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## Wide spread of OXA-23-producing carbapenem-resistant *Acinetobacter baumannii* belonging to clonal complex II in different hospitals in Lebanon



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### SUMMARY

**Objectives:** To investigate the molecular epidemiology of *Acinetobacter baumannii* strains isolated from different hospitals in Lebanon.

**Methods:** A total of 119 non-duplicate *Acinetobacter* strains were identified using matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (MALDI-TOF MS) and partial *rpoB* gene sequencing. Antibiotic susceptibility testing was performed by disc diffusion method and all identified carbapenem-resistant isolates were investigated by PCR assays for the presence of the carbapenemase-encoding genes. Multilocus sequence typing (MLST) and pulsed-field gel electrophoresis (PFGE) were used for molecular typing.

**Results:** Of the 119 *A. baumannii* isolates, 76.5% were resistant to carbapenems. The most common carbapenemase was the OXA-23-type, found in 82 isolates. The study of population structure using MLST revealed the presence of 30 sequence types (STs) including 18 new ones, with ST2 being the most commonly detected, accounting for 61% of the isolates typed. PFGE performed on all strains of ST2 identified a major cluster of 53 isolates, in addition to three other minor clusters and ten unique profiles.

**Conclusions:** This study highlights the wide dissemination of highly related OXA-23-producing carbapenem-resistant *A. baumannii* belonging to the international clone II in Lebanon. Thus, appropriate infection control measures are recommended in order to control the geographical spread of this clone in this country.

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## 1. Introduction

*Acinetobacter baumannii* is one of the most common opportunistic Gram-negative bacteria associated with community-acquired infections, outbreaks, and nosocomial infections, particularly in critically ill patients. This bacterium is involved in respiratory tract infections, bloodstream infections, skin and soft tissue infections, urinary tract infections, and meningitis, leading to increased rates of mortality and morbidity.<sup>1,2</sup>

Infections caused by *A. baumannii* are an increasing threat in many countries. Indeed, this bacterium has a strong ability to resist desiccation and to survive on inanimate surfaces. Moreover, the prevalence of multidrug-resistant (MDR) isolates has increased worldwide in recent decades,<sup>3,4</sup> due to its ability to develop multidrug resistance through either the acquisition of genetic determinants such as plasmids, integrons, and transposons, or through the acquisition of mutations leading to the modification of antibiotic targets, efflux pump expression, and membrane permeability.<sup>5</sup> As a consequence, the treatment of infections caused by such isolates has become more and more difficult, even with most clinically available drugs, including tigecycline, colistin, and carbapenems.<sup>1,4,6</sup>

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A recent retrospective nationwide study conducted by the Lebanese Society of Infectious Diseases showed that the percentage of resistance to imipenem among *Acinetobacter* spp increased significantly from 57.6% in 2011 to 84.5% in 2013.<sup>7</sup> In *A. baumannii*, carbapenem resistance was mostly associated with the production of carbapenem-hydrolyzing class D  $\beta$ -lactamases (CHDLs), including OXA-23, OXA-24, OXA-58, OXA-143, and OXA-235, in addition to carbapenemases from classes B and A.<sup>6</sup>

Nowadays, understanding the molecular characteristics of epidemic strains is the key strategy to track outbreaks and to control the spread of *A. baumannii*, both in hospitals and in the community.<sup>8,9</sup> Several molecular typing methods have been developed for this purpose. Among them, pulsed field gel electrophoresis (PFGE) and multilocus sequence typing (MLST) have been the most frequently used and have represented the gold standard methods to investigate strain clonality and the bacterial population structure, respectively.<sup>10</sup> Molecular epidemiological studies have revealed *A. baumannii* outbreaks to have been caused mainly by MDR strains belonging to the international clonal complexes CC1, CC2, and CC3.<sup>8,11</sup> In Lebanon, previous studies have reported the predominance of carbapenem-resistant *A. baumannii* strains belonging to the international clone II.<sup>12,13</sup>

The main objectives of this work were to investigate the prevalence of carbapenem-resistant *A. baumannii* isolates (CRAB) circulating in some Lebanese hospitals between 2013 and 2015, and to characterize the common resistance mechanisms. The population structure, as well as the genetic relatedness of CRAB isolates, was also studied in order to track the evolution and the clonality of these strains.

## 2. Materials and methods

### 2.1. Bacterial strain collection and identification

A total of 119 non-replicate *A. baumannii* clinical isolates were analyzed. These strains were collected between October 2013 and December 2015 from the following hospitals in Lebanon: Tripoli Governmental Hospital (TGH; 100 beds), Nini Hospital (NH; 120 beds), Makassed General Hospital (MGH; 150 beds), Saydet Zgharta Hospital (SZH; 149 beds), Hanane Hospital (HH; 45 beds), Al Youssef Medical Centre (YMC; 100 beds), Seblin Governmental Hospital (SGH; 70 beds), and Dar Ajaza Hospital (DAH; 580 beds). Isolates were sent to the Laboratory of Microbiology Health and Environment (LMSE), Tripoli, Lebanon, and were stored at  $-80^{\circ}\text{C}$ . Bacterial identification was performed by matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (MALDI-TOF MS) using the Vitek MS (bioMérieux, Marcy l'Etoile, France), and confirmed at the species level by partial RNA polymerase  $\beta$ -subunit (*rpoB*) gene sequencing, as described previously.<sup>13</sup> For each isolate, information on the sex and age of the patient, the clinical specimen, and the type of ward were provided.

### 2.2. Antibiotic susceptibility testing and investigation of carbapenem resistance mechanisms

Antibiotic susceptibility testing was performed by disc diffusion method according to the recommendations of the European Committee on Antimicrobial Susceptibility Testing (<http://www.eucast.org>). A panel of 14 antibiotics was tested, including ticarcillin, ticarcillin-clavulanic acid, piperacillin-tazobactam, ceftazidime, imipenem, ciprofloxacin, amikacin, gentamicin, tobramycin, trimethoprim-sulfamethoxazole, colistin, doxycycline, tigecycline, and rifampicin. Carbapenem resistance was confirmed by determining minimum inhibitory concentration (MICs) against imipenem and meropenem by Etest strips (bioMérieux).

Carbapenem-resistant isolates were investigated by PCR assays for the presence of the carbapenemase-encoding genes *bla*<sub>OXA-23-like</sub>, *bla*<sub>OXA-24-like</sub>, *bla*<sub>OXA-58-like</sub>, *bla*<sub>OXA-143</sub>, *bla*<sub>NDM</sub>, *bla*<sub>IMP</sub>, and *bla*<sub>VIM</sub>.<sup>12</sup> Sequencing of the entire gene was performed on all New Delhi metallo- $\beta$ -lactamase (NDM)-positive isolates.

### 2.3. Epidemiological typing

#### 2.3.1. Multilocus sequence typing (MLST)

MLST was performed according to the Pasteur scheme (<http://www.pasteur.fr/recherche/genopole/PF8/mlst/Abaumannii.html>). The internal fragments of seven housekeeping genes (*fusA*, *pyrG*, *rpoB*, *rplB*, *cpn60*, *gltA*, and *recA*) were amplified, then purified and sequenced using an ABI 3130XL DNA sequencer (Applied Biosystems, Foster City, CA, USA). The allelic number and sequence types (STs) were analyzed using the *A. baumannii* MLST database. New STs were submitted and assigned by the Institut Pasteur MLST database. The clustering of related STs (defined as clonal complexes, CCs) was analyzed using eBURST software (<http://eburst.mlst.net>). A CC is defined as a set of similar ST(s) having six identical loci among seven, so a CC is formed by the founder ST and its single locus variants (SLV).

#### 2.3.2. Pulsed field gel electrophoresis (PFGE)

*A. baumannii* DNA was digested with *Apal* (TaKaRa, Dalian, Liaoning Province, China) as a restriction enzyme. DNA fragments were separated on 1% w/v agarose gels in 0.5 $\times$  Tris/borate/ethylenediaminetetraacetic acid (TBE) buffer at 14  $^{\circ}\text{C}$  using a CHEF DRII apparatus (Bio-Rad) with 6 V/cm, pulsed from 3 to 20 s for 21 h; gels were stained with Gel Red. The Dice coefficient was used to calculate similarities, and the unweighted pair group method using average linkages (UPGMA) was used for cluster analysis with fingerprinting II software (Bio-Rad, Marne La Coquette, France). Isolates were considered to belong to the same PFGE clone if their Dice similarity index was  $\geq 80\%$ .

## 3. Results

### 3.1. Bacterial strain collection and identification

The 119 isolates analyzed in this study were collected from seven hospitals situated in different regions in Lebanon: North of Lebanon, Beirut, and Mount of Lebanon. Forty-eight isolates were from Tripoli Governmental Hospital (Tripoli, North of Lebanon), 40 from Nini Hospital (Tripoli, North of Lebanon), 21 from Makassed General Hospital (Beirut), four from Saydet Zgharta Hospital (Zgharta, North of Lebanon), two from each of Hanane Hospital (Tripoli, North of Lebanon) and Al Youssef Medical Centre (Akkar, North of Lebanon), and one from each of Dar Ajaza (Beirut) and Seblin Governmental Hospital (Seblin, Mount of Lebanon). The isolates were mostly recovered from the respiratory tract ( $n = 35$ ; 29%) and skin and soft tissue ( $n = 33$ ; 28%), followed by urine ( $n = 14$ ; 12%), blood ( $n = 9$ ; 7.6%), and vascular catheters ( $n = 6$ ; 5%). Of note, 19 (13.4%) patients were asymptotically colonized (Table 1).

### 3.2. Antibiotic susceptibility testing and investigation of carbapenem resistance mechanisms

Antibiotic susceptibility testing showed that the *A. baumannii* isolates analyzed were MDR. Indeed, most of them were resistant to  $\beta$ -lactams, aminoglycosides, ciprofloxacin, and doxycycline. However, only four isolates were resistant to rifampicin and one isolate to tigecycline, while colistin and tigecycline maintained their activity against all isolates. Among the isolates, 91 (76.5%) showed an imipenem-resistant phenotype. Etest results confirmed

**Table 1**  
Characteristics of *Acinetobacter baumannii* isolates

| Strain ID | Sex | Age, years | Origin                  | Year of study | City    | Hospital | Department | Carbapenem phenotype <sup>a</sup> | Resistance genes | ST  | CC <sup>b</sup> |
|-----------|-----|------------|-------------------------|---------------|---------|----------|------------|-----------------------------------|------------------|-----|-----------------|
| 1         | M   | NA         | Tracheal aspirate       | 2013          | Tripoli | TGH      | ICU        | S                                 | -                | 698 | S               |
| 2         | F   | 65         | Rectal swab             | 2013          | Tripoli | NH       | ICU        | R                                 | OXA-23           | 2   | 2               |
| 3         | F   | 76         | Tracheal aspirate       | 2013          | Tripoli | NH       | ICU        | R                                 | OXA-23           | 2   | 2               |
| 4         | M   | 18         | Wound                   | 2013          | Tripoli | TGH      | IM         | R                                 | OXA-23           | 2   |                 |
| 5         | F   | NA         | Broncho-tracheal lavage | 2013          | Tripoli | TGH      | IM         | R                                 | OXA-23           | 2   | 2               |
| 6         | M   | NA         | Wound                   | 2013          | Tripoli | TGH      | IM         | R                                 | OXA-23           | 2   | 2               |
| 7         | M   | 66         | Tracheal aspirate       | 2013          | Tripoli | TGH      | IM         | R                                 | OXA-23           | 2   | 2               |
| 8         | M   | NA         | Wound                   | 2013          | Tripoli | TGH      | IM         | R                                 | OXA-23           | 2   | 2               |
| 9         | M   | 45         | Catheter                | 2013          | Tripoli | HH       | NA         | R                                 | OXA-23           | 2   |                 |
| 10        | F   | 81         | Rectal swab             | 2014          | Tripoli | NH       | ICU        | R                                 | OXA-23           | 2   | 2               |
| 11        | F   | 39         | Wound                   | 2014          | Tripoli | TGH      | IM         | R                                 | OXA-23           | 2   | 2               |
| 12        | M   | NA         | Broncho-tracheal lavage | 2014          | Tripoli | TGH      | ICU        | R                                 | OXA-23           | 2   | 2               |
| 13        | M   | NA         | Blood                   | 2014          | Tripoli | TGH      | IM         | R                                 | NDM-1            | 85  | 85              |
| 14        | M   | 82         | Rectal swab             | 2014          | Tripoli | NH       | IM         | S                                 | -                | 600 | 2               |
| 15        | F   | NA         | NA                      | 2014          | Tripoli | HH       | NA         | R                                 | OXA-23           | 2   | 2               |
| 16        | F   | 86         | Tracheal aspirate       | 2014          | Tripoli | NH       | ICU        | R                                 | OXA-23           | 2   | 2               |
| 19        | F   | 23         | Urine                   | 2014          | Tripoli | NH       | OP         | S                                 | -                | 701 | S               |
| 20        | F   | 84         | Nasal swab              | 2014          | Tripoli | NH       | ICU        | R                                 | OXA-23           | 2   | 2               |
| 21        | M   | 21         | Wound                   | 2014          | Tripoli | TGH      | IM         | R                                 | OXA-23           | 2   | 2               |
| 22        | F   | NA         | Sputum                  | 2014          | Tripoli | TGH      | ICU        | R                                 | OXA-23/OXA-24    | 2   | 2               |
| 23        | M   | 60         | NA                      | 2014          | Zgharta | SZH      | NA         | S                                 | -                | 2   | 2               |
| 24        | M   | NA         | Blood                   | 2014          | Tripoli | TGH      | ICU        | S                                 | -                | 702 | S               |
| 26        | F   | NA         | Wound                   | 2014          | Tripoli | TGH      | IM         | R                                 | OXA-23           | 2   | 2               |
| 27        | M   | 83         | Rectal swab             | 2014          | Tripoli | NH       | IM         | S                                 | -                | 2   | 2               |
| 28        | M   | NA         | Sputum                  | 2014          | Tripoli | TGH      | ICU        | R                                 | OXA-23           | 2   | 2               |
| 29        | F   | 38         | Urine                   | 2014          | Tripoli | NH       | OP         | S                                 | -                | 704 | S               |
| 30        | F   | NA         | Catheter                | 2014          | Tripoli | TGH      | ICU        | S                                 | -                | 702 | S               |
| 33        | M   | NA         | Sputum                  | 2014          | Tripoli | TGH      | ICU        | S                                 | -                | 702 | S               |
| 34        | F   | 78         | Urine                   | 2014          | Tripoli | NH       | NA         | S                                 | -                | 46  | S               |
| 35        | M   | NA         | NA                      | 2014          | Zgharta | SZH      | NA         | R                                 | OXA-23           | 705 | S               |
| 36        | M   | NA         | Sputum                  | 2014          | Tripoli | TGH      | NA         | S                                 | -                | 702 | S               |
| 38        | M   | 44         | Tracheal aspirate       | 2014          | Tripoli | NH       | ICU        | R                                 | OXA-23           | 2   | 2               |
| 39        | M   | NA         | Broncho-tracheal lavage | 2014          | Tripoli | TGH      | IM         | R                                 | OXA-23           | 2   | 2               |
| 40        | M   | 84         | Urine                   | 2014          | Tripoli | NH       | IM         | S                                 | -                | 2   | 2               |
| 43        | M   | 27         | Rectal swab             | 2014          | Tripoli | NH       | ICU        | S                                 | -                | 25  | 25              |
| 44        | M   | NA         | Wound                   | 2014          | Tripoli | TGH      | IM         | R                                 | OXA-143          | 2   | 2               |
| 45        | F   | 60         | Wound                   | 2014          | Tripoli | TGH      | ICU        | R                                 | OXA-23           | 2   | 2               |
| 46        | M   | NA         | Wound                   | 2014          | Tripoli | TGH      | IM         | R                                 | OXA-23           | 2   | 2               |
| 47        | M   | NA         | Wound                   | 2014          | Tripoli | TGH      | IM         | R                                 | OXA-23           | 2   | 2               |
| 48        | F   | NA         | Wound                   | 2014          | Tripoli | TGH      | IM         | R                                 | OXA-23           | 2   | 2               |
| 50        | M   | NA         | Sputum                  | 2014          | Tripoli | TGH      | ICU        | R                                 | OXA-23           | 2   | 2               |
| 51        | M   | NA         | Blood                   | 2014          | Tripoli | TGH      | ICU        | R                                 | OXA-23           | 2   | 2               |
| 53        | M   | 65         | Rectal swab             | 2014          | Tripoli | TGH      | ICU        | S                                 | -                | 52  | S               |
| 54        | F   | NA         | Wound                   | 2014          | Tripoli | TGH      | OP         | S                                 | -                | 690 | S               |
| 55        | M   | 81         | Bed swab                | 2014          | Seblin  | SGH      | ICU        | R                                 | OXA-23           | 706 | S               |
| 56        | M   | 77         | Wound                   | 2014          | Tripoli | NH       | ICU        | S                                 | -                | 25  | 25              |
| 58        | M   | NA         | Wound                   | 2014          | Tripoli | TGH      | IM         | R                                 | OXA-23           | 2   | 2               |
| 59        | F   | NA         | Urine                   | 2014          | Tripoli | TGH      | IM         | R                                 | OXA-23/OXA-24    | 2   | 2               |
| 60        | M   | 47         | Pus                     | 2014          | Tripoli | NH       | OP         | S                                 | -                | 1   | 1               |
| 61        | M   | 82         | Sputum                  | 2014          | Zgharta | SZH      | NA         | R                                 | OXA-23           | 2   | 2               |
| 62        | M   | 23         | Wound                   | 2014          | Tripoli | TGH      | IM         | R                                 | OXA-23           | 2   | 2               |
| 63        | M   | 64         | LCR                     | 2014          | Tripoli | NH       | ICU        | S                                 | -                | 25  | 25              |
| 64        | F   | NA         | Wound                   | 2014          | Tripoli | TGH      | IM         | R                                 | OXA-23           | 2   | 2               |
| 65        | F   | 69         | Tracheal aspirate       | 2015          | Tripoli | NH       | ICU        | R                                 | OXA-23           | 2   | 2               |
| 66        | F   | NA         | Wound                   | 2015          | Tripoli | TGH      | ICU        | R                                 | NDM-1            | 85  | 85              |
| 67        | M   | 75         | Pus                     | 2015          | Tripoli | NH       | ICU        | R                                 | OXA-23           | 707 | S               |
| 68        | M   | NA         | Pus                     | 2015          | Tripoli | TGH      | IM         | R                                 | NDM-1            | 708 | S               |
| 69        | M   | 75         | Nasal swab              | 2015          | Tripoli | TGH      | ICU        | R                                 | OXA-23/OXA-58    | 2   | 2               |
| 70        | M   | 75         | Rectal swab             | 2015          | Tripoli | NH       | ICU        | R                                 | OXA-23           | 2   | 2               |
| 71        | NA  | NA         | Pus                     | 2015          | Zgharta | SZH      | NA         | R                                 | OXA-23           | 2   | 2               |
| 72        | F   | 18         | Catheter                | 2015          | Tripoli | NH       | ICU        | R                                 | OXA-23           | 2   | 2               |
| 73        | M   | 84         | Rectal swab             | 2015          | Tripoli | NH       | ICU        | R                                 | OXA-23           | 2   | 2               |
| 74        | M   | 75         | Nasal swab              | 2015          | Tripoli | NH       | ICU        | R                                 | OXA-23           | 2   | 2               |
| 75        | F   | 18         | Tracheal aspirate       | 2015          | Tripoli | NH       | ICU        | R                                 | OXA-23           | 2   | 2               |
| 76        | M   | 82         | Rectal swab             | 2015          | Tripoli | NH       | ICU        | S                                 | -                | 2   | 2               |
| 77        | F   | 69         | Axillary swab           | 2015          | Tripoli | NH       | ICU        | R                                 | OXA-23           | 2   | 2               |
| 78        | F   | 63         | Urine                   | 2015          | Tripoli | NH       | ICU        | S                                 | -                | 807 | S               |
| 79        | M   | 84         | Urine                   | 2015          | Tripoli | NH       | ICU        | S                                 | -                | 25  | 25              |
| 80        | M   | NA         | Catheter                | 2015          | Tripoli | NH       | ICU        | S                                 | -                | 25  | 25              |
| 81        | F   | 78         | Urine                   | 2015          | Beirut  | DAH      | IM         | R                                 | OXA-23/OXA-24    | 2   | 2               |
| 82        | M   | NA         | Blood                   | 2015          | Tripoli | TGH      | ICU        | S                                 | -                | 424 | 33              |
| 83        | M   | NA         | Tracheal aspirate       | 2015          | Tripoli | TGH      | ICU        | R                                 | NDM-1            | 708 | S               |
| 84        | M   | 70         | Blood                   | 2014          | Beirut  | MGH      | IM         | R                                 | OXA-23           | 2   | 2               |
| 85        | M   | 64         | Tracheal aspirate       | 2014          | Beirut  | MGH      | IM         | R                                 | OXA-23           | 2   | 2               |
| 86        | M   | 66         | Tracheal aspirate       | 2015          | Beirut  | MGH      | IM         | R                                 | OXA-23           | 2   | 2               |

Table 1 (Continued)

| Strain ID | Sex | Age, years | Origin                  | Year of study | City    | Hospital | Department | Carbapenem phenotype <sup>a</sup> | Resistance genes | ST  | CC <sup>b</sup> |
|-----------|-----|------------|-------------------------|---------------|---------|----------|------------|-----------------------------------|------------------|-----|-----------------|
| 87        | M   | 82         | Tracheal aspirate       | 2014          | Beirut  | MGH      | ICU        | R                                 | OXA-23/OXA-24    | 711 | S               |
| 88        | F   | 81         | Tracheal aspirate       | 2015          | Beirut  | MGH      | IM         | R                                 | OXA-23           | 2   | 2               |
| 89        | M   | 83         | Tracheal aspirate       | 2015          | Beirut  | MGH      | IM         | R                                 | OXA-23           | 2   | 2               |
| 90        | F   | 83         | Pus                     | 2015          | Beirut  | MGH      | IM         | R                                 | OXA-23           | 570 | 2               |
| 91        | F   | 87         | Blood                   | 2015          | Beirut  | MGH      | IM         | R                                 | OXA-23/OXA-24    | 715 | S               |
| 92        | M   | 19         | Tracheal aspirate       | 2015          | Beirut  | MGH      | ICU        | R                                 | OXA-23           | 570 | 2               |
| 93        | F   | 67         | Blood                   | 2015          | Beirut  | MGH      | CCU        | R                                 | OXA-23           | 570 | 2               |
| 94        | M   | 58         | Tracheal aspirate       | 2015          | Beirut  | MGH      | CCU        | R                                 | OXA-23           | 600 | 2               |
| 95        | M   | 26         | Tracheal aspirate       | 2014          | Beirut  | MGH      | IM         | R                                 | OXA-23           | 2   | 2               |
| 96        | F   | 71         | Tracheal aspirate       | 2015          | Beirut  | MGH      | SURG       | R                                 | OXA-23           | 570 | 2               |
| 97        | M   | 63         | Tracheal aspirate       | 2015          | Beirut  | MGH      | IM         | R                                 | OXA-23           | 2   | 2               |
| 98        | M   | 31         | Pus                     | 2015          | Beirut  | MGH      | IM         | R                                 | OXA-23           | 2   | 2               |
| 99        | M   | 79         | Sputum                  | 2015          | Beirut  | MGH      | CCU        | R                                 | OXA-23           | 2   | 2               |
| 100       | F   | 47         | Sputum                  | 2015          | Beirut  | MGH      | IM         | R                                 | OXA-23           | 713 | 2               |
| 101       | F   | 74         | Tracheal aspirate       | 2015          | Beirut  | MGH      | IM         | R                                 | OXA-23           | 2   | 2               |
| 102       | F   | 84         | Blood                   | 2015          | Beirut  | MGH      | CCU        | R                                 | OXA-23/OXA-24    | 714 | S               |
| 103       | F   | 84         | Tracheal aspirate       | 2015          | Beirut  | MGH      | ICU        | R                                 | OXA-23           | 2   | 2               |
| 104       | F   | 93         | Tracheal aspirate       | 2015          | Beirut  | MGH      | ICU        | R                                 | OXA-23           | 600 | 2               |
| 105       | F   | 50         | Urine                   | 2015          | Tripoli | NH       | IM         | S                                 | -                | 808 | S               |
| 106       | M   | 42         | Pus                     | 2015          | Tripoli | NH       | IM         | R                                 | OXA-23           | 1   | 1               |
| 107       | M   | NA         | Wound                   | 2015          | Tripoli | TGH      | IM         | R                                 | OXA-23           | 85  | 85              |
| 108       | M   | NA         | Wound                   | 2015          | Tripoli | TGH      | IM         | R                                 | OXA-24           | 636 | S               |
| 109       | M   | 74         | Rectal swab             | 2015          | Tripoli | NH       | ICU        | R                                 | OXA-23           | 2   | 2               |
| 110       | M   | 65         | Wound                   | 2015          | Akkar   | YMC      | NA         | R                                 | OXA-23           | 2   | 2               |
| 111       | M   | 55         | Urine                   | 2015          | Tripoli | NH       | IM         | R                                 | OXA-23           | 2   | 2               |
| 112       | F   | NA         | Catheter                | 2015          | Tripoli | TGH      | IM         | S                                 | -                | 193 | S               |
| 113       | F   | 38         | Wound                   | 2015          | Tripoli | TGH      | IM         | R                                 | OXA-23           | 2   | 2               |
| 114       | F   | NA         | Pus                     | 2015          | Tripoli | TGH      | ICU        | R                                 | OXA-23           | 2   | 2               |
| 115       | F   | NA         | Catheter                | 2015          | Tripoli | TGH      | ICU        | R                                 | OXA-23           | 2   | 2               |
| 116       | M   | 5          | Urine                   | 2015          | Tripoli | NH       | OP         | S                                 | -                | 809 | S               |
| 117       | F   | 19         | Urine                   | 2015          | Tripoli | NH       | OP         | S                                 | -                | 810 | S               |
| 118       | M   | NA         | Urine                   | 2015          | Akkar   | YMC      | NA         | S                                 | -                | 811 | S               |
| 119       | M   | 80         | Wound                   | 2015          | Tripoli | NH       | OP         | R                                 | OXA-23           | 2   | 2               |
| 120       | F   | NA         | Broncho-tracheal lavage | 2015          | Tripoli | TGH      | IM         | R                                 | OXA-23           | 2   | 2               |
| 121       | F   | 71         | Rectal swab             | 2015          | Tripoli | NH       | CCU        | R                                 | OXA-23           | 2   | 2               |
| 122       | M   | NA         | Wound                   | 2015          | Tripoli | TGH      | IM         | R                                 | OXA-23           | 2   | 2               |
| 123       | F   | NA         | Broncho-tracheal lavage | 2015          | Tripoli | TGH      | ICU        | R                                 | OXA-24           | 2   | 2               |
| 124       | F   | 32         | Blood                   | 2015          | Tripoli | NH       | ICU        | R                                 | OXA-23           | 2   | 2               |
| 125       | M   | NA         | Broncho-tracheal lavage | 2015          | Tripoli | TGH      | ICU        | R                                 | OXA-23           | 2   | 2               |
| 126       | F   | 75         | Pus                     | 2015          | Tripoli | NH       | P          | R                                 | OXA-23           | 2   | 2               |
| 127       | M   | 46         | Catheter                | 2015          | Tripoli | NH       | ICU        | R                                 | OXA-23           | 2   | 2               |
| 128       | M   | 46         | Nasal swab              | 2015          | Tripoli | NH       | ICU        | R                                 | OXA-23           | 25  | 25              |
| 129       | F   | NA         | Wound                   | 2015          | Tripoli | TGH      | NA         | R                                 | OXA-23           | 2   | 2               |
| 130       | M   | NA         | Urine                   | 2015          | Tripoli | TGH      | IM         | R                                 | OXA-24           | 812 | S               |

CC, clonal complex; CCU, cardiac care unit; DAH, Dar Ajar Hospital; F, female; HH, Hanane Hospital; ICU, intensive care unit; IM, internal medicine; CSF, cerebrospinal fluid; M, male; MGH, Makassed General Hospital; NA, not assigned; NH, Nini Hospital; OP, outpatient; P, paediatric; SGH, Seblin Governmental Hospital; ST, sequence type; SURG, surgery; SZH, Sayedt Zgharta Hospital; TGH, Tripoli Governmental Hospital; YMC, Al Youssef Medical Centre.

<sup>a</sup> Phenotype: 'R' resistant or 'S' susceptible to carbapenems.

<sup>b</sup> S: singleton.

carbapenem resistance since the MICs for imipenem and meropenem were >32 mg/l. Carbapenemase determinants were detected in all carbapenem-resistant isolates. *bla*<sub>OXA-23-like</sub> was the most common gene found ( $n = 76$ ; 83.5%). Furthermore, three *bla*<sub>OXA-24-like</sub> and four *bla*<sub>NDM-1</sub> were detected. Of note, six isolates carried both *bla*<sub>OXA-23-like</sub> and *bla*<sub>OXA-24-like</sub> genes and one isolate carried both *bla*<sub>OXA-23-like</sub> and *bla*<sub>OXA-58-like</sub> genes. Finally, *bla*<sub>OXA-143-like</sub> was found in one isolate.

### 3.3. Epidemiological typing

#### 3.3.1. Multilocus sequence typing

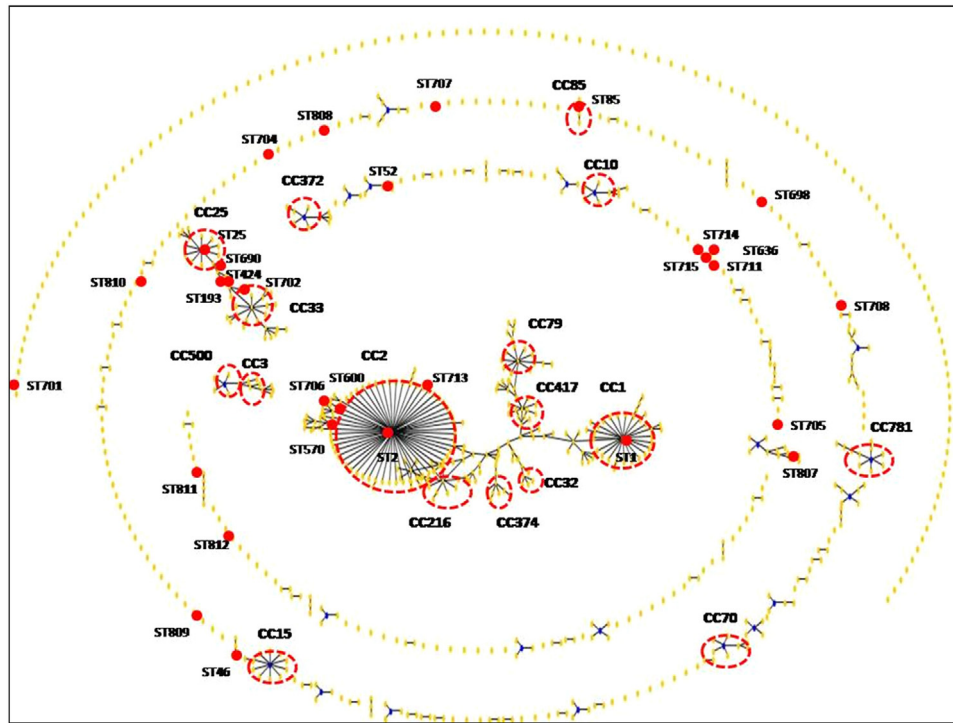
MLST was performed on all isolates. As a result, 30 STs including 18 new ones were identified in this study. ST2 was the most commonly observed (73/119 isolates), accounting for 61% of the isolates typed. Other less common STs were ST25 (six isolates) and ST570 (four isolates), followed by ST85, ST600 (both with three isolates) and ST1 (two isolates). The remaining STs were found

sporadically in this collection (Table 1). Based on eBURST analysis, ST2 as well as ST570, ST600, and ST713 (which are SLVs of ST2) belonged to CC2, while ST706 was a double locus variant (DLV) of ST2. Furthermore, ST1, ST25, ST85, and ST424 (a SLV of ST33) belonged to CC1, CC25, CC85, and CC33, respectively. ST690 was a DLV of CC25, and ST193 and ST702 were DLVs of CC33. Finally, ST46 was a SLV of ST622, and ST715 was a SLV of ST636. The remaining STs were singletons, since they did not share any homology with a known ST in the database (Fig. 1).

#### 3.3.2. PFGE analysis

Based on the above MLST results, all strains of ST2 were selected for PFGE typing in order to investigate their clonality. Overall, 73 strains were analyzed. As shown in Fig. 2, PFGE revealed the presence of four clusters with two or more isolates and 10 unique profiles. The major cluster (cluster C) comprised 52 carbapenem-resistant isolates harbouring the *bla*<sub>OXA-23-like</sub> gene with or without either the *bla*<sub>OXA-24-like</sub> gene or the *bla*<sub>OXA-58-like</sub> gene, as well as one





**Fig. 1.** Population snapshot analysed by eBURST on 836 sequences present in the MLST Pasteur database (05/05/2016). Red points and circles show sequence types identified in this study and the most important clonal complexes, respectively.

carbapenem-susceptible strain (strain 23). Interestingly, some of these strains displayed identical PFGE patterns, although they were isolated from different hospitals in different locations, mainly in Tripoli (40 isolates), Beirut (nine isolates), Zgharta (three isolates), and Akkar (one isolate). The second cluster (cluster A) contained five isolates producing the *bla*<sub>OXA-23-like</sub> gene that were recovered from two distinct hospitals in Tripoli (Table 1). Furthermore, the OXA-23-producing isolates (numbers 5, 85, and 103) that were isolated in Tripoli (TGH) and Beirut (MGH) belonged to cluster B. Finally, cluster D contained two carbapenem-resistant strains harbouring the *bla*<sub>OXA-23-like</sub> gene isolated from the same hospital (NH).

#### 4. Discussion

*A. baumannii* is the most common opportunistic pathogen causing nosocomial infections, particularly respiratory tract infections in intensive care units among critically ill patients.<sup>14</sup> Nowadays, the excessive use of antimicrobial agents in and outside hospitals may be an important cause of the isolation of MDR *A. baumannii* strains around the world.<sup>15–18</sup> The major problem is that infections caused by such isolates are associated with greater morbidity and greater healthcare costs.<sup>19,20</sup>

The current survey was conducted in different hospitals distributed across the country, with isolates mostly being recovered from two main hospitals in Tripoli, North of Lebanon and one main hospital in Beirut. A total of 119 *A. baumannii* clinical strains were included in this study to evaluate antibiotic resistance phenotypes and molecular epidemiological features. These strains were isolated from nosocomial infections, but also from infections present at the time of admission to the hospitals, and a number of patients were only colonized.

Antibiotic susceptibility testing showed a very serious situation. Of all *A. baumannii* isolates, 76.5% were carbapenem-resistant. This rate is higher than those reported in other countries such as China, Saudi Arabia, Greece, Italy, and the USA, where reported

rates were 29.4%, 69%, 57.4%, 45.7% and 34% respectively.<sup>9,14,21–23</sup> Interestingly, in previous studies in Lebanon, the rate of CRAB isolates was significantly different.<sup>13,24</sup> Moreover, 60.5% of the isolates presented here were resistant to aminoglycosides and 87% were resistant to fluoroquinolone, while tigecycline and colistin maintained their activity against all isolates.

The *bla*<sub>OXA-23</sub> gene is considered a significant cause of carbapenem resistance in *A. baumannii* worldwide.<sup>25</sup> This study revealed that carbapenem resistance in *A. baumannii* was also mainly associated with this gene. The present findings are similar to those reported previously from Lebanon and other countries.<sup>13,22,26–28</sup> Additionally, the co-occurrence of two OXA-type genes has also been reported in *A. baumannii*.<sup>22,29</sup> In the present study, the coexistence of either *bla*<sub>OXA-23</sub> and *bla*<sub>OXA-24</sub> or *bla*<sub>OXA-23</sub> and *bla*<sub>OXA-58</sub> was found in seven isolates. Moreover, the first description of a *bla*<sub>OXA-143-like</sub> strain is reported here, which was isolated in 2014 from a wound sample of a female patient admitted to TGH. Alarmingly, since the first description in Lebanon of a *bla*<sub>NDM-1</sub>-positive *A. baumannii*<sup>30</sup> and *Acinetobacter pittii*,<sup>31</sup> four more isolates were found in this study.

Epidemiological tools are important to track outbreaks and to investigate strain relatedness in order to control the spread of MDR isolates. The evolutionary history and the dynamic spread of *A. baumannii* in this study were investigated by MLST. The data revealed that CC2 (ST2, ST570, ST600, ST713) was the main clonal complex found in Lebanon over recent years. Interestingly, almost all of these isolates were resistant to carbapenems, which is in agreement with previous studies that have used MLST for epidemiological characterization of *A. baumannii*.<sup>8,12,21,32,33</sup> In Lebanon, even if different clones and STs have been described, CC2 and particularly ST2 appear to be widely distributed. The capacity for biofilm formation, adherence to abiotic surfaces, and acquisition of antimicrobial resistance determinants could be the main factors that enhance the spread and the persistence of this CC in the hospital setting, as has been described previously.<sup>34</sup> Moreover, CC1 and CC25 have also been responsible for several

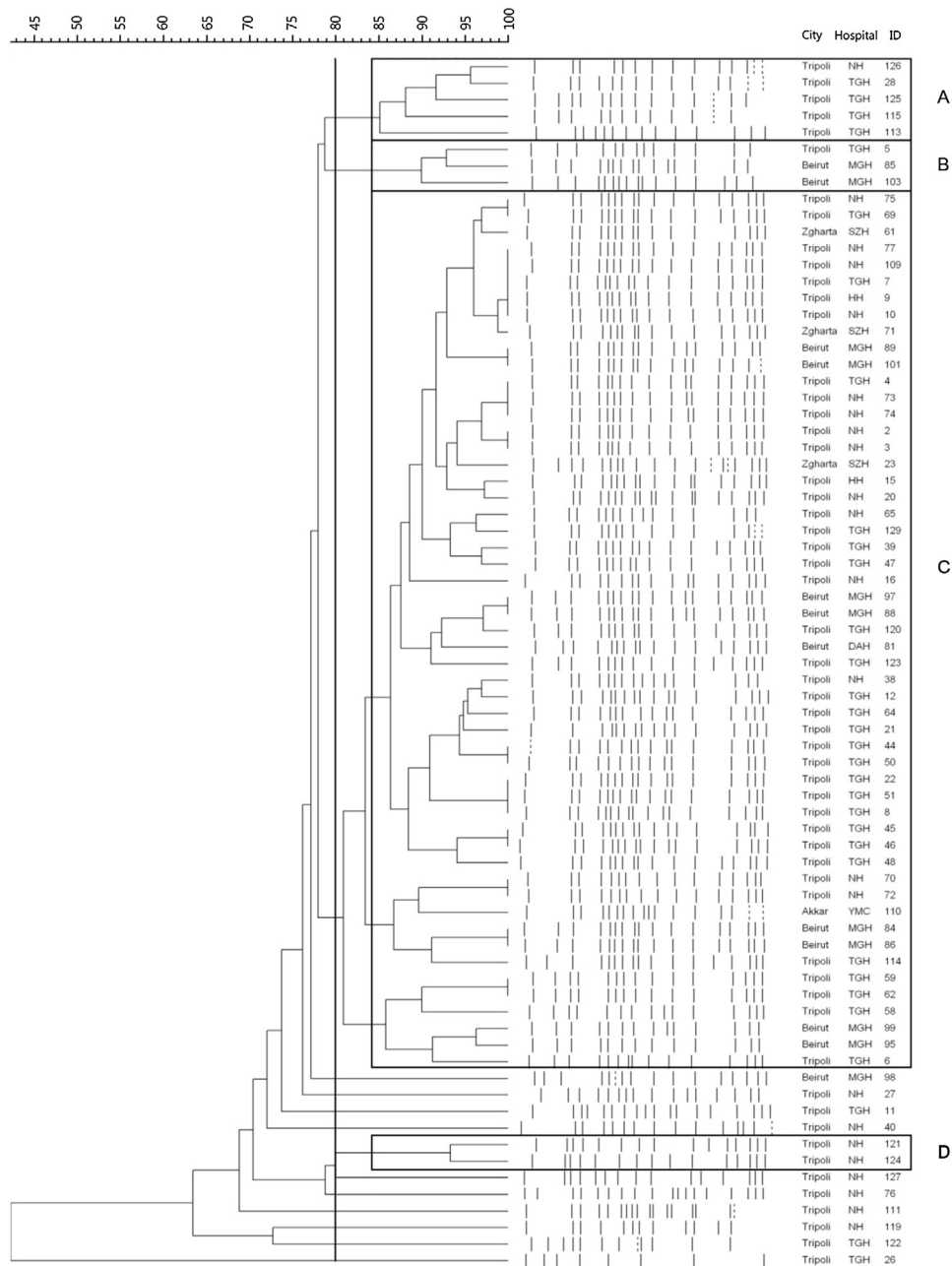


Fig. 2. Dendrogram illustrating the PFGE patterns of *Acinetobacter baumannii* isolates.

outbreaks of *A. baumannii* worldwide and have been described as emerging clones.<sup>8,32,35</sup> Strains belonging to these clones were detected in the present study. However, these strains, with the exception of one isolate (ST25), were all susceptible to carbapenems, which is not consistent with the results of Rafei et al., who found only carbapenem-resistant strains belonging to CC1 and CC25 in Lebanon.<sup>13</sup> These findings may highlight the potential role of hospitals as reservoirs for carbapenem resistance genes. Another new emerging clone, ST85 (CC85), which has long been associated with NDM-1,<sup>13,36,37</sup> was also detected in three isolates. Among them, two were NDM-1-producers and the remaining isolate was an OXA-23-producer. Of note, the detection of several new STs may support and highlight the continuous clonal evolution of *A. baumannii*. This diversity may be due to several mechanisms, such as mutations or the transfer and mobilization of genetic elements including insertion sequences.<sup>38</sup>

As shown in Table 1, 73 strains belonging to ST2 were further selected for PFGE typing. Around 72.6% ( $n = 53$ ) of them belonged to the same PFGE cluster, which appeared to be a predominant clone in Lebanon. Noteworthy, among this clone, several strains sharing identical PFGE patterns were detected, although they were not isolated in the same hospital or in the same location, such as strains 69, 71, and 75 (Fig. 2). This finding may suggest a possible inter-hospital transmission of these carbapenem-resistant strains. On the other hand, the presence of identical strains in the same hospital (Fig. 2) may also highlight the existence of pseudo outbreaks. Thus, early surveillance is warranted and the development of appropriate infection control measures (environmental and equipment cleaning and disinfection, implementation of a hand hygiene programme for healthcare workers, isolation of patients with MDR *A. baumannii*, early screening of the hospitalized patients, genotyping of the isolated strains, etc.) is recommended in order to eradicate the geographical spread of this clone.

MLST approaches have been used widely for the genotyping of *A. baumannii* due to their reproducibility and portability, facilitating comparisons between laboratories. Although MLST is an expensive typing method, it provides good information on the molecular epidemiology across different hospitals and locations.<sup>10,39</sup> Even if it is not suitable for inter-laboratory comparison, PFGE allows the investigation of outbreaks due to its high discriminatory power. PFGE analysis showed that the majority of the isolates belonging to ST2 were highly related, which is in agreement with the findings of previous studies.<sup>12,39</sup> However, it is recommended that both techniques are used when testing a high number of strains isolated from different locations at different time points.

Finally, although the clinical isolates collected may be limited, these data provide a global view on the molecular epidemiology of CRAB circulating in Beirut and the North of Lebanon during recent years. Of note, *A. baumannii* has evolved as a global pathogen causing community-acquired infections and war and natural disaster-related infections.<sup>40</sup> Thus, there is no doubt that the overall epidemiology of *A. baumannii* in Lebanon could be highly influenced by the Syrian War, since several wounded Syrian refugees have been hosted in different Lebanese cities and admitted to different Lebanese hospitals.<sup>13</sup> Therefore, further research is needed including more strains from other hospitals situated in different governorates in order to ensure the continuous surveillance of these MDR organisms in Lebanon.

In conclusion, this study provides evidence of the wide dissemination of OXA-23-producing carbapenem-resistant *A. baumannii* belonging to international clone II in Lebanon. Although PFGE results did not always correlate with MLST, both techniques remain nevertheless useful for the investigation of the molecular epidemiology and clonal spread of *A. baumannii*.

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## References

- Kempf M, Rolain JM. Emergence of resistance to carbapenems in *Acinetobacter baumannii* in Europe: clinical impact and therapeutic options. *Int J Antimicrob Agents* 2012;**39**:105–14.
- McConnell MJ, Actis L, Pachón J. *Acinetobacter baumannii*: human infections, factors contributing to pathogenesis and animal models. *FEMS Microbiol Rev* 2013;**37**:130–55.
- Reddy T, Chopra T, Marchaim D, Pogue JM, Alangaden G, Salimnia H, et al. Trends in antimicrobial resistance of *Acinetobacter baumannii* isolates from a metropolitan Detroit health system. *Antimicrob Agents Chemother* 2010;**54**:2235–8.
- Magiorakos AP, Srinivasan A, Carey RB, Carmeli Y, Falagas ME, Giske CG, et al. Multidrug-resistant, extensively drug-resistant and pandrug-resistant bacteria: an international expert proposal for interim standard definitions for acquired resistance. *Clin Microbiol Infect* 2012;**18**:268–81.
- Imperi F, Antunes LC, Blom J, Villa L, Iacono M, Visca P, et al. The genomics of *Acinetobacter baumannii*: insights into genome plasticity, antimicrobial resistance and pathogenicity. *IUBMB Life* 2011;**63**:1068–74.
- Potron A, Poirel L, Nordmann P. Emerging broad-spectrum resistance in *Pseudomonas aeruginosa* and *Acinetobacter baumannii*: mechanisms and epidemiology. *Int J Antimicrob Agents* 2015;**45**(6):568–85.
- 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.
- Zarrilli R, Pournaras S, Giannouli M, Tsakris A. Global evolution of multidrug-resistant *Acinetobacter baumannii* clonal lineages. *Int J Antimicrob Agents* 2013;**41**:11–9.
- Ying J, Lu J, Zong L, Li A, Pan R, Cheng C, et al. Molecular epidemiology and characterization of genotypic analysis of *Acinetobacter baumannii* strains isolated from south China. *Jpn J Infect Dis* 2015;**69**(3):180–5.
- Rafei R, Kempf M, Eveillard M, Dabboussi F, Hamze M, Joly-Guillou ML. Current molecular methods in epidemiological typing of *Acinetobacter baumannii*. *Future Microbiol* 2014;**9**:1179–94.
- Diancourt L, Passet V, Nemeč A, Dijkshoorn L, Brisse S. The population structure of *Acinetobacter baumannii*: expanding multidrug-resistant clones from an ancestral susceptible genetic pool. *PLoS One* 2010;**5**:e10034.
- Rafei R, Dabboussi F, Hamze M, Eveillard M, Lemarié C, Gaultier MP, et al. Molecular analysis of *Acinetobacter baumannii* strains isolated in Lebanon using four different typing methods. *PLoS One* 2014;**9**:e115969.
- Rafei R, Pailhoriés H, Hamze M, Eveillard M, Mallat H, Dabboussi F, et al. Molecular epidemiology of *Acinetobacter baumannii* in different hospitals in Tripoli, Lebanon using blaOXA-51-like sequence based typing. *BMC Microbiol* 2015;**15**:103.
- Gogou V, Pournaras S, Giannouli M, Voulgari E, Piperaki ET, Zarrilli R, et al. Evolution of multidrug-resistant *Acinetobacter baumannii* clonal lineages: a 10 year study in Greece (2000–09). *J Antimicrob Chemother* 2011;**66**:2767–72.
- Talbot GH, Bradley J, Edwards JE, Gilbert D, Scheld M, Bartlett JG, et al. Bad bugs need drugs: an update on the development pipeline from the Antimicrobial Availability Task Force of the Infectious Diseases Society of America. *Clin Infect Dis* 2006;**42**:657–68.
- Maragakis LL, Tucker MG, Miller RG, Carroll KC, Perl TM. Incidence and prevalence of multidrug-resistant *Acinetobacter* using targeted active surveillance cultures. *JAMA* 2008;**299**:2513–4.
- Boucher HW, Talbot GH, Bradley JS, Edwards JE, Gilbert D, Rice LB, et al. Bad bugs, no drugs: no ESKAPE! An update from the Infectious Diseases Society of America. *Clin Infect Dis* 2009;**48**:1–12.
- Dizbay M, Tunccan OG, Sezer BE, Hizel K. Nosocomial imipenem-resistant *Acinetobacter baumannii* infections: epidemiology and risk factors. *Scand J Infect Dis* 2010;**42**:741–6.
- Doi Y, Husain S, Potoski BA, McCurry KR, Paterson DL. Extensively drug-resistant *Acinetobacter baumannii*. *Emerg Infect Dis* 2009;**15**:980–2.
- Metan G, Sariguzel F, Sumerkan B. Factors influencing survival in patients with multi-drug-resistant *Acinetobacter* bacteraemia. *Eur J Intern Med* 2009;**20**:540–4.
- Al-Sultan AA, Evans BA, Aboulmagd E, Al-Qahtani AA, Bohol MF, Al-Haddad MN, et al. Dissemination of multiple carbapenem-resistant clones of *Acinetobacter baumannii* in the Eastern District of Saudi Arabia. *Front Microbiol* 2015;**6**:634.
- Principe L, Piazza A, Giani T, Bracco S, Caltagirone MS, Arena F, et al. Epidemic diffusion of OXA-23-producing *Acinetobacter baumannii* isolates in Italy: results of the first cross-sectional countrywide survey. *J Clin Microbiol* 2014;**52**:3004–10.
- Kallen AJ, Srinivasan A. Current epidemiology of multidrug-resistant Gram-negative bacilli in the United States. *Infect Control Hosp Epidemiol* 2010;**31**(Suppl 1):S51–4.
- Hammoudi D, Moubareck CA, Hakime N, Houmani M, Barakat A, Najjar Z, et al. Spread of imipenem-resistant *Acinetobacter baumannii* co-expressing OXA-23 and GES-11 carbapenemases in Lebanon. *Int J Infect Dis* 2015;**36**:56–61.
- Luo TL, Rickard AH, Srinivasan U, Kaye KS, Foxman B. Association of blaOXA-23 and bap with the persistence of *Acinetobacter baumannii* within a major healthcare system. *Front Microbiol* 2015;**6**:182.
- 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.
- Zowawi HM, Sartor AL, Sidjabat HE, Balkhy HH, Walsh TR, Al-Johani SM, 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.
- Merino M, Poza M, Roca I, Barba MJ, Sousa MD, Vila J, et al. Nosocomial outbreak of a multidrug-resistant *Acinetobacter baumannii* expressing OXA-23 carbapenemase in Spain. *Microb Drug Resist* 2014;**20**:259–63.
- Salimizand H, Noori N, Meshkat Z, Ghazvini K, Amel SJ. Prevalence of *Acinetobacter baumannii* harboring ISAba1/bla OXA-23-like family in a burn center. *Burns J Int Soc Burn Inj* 2015;**41**:1100–6.
- Rafei R, Dabboussi F, Hamze M, Eveillard M, Lemarié C, Mallat H, et al. First report of blaNDM-1-producing *Acinetobacter baumannii* isolated in Lebanon from civilians wounded during the Syrian war. *Int J Infect Dis* 2014;**21**:21–3.
- Al Atrouni A, Joly-Guillou ML, Hamze M, Kempf M. Emergence of NDM-1 and OXA-72 producing *Acinetobacter pittii* clinical isolates in Lebanon. *New Microbes New Infect* 2016;**12**:43–4.
- Karah N, Sundsfjord A, Towner K, Samuelsen Ø. Insights into the global molecular epidemiology of carbapenem non-susceptible clones of *Acinetobacter baumannii*. *Drug Resist Updat* 2012;**15**:237–47.
- Huber CA, Sartor AL, McOdimba F, Shah R, Shivachi P, Sidjabat HE, et al. Outbreaks of multidrug-resistant *Acinetobacter baumannii* strains in a Kenyan teaching hospital. *J Glob Antimicrob Resist* 2014;**2**:190–3.
- Giannouli M, Antunes LC, Marchetti V, Triassi M, Visca P, Zarrilli R. Virulence-related traits of epidemic *Acinetobacter baumannii* strains belonging to the



- international clonal lineages I–III and to the emerging genotypes ST25 and ST78. *BMC Infect Dis* 2013;**13**:282.
35. Villalón P, Valdezate S, Medina-Pascual MJ, Rubio V, Vindel A, Saez-Nieto JA. Clonal diversity of nosocomial epidemic *Acinetobacter baumannii* strains isolated in Spain. *J Clin Microbiol* 2011;**49**:875–82.
  36. Decousser JW, Jansen C, Nordmann P, Emirian A, Bonnin RA, Anais L, et al. Outbreak of NDM-1-producing *Acinetobacter baumannii* in France, January to May 2013. *Euro Surveill* 2013;**18**(31). pii: 20547.
  37. Heydari F, Mammina C, Koksai F. NDM-1-producing *Acinetobacter baumannii* ST85 now in Turkey, including one isolate from a Syrian refugee. *J Med Microbiol* 2015;**64**:1027–9.
  38. Wright MS, Haft DH, Harkins DM, Perez F, Hujer KM, Bajaksouzian S, et al. New insights into dissemination and variation of the health care-associated pathogen *Acinetobacter baumannii* from genomic analysis. *mBio* 2014;**5**: e00963–e00913.
  39. El-Shazly S, Dashti A, Vali L, Bolaris M, Ibrahim AS. Molecular epidemiology and characterization of multiple drug-resistant (MDR) clinical isolates of *Acinetobacter baumannii*. *Int J Infect Dis* 2015;**41**:42–9.
  40. O'Shea MK. *Acinetobacter* in modern warfare. *Int J Antimicrob Agents* 2012;**39**: 363–75.