Database for the \textit{ampC} alleles in \textit{Acinetobacter baumannii}

Nabil Karah\textsuperscript{1,2*}, Keith A. Jolley\textsuperscript{3}, Ruth M. Hall\textsuperscript{4}, Bernt Eric Uhlin\textsuperscript{1,2}

\textsuperscript{1} The Laboratory for Molecular Infection Medicine Sweden (MIMS) and Department of Molecular Biology, Umeå University, Umeå, Sweden, \textsuperscript{2} Umeå Centre for Microbial Research, Umeå University, Umeå, Sweden, \textsuperscript{3} Department of Zoology, University of Oxford, Oxford, United Kingdom, \textsuperscript{4} School of Life and Environmental Sciences, University of Sydney, Sydney, Australia

* nabil.karah@umu.se

Abstract

\textit{Acinetobacter baumannii} is a troublesome opportunistic pathogen with a high capacity for clonal dissemination. We announce the establishment of a database for the \textit{ampC} locus in \textit{A. baumannii}, in which novel \textit{ampC} alleles are differentiated based on the occurrence of \geq 1 nucleotide change, regardless of whether it is silent or missense. The database is openly accessible at the pubmlst platform for \textit{A. baumannii} (http://pubmlst.org/abaumannii). Forty-eight distinctive alleles of the \textit{ampC} locus have so far been identified and deposited in the database. Isolates from clonal complex 1 (CC1), according to the Pasteur multilocus sequence typing scheme, had a variety of the \textit{ampC} locus alleles, including alleles 1, 3, 4, 5, 6, 7, 8, 13, 14, 17, and 18. On the other hand, isolates from CC2 had the \textit{ampC} alleles 2, 3, 19, 20, 21, 22, 23, 24, 26, 27, 28, and 46. Allele 3 was characteristic for sequence types ST3 or ST32. The \textit{ampC} alleles 10, 16, and 25 were characteristic for CC10, ST16, and CC25, respectively. Our study points out that novel gene databases, in which alleles are numbered based on differences in their nucleotide identities, should replace traditional records that use amino acid substitutions to define new alleles.

Introduction

\textit{Acinetobacter baumannii} is a clinically important pathogen responsible for a wide range of hospital-acquired infections [1]. The \textit{ampC} gene of \textit{A. baumannii} was cloned and sequenced for the first time in 2000 [2]. The gene, also called \textit{bla}_{ADC} for \textit{Acinetobacter-Derived Cephalosporinase}, is intrinsic in \textit{A. baumannii} and all other members of the \textit{Acinetobacter calcoaceticus-Acinetobacter baumannii} (Acb) complex [3, 4]. It is located in the chromosome between \textit{folE}, encoding a GTP cyclohydrolase I enzyme, and an open reading frame encoding a hypothetical protein, as seen in the \textit{A. baumannii} reference strain ATCC 17978-mff (GenBank accession number CP012004, locus tag ACX60_05710). Overexpression of \textit{ampC}, due to the acquisition of a strong promoter located on an insertion sequence (IS) element, is the main mechanism of resistance to third-generation cephalosporins in \textit{A. baumannii} [5]. With few exceptions, variation in the amino acid sequence of AmpC in \textit{A. baumannii} usually does not affect the resistance spectrum [6, 7].
Some *A. baumannii* isolates were reported to carry a second copy of the *ampC* gene, located elsewhere in the chromosome [8, 9]. The additional copy was part of a DNA segment most likely derived from the chromosome of another *A. baumannii* strain. The segment was mobilized as part of Tn6168, a composite transposon made of two directly oriented copies of ISAba1 [8]. The *A. baumannii ampC* gene, together with an upstream ISOur1, was also detected in the genome of *Oligella urethralis*, leading to a cephalosporin resistance phenotype [10]. Interestingly, *A. baumannii* strain ACICU, from global clone 2 (GC2), was found to carry a 9 kb chromosomal segment, containing ISAba125-ampC, which was derived from a GC1 isolate [11]. This finding indicated the occurrence of a replacement in the chromosome of ACICU, most likely mediated by a homologous recombination event [11]. Similarly, distinctive ISAba1-associated *ampC* alleles were detected in the genome of GC1 isolates, once again highlighting the frequent occurrence of horizontal transfer of chromosomal DNA segments in *A. baumannii* [9, 12].

To track these imports, a clear numbering system of the *ampC* alleles is needed. Analysis of the *ampC* locus could also be a convenient method for exploring the molecular epidemiology of *A. baumannii*, taking into consideration that particular *ampC* alleles have been linked to certain clones of *A. baumannii* [9, 13]. This report aims to announce the establishment of a database for the *ampC* locus in *A. baumannii*.

### New database for the *ampC* locus in *A. baumannii*

The database is hosted and maintained at the pubmlst platform for *A. baumannii* ([http://pubmlst.org/abaumannii/](http://pubmlst.org/abaumannii/)) sited at the University of Oxford [14]. The platform provides an open access to all the data and allows submissions of novel sequences. However, novel sequence must simultaneously be submitted and assigned accession numbers by the International Nucleotide Sequence Database Collaboration (INSDC) ([http://www.insdc.org/](http://www.insdc.org/)). Sequences must be complete and meet the validation criteria of INSDC. *ampC* sequences with novel nucleotide identities (> 1 nucleotide substitution) will be numbered successively.

So far, we have identified, curated and numbered a total of 48 distinctive alleles of the *ampC* locus in a collection of 188 *A. baumannii* isolates by means of the online available whole genome sequence records (Table 1). The *ampC* alleles 1, 3, 4, 5, 6, 7, 8, 13, 14, 17, and 18 were carried by isolates that belong to clonal complex 1 (CC1), corresponding to GC1, according to the Pasteur scheme for multilocus sequence typing ([https://pubmlst.org/abaumannii/](https://pubmlst.org/abaumannii/)). Isolates from CC2, corresponding to GC2, had the *ampC* alleles 2, 3, 19, 20, 21, 22, 23, 24, 26, 27, 28, and 46. Nonetheless, *ampC* allele 2 was also present in one isolate from ST215 (27, 2, 7, 2, 2, 1, 2), which was not closely related to CC2. Similarly, allele 19 was present in isolates of ST500 (3, 3, 2, 2, 28, 1, 5) or ST522 (3, 3, 89, 2, 28, 1, 5), which were also not related to CC2. Although it was present in few isolates from CC1 and CC2, allele 3 was mainly characteristic for ST3 (3, 3, 2, 2, 3, 1, 3) or ST32 (1, 1, 2, 2, 3, 4, 4). The *ampC* locus alleles 10 and 16 were characteristic for CC10 and ST16, respectively. Likewise, all isolates from CC25 had the *ampC* locus allele 25. Allele 39 was present in all the ST78 (25, 3, 6, 2, 28, 1, 29) isolates, but also in one isolate from ST241 (40, 3, 15, 2, 40, 4, 4).

These linkages demonstrate that sequence analysis of the *ampC* variants is probably a practical method to search for clinically significant clones of *A. baumannii*, as previously described for the intrinsic *blaOXA-51*-like gene [15, 16]. However, the frequent occurrence of inter-strain exchanges of chromosomal segments should be taken into consideration. Therefore, analysis of *ampC* to study the epidemiology of *A. baumannii* should be complemented
Table 1. Numeration of the \textit{ampC} gene alleles in \textit{Acinetobacter baumannii}.

| \textit{ampC} allele | Isolate | Pasteur scheme multi locus sequence type | GenBank accession | PubMed Identifier (PMID) / GenBank submission authors / other references |
|---------------------|---------|-----------------------------------------|-------------------|---------------------------------------------|
| 1                   | AYE     | ST1 (1, 1, 1, 1, 5, 1, 1)               | NC_010410         | 16415984; [9]                             |
|                     | AB5075  | ST1                                     | CP008706; AHAH00000000 | 24865555; [9]                          |
|                     | A1      | ST1                                     | CP010781          | 25767221; [9]                             |
|                     | 3208    | ST1                                     | FJ172370.5; FBWZ00000000 | 19364869; [9]                          |
|                     | D2      | ST1                                     | GQ406245.5; FBWY00000000 | 20375036; [9]                          |
|                     | A92     | ST1                                     | GQ406246.3; FBWV00000000 | 20375036; [9]                          |
|                     | A85 (intrinsic) | ST1 | KC118540.6; FBXA00000000 | 24907141; [9] |
|                     | AB307-0294 | ST1 | CP001172 | 18931120; [9] |
|                     | AB0057 (intrinsic) | ST1 | CP001182 | 18931120; [9] |
|                     | 6772166 (intrinsic) | ST1 | FBWX00000000 | [9] |
|                     | RBH3 (intrinsic) | ST1 | FBXD00000000 | [9] |
|                     | AB056 (intrinsic) | ST1 | ADGZ00000000 | 20530228; [9] |
|                     | AB059 (intrinsic) | ST1 | ADHB00000000 | 20530228; [9] |
|                     | AB908–13 (intrinsic) | ST1 | AMHW00000000 | 23365658; [9] |
|                     | AB909-02-7 (intrinsic) | ST1 | AMHZ00000000 | 23365658; [9] |
|                     | TG19582 | ST1                                     | AMIV00000000 | 23365658; [9]                             |
|                     | Canada BC-1 (intrinsic) | ST1 | AMSZ00000000 | Harkins et al., unpublished; [9] |
|                     | Canada BC-5 (intrinsic) | ST1 | AFDN00000000 | Harkins et al., unpublished; [9] |
|                     | IS-58   | ST1                                     | AMGH00000000 | Harkins et al., unpublished; [9] |
|                     | IS-235  | ST1                                     | AMEI00000000 | Harkins et al., unpublished |
|                     | IS-251  | ST1                                     | AMEJ00000000 | Harkins et al., unpublished |
|                     | NIPH 290 | ST1 | APRD00000000 | Feldgarden et al., unpublished; [9] |
|                     | NIPH 527 (RUH875) | ST1 | APOW00000000 | Cerqueira et al., unpublished; [9] |
|                     | ANC 4097 | ST1 | APRF00000000 | Cerqueira et al., unpublished; [9] |
|                     | Naval-83 | ST20 (3, 1, 1, 1, 5, 1, 1) | AMFK00000000 | Harkins et al., unpublished; [9] |
| 2                   | A91     | ST2 (2, 2, 2, 2, 2, 2, 2)               | JN968483          | 22351684                                   |
|                     | NIPH 2061 | ST2 | APOW00000000 | 24277043                                   |
|                     | OIFC180 | ST2 | AMDQ00000000 | Harkins et al., unpublished |
|                     | CT77    | ST2                                     | AVOC00000000 | 24503987                                   |
|                     | MRY09-0642 | ST2 | BASA00000000 | 23868126                                   |
|                     | ORAB01  | ST2                                     | CP015483          | Adams et al., unpublished |
|                     | XH856   | ST2                                     | CP014541          | Feng et al., unpublished |
|                     | YU-R612 | ST2                                     | CP014215          | 27139604                                   |
|                     | XH836   | ST2                                     | CP010779          | 26981403                                   |
|                     | NCGM 237 | ST2 | AP013357 | 24550340                                   |
|                     | BJAB0868 | ST2 | CP003849 | 23826102                                   |
|                     | BJAB07104 | ST2 | CP003846 | 23826102                                   |
|                     | MDR-ZJ06 | ST2 | CP001937 | 21788470                                   |
|                     | TCDC-AB0715 | ST2 | CP002522.2 | 21398540                                   |

(Continued)
Table 1. (Continued)

| Strain | STA  | Accession Number | Reference |
|--------|------|------------------|-----------|
| ABNIH2 | ST2  | AFTA00000000     |           |
| AB210  | ST2  | AEOX00000000     |           |
| Naval-17 | ST2 | AFDO00000000 | Harkins *et al*., unpublished |
| Ab11111 | ST2  | AKAQ00000000     | Murphy *et al*., unpublished |
| ZWS1122 | ST2  | AMGR00000000     |           |
| ZWS1219 | ST2  | AMGS00000000     |           |
| Naval-113 | ST2 | AMZU00000000 | Harkins *et al*., unpublished |
| XH857  | ST215 | CP014540        | Feng *et al*., unpublished |
| 3      | A085 | ST3   | (3, 3, 2, 2, 1, 3) | KP881239; 26824943 |
|        | AB4456 | ST3    | LREF00000000 | Arivett *et al*., unpublished |
|        | AB3560 | ST3    | LRDV00000000 | Arivett *et al*., unpublished |
|        | AB4857 | ST3    | AHAG00000000 |           |
|        | OIFC137 | ST3   | AFDK00000000 | Harkins *et al*., unpublished |
|        | OIFC109 | ST3    | ALAL00000000 | Harkins *et al*., unpublished |
|        | IS-123  | ST3    | ALII00000000 | Harkins *et al*., unpublished |
|        | Naval-81 | ST3    | AFDB00000000 | Harkins *et al*., unpublished |
|        | Naval-13 | ST3    | AMDR00000000 | Harkins *et al*., unpublished |
|        | WC-A-694 | ST3    | AMTA00000000 | Harkins *et al*., unpublished |
|        | OIFC032 | ST32   | AFCZ00000000 | Harkins *et al*., unpublished |
|        | OIFC087 | ST32   | AMFS00000000 | Harkins *et al*., unpublished |
|        | OIFC099 | ST32   | AMFT00000000 | Harkins *et al*., unpublished |
|        | 1525283 | ST32   | JEXR00000000 | Harris *et al*., unpublished |
|        | 781407  | ST32   | JEZS00000000 | Harris *et al*., unpublished |
|        | ABBL013 | ST32   | LLCT00000000 |           |
|        | OIFC074 | ST19   | AMDE00000000 | Harkins *et al*., unpublished; [9] |
|        | Naval-21 | ST19   | AMSY00000000 | Harkins *et al*., unpublished; [9] |
|        | 1999BJAB11 | ST2    | JSDB00000000 | 25487793 |
|        | IS-143  | ST414  | (2, 2, 2, 2, 37, 2) | AMGE00000000 | Harkins *et al*., unpublished |
| 4      | D15    | ST1    | FBXJ00000000 | [9] |
|        | D13    | ST1    | FBXI00000000 | [9] |
| 5      | G7     | ST1    | FBXF00000000 | [9] |
| 6      | AB058  | ST20   | ADHA00000000 | 20530228; [9] |
| 7a     | A388   | ST1    | JQ684178; FBXE00000000 | 22915466; [9] |
| 8a     | A100   | ST1    | KP881241     | 26824943 |
|        | A85 (acquired) | ST1 | KC118540; 6, FBXA00000000 | 24907141 |
|        | AB0057 (acquired) | ST1 | CP001182 | 18931120; [9] |
|        | 6772166 (acquired) | ST1 | FBWX00000000 | [9] |
|        | RBH3 (acquired) | ST1 | FBXD00000000 | [9] |
|        | AB056 (acquired) | ST1 | ADGZ00000000 | 20530228; [9] |
|        | AB059 (acquired) | ST1 | ADHB00000000 | 20530228; [9] |
|        | AB_908–13 (acquired) | ST1 | AMHW00000000 | 23365658; [9] |
|        | AB_909-02-7 (acquired) | ST1 | AMHZ00000000 | 23365658; [9] |
|        | Canada BC-1 (acquired) | ST1 | AMSZ00000000 | Harkins *et al*., unpublished; [9] |

*Continued*
|   | Sample ID | ST | Accession Number | Reference |
|---|-----------|----|------------------|-----------|
| 9 | NIPH 190  | ST9 (3, 1, 5, 3, 6, 1, 3) | APPL00000000 | Kamolvit et al., unpublished |
| 10| T214      | ST10 (1, 3, 2, 1, 4, 4, 4) | JRTZ00000000 | Cerqueira et al., unpublished |
|   | NIPH 335  | ST10 | APOX00000000 | Harkins et al., unpublished |
|   | OIFC098   | ST10 | AMDF00000000 | Harkins et al., unpublished |
|   | 466760    | ST10 | JEXB00000000 | Harris et al., unpublished |
|   | 50595     | ST10 | JEXP00000000 | Harris et al., unpublished |
|   | 3390      | ST10 | JFER00000000 | Harris et al., unpublished |
|   | 1262761–105| ST10 | JMOJ00000000 | Harris et al., unpublished |
|   | Ab04-mff  | ST10 | CP012006 | 26170289 |
|   | A078      | ST23 (1, 3, 10, 1, 4, 4, 4) | KP881236 | 26824943 |
|   | BJAB0715  | ST23 | CP003847 | 23881610 |
|   | XH858     | ST23 | CP014528 | Feng et al., unpublished |
|   | 11 NIPH 329 | ST11 (1, 2, 6, 2, 3, 4, 4) | APQY00000000 | 24277043 |
|   | 12 NIPH 615 | ST12 (3, 5, 7, 1, 7, 2, 6) | JRTF00000000 | 24277043 |
|   | A076      | ST1  | KP881235 | 26824943 |
|   | A082      | ST1  | KP881238 | 26824943 |
| 15b| NIPH 1734 (LUH 8406) | ST15 (6, 6, 8, 2, 3, 5, 4) | APOX00000000 | 24277043 |
|   | 16 UMB002 | ST16 (7, 7, 2, 8, 4, 4) | AEPL00000000 | 21639920 |
|   | 1043794   | ST16 | JEXB00000000 | Harris et al., unpublished |
|   | 972082    | ST16 | JFAX00000000 | Harris et al., unpublished |
|   | 232184    | ST16 | JEXF00000000 | Harris et al., unpublished |
|   | 266680    | ST16 | JEXG00000000 | Harris et al., unpublished |
|   | 655378    | ST16 | JEXH00000000 | Harris et al., unpublished |
|   | 1064293_45| ST16 | JEXI00000000 | Harris et al., unpublished |
|   | 17c D36   | ST81 (1, 1, 1, 1, 5, 1, 2) | CP012952 | 26879588; [9] |
|   | 18c D81   | ST2  | FBX00000000 | 23788477 |
|   | D78       | ST1  | FBX00000000 | 23788477 |
| 19c| RUH 134 (A320) | ST2 | JN247441 | 23788477 |
|   | NIPH 24   | ST2  | APOF00000000 | Cerqueira et al., unpublished |
|   | NIPH 528  | ST2  | APRB00000000 | Cerqueira et al., unpublished |
|   | OIFC338   | ST2  | AMFX00000000 | Cerqueira et al., unpublished |
|   | XH859     | ST2  | CP014539 | Feng et al., unpublished |
|   | AB1H8     | ST2  | ANNO00000000 | 23723398 |
|   | AB5711    | ST2  | AHAJ00000000 | 23723398 |
|   | 472237–120| ST500 (3, 3, 2, 2, 8, 1, 5) | JFCW00000000 | Harris et al., unpublished |
|   | 1188188   | ST500 | JFDV00000000 | Harris et al., unpublished |
|   | 1271213   | ST500 | JFDX00000000 | Harris et al., unpublished |
|   | 1237893   | ST500 | JFEA00000000 | Harris et al., unpublished |
|   | 480175    | ST500 | JFEU00000000 | Harris et al., unpublished |
|   | 1276470–86| ST500 | JFEU00000000 | Harris et al., unpublished |
|   | 1121032   | ST500 | JEZD00000000 | Harris et al., unpublished |
|   | 940793    | ST500 | JMNW00000000 | Harris et al., unpublished |
|   | 29280     | ST522 (3, 3, 89, 2, 28, 1, 5) | JEZT00000000 | Harris et al., unpublished |
| 20| A072      | ST2  | KP881233 | 26824943 |
|   | XH860     | ST2  | CP014538 | Feng et al., unpublished |

(Continued)
Table 1. (Continued)

|   |   |   |   |
|---|---|---|---|
| AC29 | ST2 | CP007535 | 26824943 |
| AC30 | ST2 | CP007577 | 26824943 |
| PKAB07 | ST2 | CP006963 | 24652977 |
| J65 | ST2 | JO867374 | Wang, unpublished |
| MDR.MM | ST2 | AZNQ00000000 | 20609238 |
| DU202 | ST2 | AVGF00000000 | 24486871 |
| TYTH-1 | ST2 | CP003856 | 23209228 |
| KBN10P02143 | ST2 | CP013924 | 2714392 |
| OIFC143 | ST25 | AFDL00000000 | Harkins et al., unpublished |
| Naval-18 | ST25 | AFDA00000000 | Harkins et al., unpublished |
| CI86 | ST25 | AVOB00000000 | 24503987 |
| CI79 | ST25 | AVOD00000000 | 24503987 |
| KBN10 | ST25 | JEVX00000000 | Harris et al., unpublished |
| 1429530 | ST25 | JEWM00000000 | Harris et al., unpublished |
| NM3 | ST25 | JZBV00000000 | 23264451 |
| RUH 1486 | ST25 | JZBU00000000 | 26462752 |
| LUH 6220 | ST25 | JZBW00000000 | 26462752 |
| 161/07 | ST25 | JZCA00000000 | 26462752 |
| 4390 | ST25 | JZBY00000000 | 26462752 |
| LUH 7841 | ST402 | JZBX00000000 | 26462752 |
| ST2 | JEZV00000000 | Harris et al., unpublished |
| ST2 | AYGO00000000 | 24449752 |
| Naval-2 | ST2 | AMSX00000000 | Harkins et al., unpublished |
| TG15234 | ST2 | ASEW00000000 | 23365658 |
| TG15240 | ST2 | ASFB00000000 | 23365658 |
| 1043903 | ST2 | JETY00000000 | Harris et al., unpublished |
| ST2 | JETY00000000 | Harris et al., unpublished |
| 1294217 | ST2 | JEWF01000000 | Harris et al., unpublished |
| 1406750 | ST2 | JEWK00000000 | Harris et al., unpublished |
| 724909 | ST2 | JEXF01000000 | Harris et al., unpublished |
| UMB001 | ST2 | AEPI00000000 | 21639920 |
| ABIsac_ColiS | ST2 | CAKA00000000 | 23070160 |
| ST2 | APOQ00000000 | 24277043 |
| LAC-4 | ST10 | JICJ00000000 | Cerqueira et al., unpublished |
| D46 | ST25 | KF030679.2 | 2378847 |
| ST2 | APPM00000000 | 24277043 |
| ST35 | ST37 | APRA00000000 | 24277043 |
| ST38 | APRE00000000 | 24277043 |
| ST38 | APQV00000000 | 24277043 |
| ST40 | ST49 | APOQ00000000 | 24277043 |
| J9 | ST49 | APYQ00000000 | 24277043 |
| ST78 | ST78 | JEMX00000000 | Harris et al., unpublished |
| 831240 | ST78 | JEOO00000000 | Harris et al., unpublished |
| 855125 | ST78 | JMNTO00000000 | Harris et al., unpublished |

(Continued)
by characterizing other loci or preferably be taken within the context of whole-genome sequence analysis.

### Updated list of the AmpC protein variants

In parallel, we revised and updated a previous collection of the AmpC variants (Table 2) [13]. As previously recommended, the AmpC variants were numbered according to the chronology of getting published and/or submitted to the INSDC databases. Numbers were preceded by a hyphen. When it was possible, numbers assigned by previous studies were retained. Accordingly, AmpC-1 was used to label the first AmpC protein variant reported in 2000 [2, 13].

The designation AmpC-72 (GenBank accession: AIL90389) was omitted since it showed 100% amino acid similarity to AmpC-70 (GenBank accession: KQG48886). Two variants with different amino acid sequences were designated as AmpC-57 (GenBank accessions: ADO51072 and AEZ36052). Subjectively, AmpC-57 was given to the variant detected in two *A. baumannii* isolates from East Africa [17]. New variants were defined, based on ≥1 amino acid substitution, and numbered under supervision of the INSDC curators. It is very important to re-emphasize that the AmpC variant numbers (Table 2) are not matching and not exchangeable with the *ampC* allele numbers (Table 1).

### Concluding remarks

In our opinion, having two databases, one for the gene alleles and one for the protein variants, will create a lot of confusion. With the rapid accumulation of bacterial whole genome sequences, we argue that genes and alleles should reasonably be defined and numbered based on their nucleotide identities. For molecular epidemiological studies, the novel database for *ampC* in *A. baumannii* will provide unambiguous details beyond traditional list of AmpC variants that are limited to alleles with amino acid substitutions. To conclude, we emphasize on using the basic definition of the word “allele” for bacterial genes, by which novel alleles should be defined regardless if they are associated with amino acid changes or not.
Table 2. Numeration of the AmpC protein variants encoded by Acinetobacter baumannii.

| AmpC protein variant | GenBank accession number | Size (amino acid) | NCBI reference sequence | Other previous designations | PubMed Identifier (PMID) / GenBank submission authors |
|----------------------|--------------------------|-------------------|-------------------------|----------------------------|-----------------------------------------------------|
| AmpC-1 (ADC-1)       | CAB77444                 | 383               | WP_004714775            | ADC-NIPH 1362              | 10639377                                           |
| AmpC-2 (ADC-2)       | AAO43172                 | 383               | WP_004746565            | ADC-NIPH 1734              | 12709319                                           |
| AmpC-3               | AAOS59456                | 383               | WP_063857798            | –                          | 12709319                                           |
| AmpC-4               | AAOS59475                | 383               | WP_063857801            | –                          | 12709319                                           |
| AmpC-5               | CAE080827                | 383               | WP_038405930            | –                          | 15047547                                           |
| AmpC-6               | AAR13676                 | 383               | WP_017725267            | –                          | 14742218                                           |
| AmpC-7               | AAT70411                 | 383               | WP_063857816            | –                          | 15980372                                           |
| AmpC-10              | ABI18382                 | 388               | WP_063857786            | –                          | Hujer et al., unpublished                         |
| AmpC-11              | ADG46039                 | 383               | WP_001211205            | –                          | 20713667; 16415984                                  |
| AmpC-12              | CAK95249                 | 383               | WP_063857787            | –                          | 19029333                                           |
| AmpC-13              | CAK95248                 | 383               | WP_063857788            | –                          | 19029333                                           |
| AmpC-14              | CAK95247                 | 383               | WP_063857789            | –                          | 19029333                                           |
| AmpC-15              | CAK95246                 | 383               | WP_063857790            | –                          | 19029333                                           |
| AmpC-16              | CAK95245                 | 383               | WP_063857791            | –                          | 19029333                                           |
| AmpC-17              | CAK95244                 | 383               | WP_063857792            | –                          | 19029333                                           |
| AmpC-18              | CAK95243                 | 383               | WP_002118772            | –                          | 19029333                                           |
| AmpC-19              | CAK95242                 | 383               | WP_063857793            | –                          | 19029333                                           |
| AmpC-20              | CAK95241                 | 383               | WP_063857794            | –                          | 19029333                                           |
| AmpC-21              | CAK95240                 | 383               | WP_063857795            | –                          | 19029333                                           |
| AmpC-22              | CAK95239                 | 383               | WP_063857796            | –                          | 19029333                                           |
| AmpC-23              | CAK95238                 | 383               | WP_063857797            | –                          | 19029333                                           |
| AmpC-24              | CAK95237                 | 383               | –                       | ADC-19                     | Beceiro & Bou., unpublished                        |
| AmpC-25              | ABK34773                 | 383               | WP_0012112217           | ADC-NIPH 528               | 18077114                                           |
| AmpC-26              | ADG46043                 | 383               | WP_001211238            | ADC-NIPH 146               | 20713667                                           |
| AmpC-29              | ACC66195                 | 383               | –                       | –                          | Chiu et al., unpublished                          |
| AmpC-30              | ADG46041                 | 383               | WP_001211218            | ADC-NIPH 2061              | 20713667                                           |
| AmpC-31              | ADX04315                 | 383               | WP_001211223            | –                          | 22038960                                           |
| AmpC-32              | ENU68675                 | 383               | WP_004739487            | ADC-NIPH 615               | 24277043                                           |
| AmpC-38              | ACC05873                 | 383               | WP_063857799            | –                          | 18765689                                           |
| AmpC-39              | ACC05874                 | 383               | WP_063857800            | –                          | 18765689                                           |
| AmpC-41              | ACN62070                 | 383               | WP_063857802            | –                          | 20368407                                           |
| AmpC-42              | ACN62071                 | 383               | WP_063857803            | –                          | 20368407                                           |
| AmpC-43              | ACN62072                 | 383               | WP_032053538            | –                          | 20368407                                           |
| AmpC-44              | ACN62073                 | 383               | WP_063857804            | –                          | 20368407                                           |
| AmpC-50              | ADG46038                 | 383               | WP_031965243            | –                          | Rodriguez-Martinez et al., unpublished               |
| AmpC-51              | ADG46040                 | 383               | WP_063857805            | –                          | 20713667                                           |
| AmpC-52              | ADG46042                 | 383               | WP_001211232            | –                          | 20713667                                           |
| AmpC-53              | ADG46044                 | 383               | WP_063857806            | –                          | 20713667                                           |
| AmpC-54              | ADK35761                 | 383               | WP_063857807            | –                          | 20805394                                           |
| AmpC-56              | AEL30570                 | 383               | WP_031973850            | –                          | 21788456                                           |
| AmpC-57              | ADO51072                 | 383               | WP_001211226            | –                          | 24176550                                           |
| AmpC-58              | AFG25594                 | 383               | WP_063857808            | –                          | Zhang, unpublished                                  |
| AmpC-59              | AFG25595                 | 383               | WP_063857809            | –                          | Zhang, unpublished                                  |
| AmpC-60              | AFH53180                 | 383               | WP_063857810            | –                          | Huang, unpublished                                  |
| AmpC-61              | AFI58570                 | 383               | WP_033503051            | –                          | Zhou, unpublished                                   |
| AmpC-62              | AFK24475                 | 383               | WP_063857811            | –                          | Wang, unpublished                                   |

(Continued)
## Table 2. (Continued)

| AmpC-63   | AFM80040 | 383 | WP_063857812 | − | Zhang, unpublished |
| AmpC-65   | AFP73417 | 385 | − | − | Ling, unpublished |
| AmpC-66   | A FP73418 | 383 | − | − | Ling, unpublished |
| AmpC-67   | AEZ36052 | 383 | WP_063857814 | − | ADC-57, Zhou, unpublished; 24619228 |
| AmpC-68   | AGL39360 | 383 | WP_063857815 | − | Lee et al., 2014 (as a poster); 25372683 |
| AmpC-70   | KQG48886 | 383 | WP_017480710 | − | ADC-72a, Ozer et al., unpublished |
| AmpC-73   | ALA14808 | 383 | WP_001211219 | − | 26824943 |
| AmpC-74   | ALA14809 | 383 | WP_001211203 | − | 26824943 |
| AmpC-75   | ALA14810 | 383 | WP_063857817 | − | 26824943 |
| AmpC-76   | ALA14811 | 383 | WP_001211237 | − | ADC-NiPH 335, 26824943 |
| AmpC-77   | ALA14812 | 383 | WP_063857818 | − | 26824943 |
| AmpC-78   | ALA14813 | 383 | WP_057691006 | − | 26824943 |
| AmpC-79   | ALA14814 | 383 | WP_001159760 | − | 26824943 |
| AmpC-80   | ALA14815 | 383 | WP_029424536 | − | 26824943 |
| AmpC-81   | ALA14816 | 388 | WP_059262723 | − | 26824943 |
| AmpC-82   | AOA49613 | 383 | − | − | Saranathan et al., unpublished |
| AmpC-83   | ANW47146 | 383 | − | − | Kulkarni et al., unpublished |
| AmpC-84   | ANW47149 | 383 | − | − | Kulkarni et al., unpublished |
| AmpC-85   | ANW47142 | 383 | − | − | Kulkarni et al., unpublished |
| AmpC-86   | ANW47143 | 383 | − | − | Kulkarni et al., unpublished |
| AmpC-87   | ANW47154 | 383 | − | − | Kulkarni et al., unpublished |
| AmpC-88   | ANW47135 | 383 | − | − | Kulkarni et al., unpublished |
| AmpC-89   | ANW47136 | 383 | − | − | Kulkarni et al., unpublished |
| AmpC-90   | ANW47147 | 383 | − | − | Kulkarni et al., unpublished |
| AmpC-91   | ANW47132 | 383 | − | − | Kulkarni et al., unpublished |
| AmpC-92   | ANW47134 | 383 | − | − | Kulkarni et al., unpublished |
| AmpC-93   | ANW47145 | 383 | − | − | Kulkarni et al., unpublished |
| AmpC-94   | ANW47137 | 383 | − | − | Kulkarni et al., unpublished |
| AmpC-95   | ANW47153 | 383 | − | − | Kulkarni et al., unpublished |
| AmpC-96   | ANW47150 | 388 | − | − | Kulkarni et al., unpublished |
| AmpC-97   | ANW47139 | 383 | − | − | Kulkarni et al., unpublished |
| AmpC-98   | ANW47138 | 383 | − | − | Kulkarni et al., unpublished |
| AmpC-99   | ANW47140 | 383 | − | − | Kulkarni et al., unpublished |
| AmpC-100  | ANW47141 | 385 | − | − | Kulkarni et al., unpublished |
| AmpC-101  | ANW47133 | 383 | − | − | Kulkarni et al., unpublished |
| AmpC-102  | ANW47148 | 383 | − | − | Kulkarni et al., unpublished |
| AmpC-103  | ANW69905 | 383 | − | − | Kulkarni et al., unpublished |
| AmpC-104  | ANW69906 | 383 | − | − | Kulkarni et al., unpublished |
| AmpC-105  | ANW69907 | 383 | − | − | Kulkarni et al., unpublished |
| AmpC-106  | ANW69909 | 383 | − | − | Kulkarni et al., unpublished |
| AmpC-107  | ANW69912 | 383 | − | − | Kulkarni et al., unpublished |
| AmpC-108  | AFJ94770 | 383 | WP_001211216 | − | 22952140 |
| AmpC-109  | AAV32519 | 383 | − | − | 16441449 |
| AmpC-110  | ABO3812 | 383 | − | − | Huang et al., unpublished |
| AmpC-111  | ABV21800 | 384 | WP_001211220 | − | 18591275 |
| AmpC-112  | ABV21801 | 383 | − | − | 18591275 |
| AmpC-113  | ABV21802 | 383 | − | − | 18591275 |
| AmpC-114  | ETY67158 | 384 | − | − | 20809238 |
| AmpC-115  | AFU38919 | 383 | − | − | 23209228 |

(Continued)
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Author Contributions

Conceptualization: NK KJ RH BEU.

Table 2. (Continued)

| AmpC | Accession | Length | Accession | Description | PubMed ID |
|------|-----------|--------|-----------|-------------|-----------|
| AmpC-116 | WP_017816757 | 383 | WP_017816757 | – | 23723398 |
| AmpC-117 | ELW88222 | 383 | WP_002157727 | – | 24277043 |
| AmpC-118 | ENW75976 | 383 | WP_001211227 | ADC-CIP 70–34T | 24277043 |
| AmpC-119 | ENU51112 | 383 | WP_004712857 | ADC-NIPH 1669 | 24277043 |
| AmpC-120 | ENV26641 | 383 | WP_002126587 | ADC-NIPH 190 | 24277043 |
| AmpC-121 | ENW36647 | 383 | WP_005109685 | ADC-NIPH 201 | 24277043 |
| AmpC-122 | ENW46489 | 383 | WP_005123276 | ADC-NIPH 329 | 24277043 |
| AmpC-123 | ENV30802 | 383 | WP_004840559 | ADC-NIPH 60 | 24277043 |
| AmpC-124 | ENW51893 | 383 | WP_005128228 | ADC-NIPH 601 | 24277043 |
| AmpC-125 | ENV51227 | 383 | WP_005131186 | ADC-NIPH 67 | 24277043 |
| AmpC-126 | ENW72863 | 383 | WP_005138362 | ADC-NIPH 80 | 24277043 |
| AmpC-127 | ENW00696 | 383 | WP_005046018 | ADC-CIP 81–8T | 24277043 |
| AmpC-128 | ENU07956 | 383 | WP_004643536 | ADC-NIPH 13 | 24277043 |
| AmpC-129 | ENV92309 | 383 | WP_005039111 | ADC-ANC 3680 | 24277043 |
| AmpC-130 | ENV41121 | 383 | WP_004886093 | ADC-NIPH 386 | 24277043 |
| AmpC-131 | ENU48760 | 383 | WP_004707701 | ADC-NIPH 2119T | 24277043 |
| AmpC-132 | ENW11417 | 383 | WP_005068074 | ADC-ANC 3678 | 24277043 |
| AmpC-133 | ENU43147 | 383 | WP_004700205 | ADC-NIPH 973 | 24277043 |
| AmpC-134 | ENX43770 | 383 | WP_005307218 | ADC-NIPH 542 | 24277043 |
| AmpC-135 | ENV03983 | 383 | WP_005790939 | ADC-NIPH 817 | 24277043 |
| AmpC-136 | EOQ64883 | 383 | WP_016137488 | ADC-ANC 3811 | 24277043 |
| AmpC-137 | EOQ71234 | 383 | WP_016140427 | ADC-ANC 4050 | 24277043 |
| AmpC-138 | EOQ73533 | 383 | WP_016146025 | ADC-ANC 4052 | 24277043 |
| AmpC-139 | EXS60093 | 383 | WP_032039838 | – | Harris et al., unpublished |
| AmpC-140 | EYSS5294 | 383 | WP_001211209 | – | Harris et al., unpublished |
| AmpC-141 | EXD64655 | 383 | WP_032062810 | – | Harris et al., unpublished |
| AmpC-142 | ETP95102 | 383 | WP_031980335 | – | 24449752 |
| AmpC-143 | WP_033502167 | 383 | WP_033502167 | – | Liou et al., unpublished |
| AmpC-144 | WP_001211214 | 383 | WP_001211214 | – | Sahl et al., unpublished |
| AmpC-145 | KHY08585 | 383 | WP_039270258 | – | Adams et al., unpublished |
| AmpC-146 | KVH30477 | 383 | WP_039258389 | – | Adams et al., unpublished |
| AmpC-147 | KJC71195 | 383 | WP_044718369 | – | Adams et al., unpublished |
| AmpC-148 | AJB47604 | 383 | WP_039246976 | – | McCrorison et al., unpublished |
| AmpC-149 | ADY82440 | 383 | WP_014207272 | – | 21441526 |
| AmpC-150 | AKT73351 | 383 | WP_017386568 | – | Ang et al., unpublished |
| AmpC-151 | AMX20227 | 383 | WP_063099318 | – | Brasiliense et al., unpublished |
| AmpC-152 | ADI89941 | 383 | WP_013197184 | – | 20639327 |

*a AmpC-70 has the same amino acid sequence as AmpC-72 (ADC-72) with the GenBank accession number AIL90389 and PubMed IDentifier 25181293

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Data curation: NK KJ RH BEU.

Resources: NK BEU.

Supervision: NK KJ RH BEU.

Visualization: NK KJ RH BEU.

Writing – original draft: NK.

Writing – review & editing: NK KJ RH BEU.

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