawaja S, Fawzy Abd El Moez Azam N, Alaradi K, Al-Biltagi M. Epidemiology of carbapenem-resistant Enterobacteriaceae in a tertiary care center in the Kingdom of Bahrain 2019. J Lab Physicians 2019;11:111–17. doi:10.4103/JLP.JLP_101_18.
[103] Ali I, Rafaque Z, Ahmed S, Malik S, Dasti JI. Prevalence of multi-drug resistant uropathogenic *Escherichia coli* in Potohar Region of Pakistan. Asian Pac J Trop Biomed 2016;6:60–6. doi:10.1016/j.apjtb.2015.09.022.
[104] Ain NU, Iftikhar A, Bukhari SS, Abrar S, Hussain S, Haider MH, et al. High frequency and molecular epidemiology of metallo-β-lactamase-producing Gram-negative bacilli in a tertiary care hospital in Lahore. Pakistan. Antimicrob Resist Infect Control 2018;7:128. doi:10.1186/s13756-018-0417-y.
[105] Day KM, Ali S, Mirza IA, Sidjabat HE, Silvey A, Lanyon CV, et al. Prevalence and molecular characterization of Enterobacteriaceae producing NDM-1 carbapenemase at a military hospital in Pakistan and evaluation of two chromogenic media. Diagn Microbiol Infect Dis 2013;75:187–91. doi:10.1016/j.diagmicrobio.2012.11.006.
[106] Nahid F, Khan AA, Rehman S, Zahra R. Prevalence of metallo-β-lactamase NDM-1-producing multi-drug resistant bacteria at two Pakistani hospitals and implications for public health. J Infect Public Health 2013;6:487–93. doi:10.1016/j.jiph.2013.06.006.
[107] Perry JD, Naqvi SH, Mirza IA, Alizai SA, Hussain A, Ghirardi S, et al. Prevalence of faecal carriage of Enterobacteriaceae with NDM-1 carbapenemase at military hospitals in Pakistan, and evaluation of two chromogenic media. J Antimicrob Chemother 2011;66:2288–94. doi:10.1093/jac/dkr299.
[108] Mende K, Beckius ML, Zera WC, Onmus-Leone F, Murray CK, Tribble DR. Low prevalence of carbapenem-resistant Enterobacteriaceae among wounded military personnel. US Army Med Dep J 2017(2–17):12–17.
[109] Chamoun K, Farah M, Araj G, Daoud Z, Moghnieh R, Salameh P, et al. Surveillance of antimicrobial resistance in Lebanese hospitals: retrospective nationwide compiled data. Int J Infect Dis 2016;46:64–70. doi:10.1016/j.ijid.2016.03.010.
[110] Al Atrouni A, Hamze M, Jisr T, Lemarié C, Eveillard M, Joly-Guillou M-L, et al. Wide spread of OXA-23-producing carbapenem-resistant *Acinetobacter baumannii* belonging to clonal complex II in different hospitals in Lebanon. Int J Infect Dis 2016;52:29–36. doi:10.1016/j.ijid.2016.09.017.
[111] Nawfal Dagher T, Al-Bayssari C, Chabou S, Antar N, Diene SM, Azar E, et al. Investigation of multidrug-resistant ST2 *Acinetobacter baumannii* isolated from Saint George Hospital in Lebanon. BMC Microbiol 2019;19:29. doi:10.1186/s12866-019-1401-2.
[112] Dahdouh E, Hajjar M, Suarez M, Daoud Z. *Acinetobacter baumannii* isolated from Lebanese patients: phenotypes and genotypes of resistance, clonality, and determinants of pathogenicity. Front Cell Infect Microbiol 2016;6:163. doi:10.3389/fcimb.2016.00163.
[113] Alkasaby NM, El Sayed Zaki M. Molecular study of *Acinetobacter baumannii* isolates for metallo-β-lactamases and extended-spectrum-β-lactamases genes in intensive care unit, Mansoura University Hospital, Egypt. Int J Microbiol 2017;2017:3925868. doi:10.1155/2017/3925868.
[114] Al-Agamy MH, Khalaf NG, Tawfick MM, Shibl AM, El Kholy AA. Molecular characterization of carbapenem-insensitive *Acinetobacter baumannii* in Egypt. Int J Infect Dis 2014;22:49–54. doi:10.1016/j.ijid.2013.12.004.
[115] Ghaith DM, Zafer MM, Al-Agamy MH, Alyamani EJ, Booq RY, Almoazzamy O. The emergence of a novel sequence type of MDR *Acinetobacter baumannii* from the intensive care unit of an Egyptian tertiary care hospital. Ann Clin Microbiol Antimicrob 2017;16:34. doi:10.1186/s12941-017-0208-y.
[116] Fouad M, Attia AS, Tawakkol WM, Hashem AM. Emergence of carbapenem-resistant *Acinetobacter baumannii* harboring the OXA-23 carbapenemase in intensive care units of Egyptian hospitals. Int J Infect Dis 2013;17:e1252–4. doi:10.1016/j.ijid.2013.07.012.
[117] Al-Hassan L, El Mehallawy H, Amyes SGB. Diversity in *Acinetobacter baumannii* isolates from paediatric cancer patients in Egypt. Clin Microbiol Infect 2014;19:1082–8. doi:10.1111/1469-0691.12143.
[118] Kaase M, Nordmann P, Wichelhaus TA, Gatermann SG, Bonnin RA, Poirel L. NDM-2 carbapenemase in *Acinetobacter baumannii* from Egypt. J Antimicrob Chemother 2011;66:1260–2. doi:10.1093/jac/dkr135.
[119] Aljindan R, Bukharie H, Alomar A, Abdalhamid B. Prevalence of digestive tract colonization of carbapenem-resistant *Acinetobacter baumannii* in hospitals in Saudi Arabia. J Med Microbiol 2015;64:400–6. doi:10.1099/jmm.0.000033.
[120] Alhaddad M, AlBarjas A, Alhammar L, Al Rashed A, Badger-Emeka L. Molecular characterization and antibiotic susceptibility pattern of *Acinetobacter baumannii* isolated in intensive care unit patients in Al-Hassa, Kingdom of Saudi Arabia. Int J Appl Basic Med Res 2018;8:19. doi:10.4103/ijabmr.ijabmr_91_17.
[121] Alsultan AA, Aboulmagd E, Evans BA, Amyes SGB. Clonal diversity of *Acinetobacter baumannii* from diabetic patients in Saudi Arabian hospitals. J Med Microbiol 2014;63:1460–6. doi:10.1099/jmm.0.079640-0.
[122] Jaidane N, Naas T, Oueslati S, Bernabeu S, Boujaafar N, Bouallegue O, et al. Whole-genome sequencing of NDM-1-producing ST85 *Acinetobacter baumannii* isolates from Tunisia. Int J Antimicrob Agents 2018;52:916–21. doi:10.1016/j.ijantimicag.2018.05.017.
[123] Mathlouthi N, Ben Lamine Y, Somai R, Bouhalila-Besbes S, Bakour S, Rolain JM, et al. Incidence of OXA-23 and OXA-58 carbapenemases coexpressed in clinical isolates of *Acinetobacter baumannii* in Tunisia. Microb Drug Resist 2018;24:136–41. doi:10.1089/mdr.2016.0306.
[124] Chihi H, Bonnin RA, Bourouis A, Mahrouki S, Besbes S, Ben Moussa M, et al. GES-11-producing *Acinetobacter baumannii* clinical isolates from Tunisian hospitals: long-term dissemination of GES-type carbapenemases in North Africa. J Glob Antimicrob Resist 2016;5:47–50. doi:10.1016/j.jgar.2016.03.005.
[125] Sohrabi N, Farajnia S, Akhi MT, Nahaei MR, Naghili B, Peymani A, et al. Prevalence of OXA-type β-lactamases among *Acinetobacter baumannii* isolates from northwest of Iran. Microb Drug Resist 2012;18:385–9. doi:10.1089/mdr.2011.0077.
[126] Peymani A, Nahaei MR, Farajnia S, Hasani A, Mirsalehian A, Sohrabi N, et al. High prevalence of metallo-β-lactamase-producing *Acinetobacter baumannii* in a teaching hospital in Tabriz, Iran. Jpn J Infect Dis 2011;64:69–71.
[127] Azizi O, Shakibaie MR, Badmasti F, Modarresi F, Ramazanzadeh R, Mansouri S, et al. Class 1 integrons in non-clonal multidrug-resistant *Acinetobacter baumannii* from Iran, description of the new bla_{IMP-55} allele in In*1243*. J Med Microbiol 2016;65:928–36. doi:10.1099/jmm.0.000315.
[128] Sarhaddi N, Soleimanpour S, Farsiani H, Mosavat A, Dolatabadi S, Salimizand H, et al. Elevated prevalence of multidrug-resistant *Acinetobacter baumannii* with extensive genetic diversity in the largest burn centre of northeast Iran. J Glob Antimicrob Resist 2017;8:60–6. doi:10.1016/j.jgar.2016.10.009.
[129] Bagheri Josheghani S, Moniri R, Firoozeh F, Sehat M, Dasteh Goli Y. Susceptibility pattern and distribution of oxacillinases and bla_{PER-1} genes among

multidrug resistant *Acinetobacter baumannii* in a teaching hospital in Iran. J Pathog 2015;2015:957259. doi:10.1155/2015/957259.
[130] Sarikhani Z, Nazari R, Rostami NN. First report of OXA-143-lactamase producing *Acinetobacter baumannii* in Qom. Iran. Iran J Basic Med Sci 2017;20:1282–6. doi:10.22038/IJBMS.2017.9490.
[131] Al Kaabi MR, Tariq WUZ, Hassanein AA. Rising bacterial resistance to common antibiotics in Al Ain, United Arab Emirates. East Mediterr Health J 2011;17:479–84. doi:10.26719/2011.17.6.479.
[132] Ghazawi A, Sonnevend Á, Bonnin RA, Poirel L, Nordmann P, Hashmey R, et al. NDM-2 carbapenemase-producing *Acinetobacter baumannii* in the United Arab Emirates. Clin Microbiol Infect 2012;18:E34–6. doi:10.1111/j.1469-0691.2011.03726.x.
[133] Zowawi HM, Sartor AL, Sidjabat HE, Balkhy HH, Walsh TR, Johani SMA, et al. Molecular epidemiology of carbapenem-resistant *Acinetobacter baumannii* isolates in the Gulf Cooperation Council states: dominance of OXA-23-type producers. J Clin Microbiol 2015;53:896–903. doi:10.1128/JCM.02784-14.
[134] Sonnevend Á, Ghazawi A, Al Munthari N, Pitout M, Hamadeh MB, Hashmey R, et al. Characteristics of epidemic and sporadic strains of *Acinetobacter baumannii* isolated in Abu Dhabi hospitals. J Med Microbiol 2013;62:582–90. doi:10.1099/jmm.0.055681-0.
[135] Al Samawi MS, Khan FY, Eldeeb Y, Almaslamani M, Alkhal A, Alsoub H, et al. *Acinetobacter* infections among adult patients in Qatar: a 2-year hospital-based study. Can J Infect Dis Med Microbiol 2016;2016:6873689. doi:10.1155/2016/6873689.
[136] Rolain J-M, Loucif L, Al-Maslamani M, Elmagboul E, Al-Ansari N, Taj-Aldeen S, et al. Emergence of multidrug-resistant *Acinetobacter baumannii* producing OXA-23 carbapenemase in Qatar. New Microbes New Infect 2016;11:47–51. doi:10.1016/j.nmni.2016.02.006.
[137] Ganjo AR, Maghdid DM, Mansoor IY, Kok DJ, Severin JA, Verbrugh HA, et al. OXA-carbapenemases present in clinical *Acinetobacter baumannii–calcoaceticus* complex isolates from patients in Kurdistan Region. Iraq. Microb Drug Resist 2016;22:627–37. doi:10.1089/mdr.2015.0060.
[138] Anoar KA, Ali FA, Omer SA. Detection of metallo β-lactamase enzyme in some Gram negative bacteria isolated from burn patients in Sulaimani City, Iraq. Eur Sci J 2014;10:485–96.
[139] Al-Sweih NA, Al-Hubail MA, Rotimi VO. Emergence of tigecycline and colistin resistance in *Acinetobacter* species isolated from patients in Kuwait hospitals. J Chemother 2011;23:13–16. doi:10.1179/joc.2011.23.1.13.
[140] Al-Sweih NA, Al-Hubail M, Rotimi VO. Three distinct clones of carbapenem-resistant *Acinetobacter baumannii* with high diversity of carbapenemases isolated from patients in two hospitals in Kuwait. J Infect Public Health 2012;5:102–8. doi:10.1016/j.jiph.2011.11.004.
[141] Bonnin RA, Rotimi VO, Al Hubail M, Gasiorowski E, Al Sweih N, Nordmann P, et al. Wide dissemination of GES-type carbapenemases in *Acinetobacter baumannii* isolates in Kuwait. Antimicrob Agents Chemother 2013;57:183–8. doi:10.1128/AAC.01384-12.
[142] Zorgani A, Ziglam H. Injured Libyan combatant patients: both vectors and victims of multiresistance bacteria? Libyan J Med 2013;8. doi:10.3402/ljm.v8i0.20325.
[143] Mathlouthi N, Areig Z, Al Bayssari C, Bakour S, El Salabi AA, Ben Gwierif S, et al. Emergence of carbapenem-resistant *Pseudomonas aeruginosa* and *Acinetobacter baumannii* clinical isolates collected from some Libyan hospitals. Microb Drug Resist 2015;21:335–41. doi:10.1089/mdr.2014.0235.
[144] Uwingabiye J, Frikh M, Lemnouer A, Bssaibis F, Belefquih B, Maleb A, et al. *Acinetobacter* infections prevalence and frequency of the antibiotics resistance: comparative study of intensive care units versus other hospital units. Pan Afr Med J 2016;23:191. doi:10.11604/pamj.2016.23.191.7915.
[145] El Hafa H, Nayme K, El Hamzaoui N, Maroui I, Sbiti M, Zerouali K, et al. Dissemination of carbapenem-resistant *Acinetobacter baumannii* strains carrying the bla_{GES}, bla_{NDM} and bla_{OXA23} in Morocco. Germs 2019;9:133–41. doi:10.18683/germs.2019.1168.
[146] Uwingabiye J, Lemnouer A, Roca I, Alouane T, Frikh M, Belefquih B, et al. Clonal diversity and detection of carbapenem resistance encoding genes among multidrug-resistant *Acinetobacter baumannii* isolates recovered from patients and environment in two intensive care units in a Moroccan hospital. Antimicrob Resist Infect Control 2017;6:99. doi:10.1186/s13756-017-0262-4.
[147] Natoubi S, Barguigua A, Zerhouni N, Baghdad N, Timinouni M, Hilali A, et al. First report of an OXA-58 carbapenemase-producing *Acinetobacter baumannii* isolated from urinary tract infection, in Morocco. Afr J Urol 2017;23:66–7. doi:10.1016/j.afju.2016.05.008.
[148] Balkhair A, Al-Muharrmi Z, Al'Adawi B, Al Busaidi I, Taher HB, Al-Siyabi T, et al. Prevalence and 30-day all-cause mortality of carbapenem- and colistin-resistant bacteraemia caused by *Acinetobacter baumannii, Pseudomonas aeruginosa*, and *Klebsiella pneumoniae*: description of a decade-long trend. Int J Infect Dis 2019;85:10–15. doi:10.1016/j.ijid.2019.05.004.
[149] Al-Kasaby N, Sachdeva V. Antibiotic resistance patterns of bacterial isolates in adult intensive care unit at Nizwa Hospital, Oman. Br Microbiol Res J 2015;10:1–10. doi:10.9734/bmrj/2015/20821.
[150] Obeidat N, Jawdat F, Al-Bakri AG, Shehabi AA. Major biologic characteristics of *Acinetobacter baumannii* isolates from hospital environmental and patients' respiratory tract sources. Am J Infect Control 2014;42:401–4. doi:10.1016/j.ajic.2013.10.010.
[151] Qouzah HF, Hawari F, Abu-Qatouseh LF, Shehabi AA. Occurrence and molecular characterization of metallo-β-lactamases (MBLs) among *Acinetobacter baumannii* isolates from cancer patients. Int Arab J Antimicrob Agents 2018;8. doi:10.3823/821.
[152] Ali Mohammed Zabad A, Ayesh Mohammed Saghir S, Kassem Al-Madhagi A, Abdulkarim Al-Moyed K. *Acinetobacter baumannii* complex and its antibiotics susceptibility in selected hospital's intensive care units at Sana'a city–Yemen. Glob Adv Res J Microbiol 2018;7:047–56.
[153] Bakour S, Alsharapy SA, Touati A, Rolain JM. Characterization of *Acinetobacter baumannii* clinical isolates carrying bla_{OXA-23} carbapenemase and 16S rRNA methylase *armA* genes in Yemen. Microb Drug Resist 2014;20:604–9. doi:10.1089/mdr.2014.0018.
[154] Handal R, Qunibi L, Sahouri I, Juhari M, Dawodi R, Marzouqa H, et al. Characterization of carbapenem-resistant *Acinetobacter baumannii* strains isolated from hospitalized patients in Palestine. Int J Microbiol 2017;2017:8012104. doi:10.1155/2017/8012104.
[155] Sjölander I, Hansen F, Elmanama A, Khayyat R, Abu-Zant A, Hussein A, et al. Detection of NDM-2-producing *Acinetobacter baumannii* and VIM-producing *Pseudomonas aeruginosa* in Palestine. J Glob Antimicrob Resist 2014;2:93–7. doi:10.1016/j.jgar.2013.11.002.
[156] Rafei R, Pailhoriès H, Hamze M, Eveillard M, Mallat H, Dabboussi F, et al. Molecular epidemiology of *Acinetobacter baumannii* in different hospitals in Tripoli, Lebanon using $bla_{OXA-51-like}$ sequence based typing. BMC Microbiol 2015;15:103. doi:10.1186/s12866-015-0441-5.
[157] Mugnier PD, Bindayna KM, Poirel L, Nordmann P. Diversity of plasmid-mediated carbapenem-hydrolysing oxacillinases among carbapenem-resistant *Acinetobacter baumannii* isolates from Kingdom of Bahrain. J Antimicrob Chemother 2009;63:1071–3. doi:10.1093/jac/dkp052.
[158] Hasan B, Perveen K, Olsen B, Zahra R. Emergence of carbapenem-resistant *Acinetobacter baumannii* in hospitals in Pakistan. J Med Microbiol 2013;63:50–5. doi:10.1099/jmm.0.063925-0.
[159] Khurshid M, Rasool MH, Ashfaq UA, Aslam B, Waseem M. Emergence of IS*Aba1* harboring carbapenem-resistant *Acinetobacter baumannii* isolates in Pakistan. Future Microbiol 2017;12:1261–9. doi:10.2217/fmb-2017-0080.
[160] Hammoudi Halat D, Moubareck CA, Sarkis DK. Heterogeneity of carbapenem resistance mechanisms among Gram-negative pathogens in Lebanon: results of the first cross-sectional countrywide study. Microb Drug Resist 2017;23:733–43. doi:10.1089/mdr.2016.0077.
[161] Al Bayssari C, Diene SM, Loucif L, Gupta SK, Dabboussi F, Mallat H, et al. Emergence of VIM-2 and IMP-15 carbapenemases and inactivation of *oprD* gene in carbapenem-resistant *Pseudomonas aeruginosa* clinical isolates from Lebanon. Antimicrob Agents Chemother 2014;58:4966–70. doi:10.1128/AAC.02523-13.
[162] Zafer MM, Al-Agamy MH, El-Mahallawy HA, Amin MA, Ashour MSED. Antimicrobial resistance pattern and their β-lactamase encoding genes among *Pseudomonas aeruginosa* strains isolated from cancer patients. Biomed Res Int 2014;2014:101635. doi:10.1155/2014/101635.
[163] Abaza AF, El Shazly SA, Selim HSA, Aly GSA. Metallo-β-lactamase producing *Pseudomonas aeruginosa* in a healthcare setting in Alexandria, Egypt. Pol J Microbiol 2017;66:297–308. doi:10.5604/01.3001.0010.4855.
[164] Hashem H, Hanora A, Abdalla S, Shawky A, Saad A. Carbapenem susceptibility and multidrug-resistance in *Pseudomonas aeruginosa* isolates in Egypt. Jundishapur J Microbiol 2016;9:30257. doi:10.5812/jjm.30257.
[165] Zafer MM, Amin M, ElMahallawy H, Ashour MSED, AlAgamy M. First report of NDM-1-producing *Pseudomonas aeruginosa* in Egypt. Int J Infect Dis 2014;29:e80–1. doi:10.1016/j.ijid.2014.07.008.
[166] Khalifa HO, Soliman AM, Ahmed AM, Shimamoto T, Hara T, Ikeda M, et al. High carbapenem resistance in clinical Gram-negative pathogens isolated in Egypt. Microb Drug Resist 2017;23:838–44. doi:10.1089/mdr.2015.0339.
[167] Hashem H, Hanora A, Abdalla S, Shaeky A, Saad A. Dissemination of metallo-β-lactamase in *Pseudomonas aeruginosa* isolates in Egypt: mutation in bla_{VIM-4}. APMIS 2017;125:499–505. doi:10.1111/apm.12669.
[168] Al-Agamy Mohamed H. Antimicrobial resistance pattern and prevalence of metallo-β-lactamases in *Pseudomonas aeruginosa* from Saudi Arabia. Afr J Microbiol Res 2011;5. doi:10.5897/ajmr11.1024.
[169] Tawfik AF, Shibl AM, Aljohi MA, Altammami MA, Al-Agamy MH. Distribution of Ambler class A, B and D β-lactamases among *Pseudomonas aeruginosa* isolates. Burns 2012;38:855–60. doi:10.1016/j.burns.2012.01.005.
[170] Khan MA, Faiz A. Antimicrobial resistance patterns of *Pseudomonas aeruginosa* in tertiary care hospitals of Makkah and Jeddah. Ann Saudi Med 2016;36:23–8. doi:10.5144/0256-4947.2016.23.
[171] Zowawi HM, Syrmis MW, Kidd TJ, Balkhy HH, Walsh TR, Al Johani SM, et al. Identification of carbapenem-resistant *Pseudomonas aeruginosa* in selected hospitals of the Gulf Cooperation Council states: dominance of high-risk clones in the region. J Med Microbiol 2018;67:846–53. doi:10.1099/jmm.0.000730.
[172] Chairat S, Ben Yahia H, Rojo-Bezares B, Sáenz Y, Torres C, Ben Slama K. High prevalence of imipenem-resistant and metallo-β-lactamase-producing *Pseudomonas aeruginosa* in the burns hospital in Tunisia: detection of a novel class 1 integron. J Chemother 2019;31:120–6. doi:10.1080/1120009X.2019.1582168.
[173] Hammami S, Boutiba-Ben Boubaker I, Ghozzi R, Saidani M, Amine S, Ben Redjeb S. Nosocomial outbreak of imipenem-resistant *Pseudomonas aeruginosa* producing VIM-2 metallo-β-lactamase in a kidney transplantation unit. Diagn Pathol 2011;6:106. doi:10.1186/1746-1596-6-106.
[174] Ktari S, Mnif B, Znazen A, Rekik M, Mezghani S, Mahjoubi-Rhimi F, et al. Diversity of β-lactamases in *Pseudomonas aeruginosa* isolates producing metallo-β-lactamase in two Tunisian hospitals. Microb Drug Resist 2011;17:25–30. doi:10.1089/mdr.2010.0104.
[175] Lari AR, Azimi L, Soroush S, Taherikalani M. Low prevalence of metallo-β-lactamase in *Pseudomonas aeruginosa* isolated from a tertiary burn care cen-

ter in Tehran. Int J Immunopathol Pharmacol 2015;28:384–9. doi:10.1177/0394632015578343.
[176] Farajzadeh Sheikh A, Shahin M, Shokoohizadeh L, Halaji M, Shahcheraghi F, Ghanbari F. Molecular epidemiology of colistin-resistant *Pseudomonas aeruginosa* producing NDM-1 from hospitalized patients in Iran. Iran J Basic Med Sci 2019;22:38–42. doi:10.22038/ijbms.2018.29264.7096.
[177] Ayoub Moubareck C, Hammoudi Halat D, Akkawi C, Nabi A, AlSharhan MA, AlDeesi ZO, et al. Role of outer membrane permeability, efflux mechanism, and carbapenemases in carbapenem-nonsusceptible *Pseudomonas aeruginosa* from Dubai hospitals: results of the first cross-sectional survey. Int J Infect Dis 2019;84:143–50. doi:10.1016/j.ijid.2019.04.027.
[178] Al-Charrakh AH, Al-Awadi SJ, Mohammed AS. Detection of metallo-β-lactamase producing *Pseudomonas aeruginosa* isolated from public and private hospitals in Baghdad, Iraq. Acta Med Iran 2016;54:107–13.
[179] Mohammed Alshara JR, Sadiq Alsehlawi ZR, Shnan Aljameel DA, Sh Al-Zubbedy Z, Almohana AM. First report of New Delhi metallo-β-lactamase (NDM-1) producing *Pseudomonas aeruginosa* in Iraq. J Biol Agric Healthc 2014;4:40–7.
[180] Al Benwan K, Al Mulla A, Rotimi VO. A study of the microbiology of diabetic foot infections in a teaching hospital in Kuwait. J Infect Public Health 2012;5:1–8. doi:10.1016/j.jiph.2011.07.004.
[181] El Essawy AK, Abu Shady HM, El Biaa BA. Prevalence and impact of carbapenemase-encoding genes in clinical isolates of carbapenem-resistant *Pseudomonas aeruginosa*. J Exp Biol 2018;14:161–9. doi:10.5455/egyjebb.20180419081423.
[182] Maroui I, Barguigua A, Aboulkacem A, Ouarrak K, Sbiti M, Louzi H, et al. First report of VIM-2 metallo-β-lactamases producing *Pseudomonas aeruginosa* isolates in Morocco. J Infect Chemother 2016;22:127–32. doi:10.1016/j.jiac.2015.11.008.
[183] Elnasser ZA, Al Aseel SM. Antibiotic resistance of *Pseudomonas aeruginosa* isolates from patients in King Abdullah University Hospital in Jordan. J Chemother 2009;21:356–9. doi:10.1179/joc.2009.21.3.356.
[184] Al Dawodeyah HY, Obeidat N, Abu-Qatouseh LF, Shehabi AA. Antimicrobial resistance and putative virulence genes of *Pseudomonas aeruginosa* isolates from patients with respiratory tract infection. Germs 2018;8:31.
[185] Rodriguez-Martinez LM. Prevalence of *Pseudomonas aeruginosa* (*P. aeruginosa*) and antimicrobial susceptibility patterns at a local hospital in Sana'a, Yemen. Immunome Res 2018;14:7580. doi:10.4172/1745-7580-c3-020.
[186] Nasser M, Kharat AS. Phenotypic demonstration of β-lactamase (ESβLs, MβLs, and Amp-C) among MDR *Pseudomonas aeruginosa* isolates obtained from burn wound infected in Yemen. J Appl Biol Biotechnol 2019;7:31–4. doi:10.7324/JABB.2019.70605.
[187] Elnour Rahma Mohamed S, Alobied A, Ibrahim Saeed M, Mohamed Hussien W. New Delhi metallo-β-lactamase (NDM)-mediated carbapenem-resistant *Pseudomonas aeruginosa* clinical isolates in Sudan. South Asian J Res Microbiol 2018;1:1–5. doi:10.9734/sajrm/2018/v1i3775.
[188] Rida RH, Al Laham NA, Elmanama AA. Carbapenem resistance among clinical and environmental Gram-negative isolates recovered from hospitals in Gaza Strip. Palestine. Germs 2018;8:147–54.
[189] Adwan G, Shtayah A, Adwan K, Al-Sheboul S, Othman S. Prevalence and molecular characterization of *P. aeruginosa* isolates in the West Bank–Palestine for ESBLs, MBLs and Integrons. J Appl Life Sci Int 2016;8:1–11. doi:10.9734/jalsi/2016/29259.
[190] Mahfoud M, Al Najjar M, Hamzeh AR. Multidrug resistance in *Pseudomonas aeruginosa* isolated from nosocomial respiratory and urinary infections in Aleppo, Syria. J Infect Dev Ctries 2015;9:210–13. doi:10.3855/jidc.5643.
[191] Joji RM, Al-Rashed N, Saeed NK, Bindayna KM. Detection of VIM and NDM-1 metallo-β-lactamase genes in carbapenem-resistant *Pseudomonas aeruginosa* clinical strains in Bahrain. J Lab Physicians 2019;11:138–43. doi:10.4103/JLP.JLP_118_18.
[192] Braun SD, Jamil B, Syed MA, Abbasi SA, Weiß D, Slickers P, et al. Prevalence of carbapenemase-producing organisms at the Kidney Center of Rawalpindi (Pakistan) and evaluation of an advanced molecular microarray-based carbapenemase assay. Future Microbiol 2018;13:1225–46. doi:10.2217/fmb-2018-0082.
[193] Badur S, Öztürk S, Pereira P, AbdelGhany M, Khalaf M, Lagoubi Y, et al. Systematic review of the rotavirus infection burden in the WHO-EMRO region. Hum Vaccines Immunother 2019;15:2754–68. doi:10.1080/21645515.2019.1603984.