Southern African Journal of Infectious Diseases 2018; 33(4):118–129
https://doi.org/10.1080/23120053.2018.1469851

South Afr J Infect Dis
ISSN 2312-0053 EISSN 2313-1810

RESEARCH

Antimicrobial resistance surveillance in the South African public sector

Olga Perovic[a,b*], Husna Ismail[a] and Erika Van Schalkwyk[a]

[a]*Centre for Healthcare-Associated Infections (HAIs), Antimicrobial Resistance (AMR) and Mycoses, National Institute for Communicable Diseases, a division in the National Health Laboratory Service Johannesburg, South Africa*
[b]*Department of Clinical Microbiology and Infectious Diseases, School of Pathology, University of Witwatersrand Johannesburg, South Africa*
**Corresponding author, email: olgap@nicd.ac.za*

Electronic surveillance for antimicrobial resistance was established in 2013 for public sector laboratories and released annually. This article reports susceptibility data on ESKAPE pathogens for 2016.

Keywords: antimicrobial resistance, ESKAPE organisms, surveillance

Introduction

Colonisation and infection due to multidrug-resistant (MDR) bacteria has become a significant public health concern with both clinical and economic consequences.[1,2] Surveillance for antimicrobial resistance (AMR) is conducted not only to detect changes or variation in AMR either geographically or over time, but is a vital component of any antimicrobial stewardship programme.[3] Integrated health data on bacterial AMR were obtained from an electronic database of antimicrobial susceptibility testing (AST) results generated by public health laboratories in South Africa. This report was designed to provide information on AMR rates in bacterial pathogens causing both community-associated and healthcare-associated infections and was prepared by the Centre for HAIs, AMR and Mycoses (CHARM) and Surveillance Information Management Unit (SIMU) at the National Institute for Communicable Diseases (NICD) and Corporate Data Warehouse (CDW) at the National Health Laboratory Service (NHLS).

Report objectives and scope

1. To determine the number of cases for each of the following ESKAPE pathogens isolated from blood cultures in 2016: *Enterococcus faecalis, Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa, Enterobacter cloacae*, and *Escherichia coli*.
2. To compare AST patterns for each of the ESKAPE pathogens in 2016 with the previous year, 2015.
3. To describe the AST patterns for each of the ESKAPE pathogens by sentinel hospital in 2016.
4. To determine the number of laboratory-confirmed carbapenemase-producing Enterobacteriaceae (CPE) isolated from all specimen types in 2016.

Methods

Data collection and analysis

Data for this report were sourced from the NHLS, CDW. The CDW exists as a national repository for all laboratory tests performed from public sector hospitals in South Africa and contains archived data (demographic and laboratory) from the laboratory information system (LIS), TrakCare. These data were mapped as national, provincial, district and sentinel hospitals by the SIMU at NICD and are available in a dashboard from the NICD website, http://www.nicd.ac.za.

AMR surveillance in the public sector relies on submission of data from the NHLS laboratories that serve academic secondary and tertiary hospitals.[4] Data containing routine AST results for the ESKAPE pathogens were extracted, from January 1, 2016 to December 31, 2016 for 16 sentinel hospitals across South Africa (Table 1).[4]

For the analysis of ESKAPE pathogens, AST results were interpreted in accordance with the Clinical and Laboratory Standards Institute (CLSI) 2016 guidelines and were categorised based on categorical data, susceptible (S) and non-susceptible including intermediate (I) and resistant (R).[5] Due to site-specific differences in testing methodologies and data capture on the LIS, extensive cleaning and recording of data were necessary, which was done within the CDW (Table 2).

For the analysis of carbapenemase-producing Enterobacteriaceae (CPE), data were obtained from the Antimicrobial Resistance Laboratory (AMRL) at CHARM where carbapenem-resistant isolates are referred for phenotypic characterisation, AST and molecular characterisation.

Results

For the purpose of this report, ESKAPE pathogens were categorised as Enterobacteriaceae (*Klebsiella pneumoniae*, *Enterobacter cloacae*, and *Escherichia coli*), non-fermentative Gram-negative bacteria (*Acinetobacter baumannii* and *Pseudomonas aeruginosa*) and Gram-positive bacteria (*Enterococcus faecalis, Enterococcus faecium* and *Staphylococcus aureus*).

Enterobacteriaceae

Of the 5 265 lactose-fermenting bacteria, 53% (2 783/5 265) were identified as *Klebsiella pneumoniae*, 35% (1 850/5 265) were identified as *Escherichia coli* and 12% (632/5265) were identified as *Enterobacter cloacae*. All three pathogens were reported from all 16 sentinel hospitals in South Africa. Some 21% (1 095/5 265) of all three pathogens were reported from Chris Hani Baragwanath Hospital (Figure 1).

Table 1: List of 16 sentinel hospitals participating in antimicrobial resistance surveillance

Hospital name	Academic	Number of beds	Province
Charlotte Maxeke Johannesburg Academic Hospital	Yes	1 088	Gauteng
Chris Hani Baragwanath Hospital	Yes	3 200	Gauteng
Dr George Mukhari Hospital	Yes	1 200	Gauteng
Frere Hospital	No	916	Eastern Cape
Grey's Hospital	Yes	530	KwaZulu-Natal
Groote Schuur Hospital	Yes	893	Western Cape
Helen Joseph Hospital	Yes	700	Gauteng
Inkosi Albert Luthuli Central Hospital	Yes	846	KwaZulu-Natal
King Edward VIII Hospital	Yes	922	KwaZulu-Natal
Livingstone Hospital	Yes	616	Eastern Cape
Mahatma Gandhi Hospital	No	350	KwaZulu-Natal
Nelson Mandela Academic Hospital/ Mthatha Tertiary	Yes	520	Eastern Cape
RK Khan Hospital	No	543	KwaZulu-Natal
Steve Biko Academic Hospital	Yes	832	Gauteng
Tygerberg Hospital	Yes	1310	Western Cape
Universitas Hospital	Yes	650	Free State

Table 2: Antimicrobial susceptibility testing methods performed at the 16 sentinel hospitals

NHLS laboratories at public sector hospitals	MicroScan	Vitek 2	Disk diffusion method
Charlotte Maxeke Johannesburg Academic Hospital	√	√	√
Chris Hani Baragwanath Hospital	√		√
Dr George Mukhari Hospital		√	
Frere Hospital		√	
Grey's Hospital/Northdale Laboratory		√	
Groote Schuur Hospital		√	
Helen Joseph Hospital		√	√
Inkosi Albert Luthuli Central Hospital		√	
King Edward VIII Hospital		√	
Livingstone Hospital		√	
Mahatma Gandhi Hospital		√	
Nelson Mandela Academic Hospital/Mthatha Tertiary			√
RK Khan Hospital		√	
Steve Biko Academic Hospital		√	
Tygerberg Hospital		√	
Universitas Hospital		√	

Of the panel of antimicrobial agents that were tested, more than 65% of *Klebsiella pneumoniae* isolates were non-susceptible to third and fourth generation cephalosporins, which is indicative of extended-spectrum beta-lactamase (ESBL) production. In total, 36% (952/2 642) of *Klebsiella pneumoniae* isolates were non-susceptible to ciprofloxacin, 44% (1 183/2 686) of isolates were non-susceptible to piperacillin/tazobactam and 59% (1 568/2 676) were non-susceptible to gentamicin (Table 3). In comparison with 2015, *Klebsiella pneumoniae* isolates demonstrated higher susceptibility to cefepime ($p = 0.65$), piperacillin/tazobactam ($p = 0.26$) and gentamicin in 2016. Although a higher susceptibility was observed for cefepime and piperacillin/tazobactam in 2016, this was not statistically significant. Overall, antimicrobial susceptibility to carbapenems remained constant over the two-year period (Figure 2). However, high proportions of *Klebsiella pneumoniae* isolates reported from King Edward VIII Hospital Grey's Hospital, Frere Hospital and Nelson Mandela Academic Hospital/Mthatha Tertiary were shown to display reduced susceptibility to cephalosporins (Table 4).

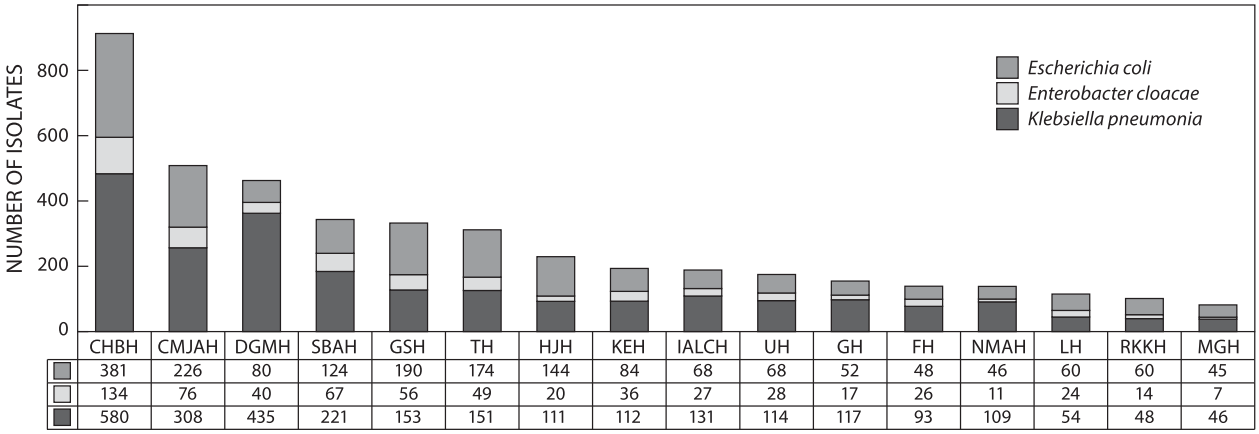

Figure 1: Number of Enterobacteriaceae: *Klebsiella pneumoniae* ($n = 2\,783$), *Escherichia coli* ($n = 1\,850$) and *Enterobacter cloacae* ($n = 632$) reported from 16 sentinel hospitals across South Africa, January 1, 2016 to December 31, 2016. Abbreviations: Chris Hani Baragwanath Hospital (CHBH), Charlotte Maxeke Johannesburg Academic Hospital (CMJAH), Dr George Mukhari Hospital (DGMH), Steve Biko Academic Hospital (SBAH), Groote Schuur Hospital (GSH), Tygerberg Hospital (TH), Helen Joseph Hospital (HJH), King Edward VIII Hospital (KEH), Inkosi Albert Luthuli Central Hospital (IALCH), Universitas Hospital (UH), Grey's Hospital (GH), Frere Hospital (FH), Nelson Mandela Academic Hospital/Mthatha Tertiary (NMAH), Livingstone Hospital (LH), RK Khan Hospital (RKKH) and Mahatma Gandhi Hospital (MGH), number of isolates (*n*).

Table 3: Antimicrobial susceptibility patterns of Enterobacteriaceae isolated from blood cultures reported from 16 sentinel hospitals across South Africa, January 1, 2016 to December 31, 2016

Antimicrobial agent	*Klebsiella pneumoniae*				*Escherichia coli*			
	Non-susceptible		Susceptible		Non-susceptible		Susceptible	
	n	%	*n*	%	*n*	%	*n*	%
Amikacin	442	16.4	2 251	83.6	160	8.8	1 651	91.2
Amoxicillin-clavulanic acid	1 785	66.3	909	33.7	708	39.2	1 096	60.8
Ampicillin/amoxicillin	–	–	–	–	1 539	86.3	244	13.7
Cefepime	1 748	65.0	941	35.0	470	26.5	1 305	73.5
Cefotaxime/ceftriaxone	1 779	66.0	916	34.0	500	27.8	1 297	72.2
Ceftazidime	1 768	65.7	921	34.3	483	26.8	1 317	73.2
Ciprofloxacin	952	36.0	1 690	64.0	530	30.1	1 230	69.9
Ertapenem	137	5.2	2 476	94.8	23	1.3	1 754	98.7
Gentamicin	1 568	58.6	1 108	41.4	348	19.5	1 441	80.5
Imipenem	168	6.2	2 541	93.8	14	0.8	1 797	99.2
Meropenem	178	6.6	2 535	93.4	15	0.8	1 797	99.2
Piperacillin/tazobactam	1 183	44.0	1 503	56.0	257	14.5	1 513	85.5

Notes: number of isolates (*n*), percentage (%), not reported (–).
Colistin was not reported as no reference method was applied at routine laboratories.

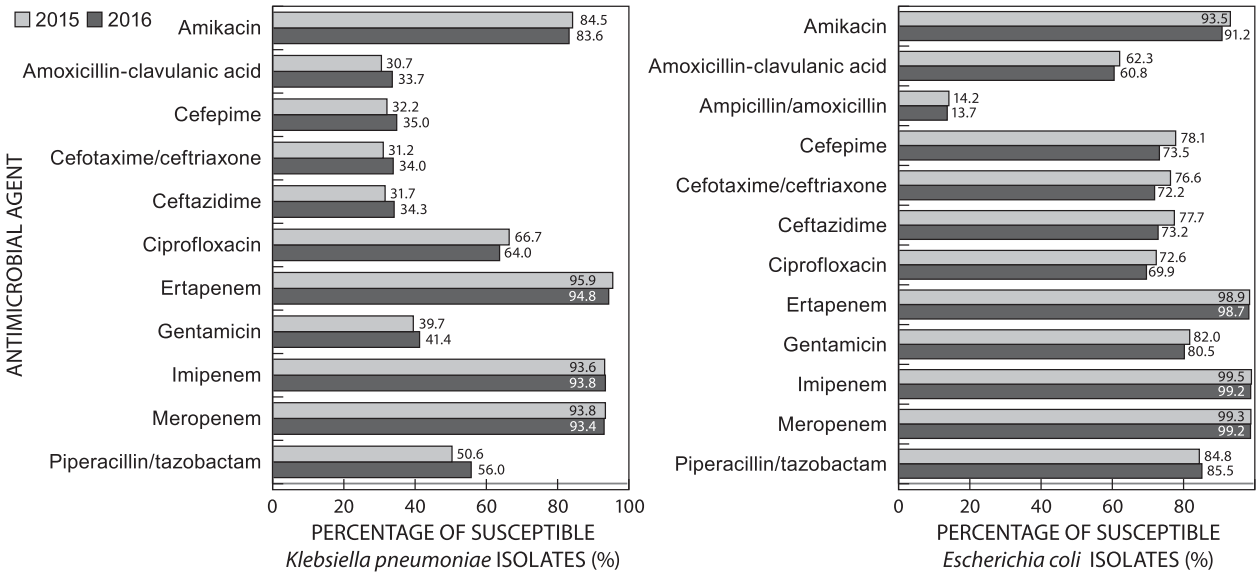

Figure 2: Percentage of susceptible *Klebsiella pneumoniae* and *Escherichia coli* isolates, 2015 to 2016.

Less than 30% of *Escherichia coli* isolates were non-susceptible to third and fourth generation cephalosporins and 30% (530/1760) of isolates were non-susceptible to ciprofloxacin (see Table 3). In comparison with 2015, *Escherichia coli* isolates showed reduced susceptibility in almost all antimicrobial agents (Figure 2). Overall, high proportions of *Escherichia coli* isolates were shown to be susceptible to carbapenems across all 16 sentinel hospitals (Table 5).

Antimicrobial susceptibility patterns for *Enterobacter cloacae* were not reported as data were not available during the preparation of this report.

Non-fermentative gram-negative bacteria

Of the 2 318 non-fermentative Gram-negative bacteria, 71% (1 637/2 318) were identified as *Acinetobacter baumannii* and 29% (681/2 318) were identified as *Pseudomonas aeruginosa*. Both pathogens were reported from all 16 sentinel hospitals in South Africa. Approximately 32% (738/2 318) of both pathogens were reported from Chris Hani Baragwanath Hospital (Figure 3).

Of the panel of antimicrobial agents that were tested, more than 80% of *Acinetobacter baumannii* isolates were non-susceptible to imipenem and meropenem, while 72% (1 140/1 583) and 60% (791/1 320) were non-susceptible to gentamicin and amikacin (Table 6). In comparison to 2015, isolates non-susceptible to gentamicin and amikacin increased but, susceptibility to carbapenems and tigecycline remained constant (Figure 4). A high proportion of *Acinetobacter baumannii* isolates reported from Chris Hani Baragwanath Hospital, Charlotte Maxeke Johannesburg Academic Hospital, Dr George Mukhari Hospital, Helen Joseph Hospital, Inkosi Albert Luthuli Central Hospital, King Edward VIII Hospital, Steve Biko Academic Hospital and Universitas Hospital showed reduced susceptibility to carbapenems (Table 7).

Table 4: Number and percentage of susceptible *Klebsiella pneumoniae* isolates per antimicrobial agent from 16 sentinel hospitals across South Africa, January 1, 2016 to December 31, 2016

Antimicrobial agent	CHBH	CMJAH	DGMH	SBAH	GSH	TH	HJH	KEH*	IALCH*	UH	GH*	FH	NMAH	LH	RKKH*	MGH*
	n	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Amikacin	560	288	416	220	151	149	106	106	130	112	113	91	106	54	47	44
	94.8	**93.8**	**89.2**	**64.1**	**94.7**	**81.2**	**98.1**	**60.4**	**67.7**	**87.5**	**88.5**	**64.8**	**45.3**	**87.0**	**76.6**	**68.2**
Amoxicillin-clavulanic acid	556	292	413	221	152	150	107	109	128	111	113	90	106	54	48	44
	27.0	**32.9**	**56.4**	**29.9**	**38.2**	**38.7**	**36.4**	**21.1**	**27.3**	**33.3**	**15.9**	**15.6**	**20.8**	**40.7**	**43.8**	**38.6**
Cefepime	566	297	413	221	152	150	110	100	120	111	111	90	105	53	45	45
	32.5	**38.0**	**58.1**	**33.0**	**41.1**	**40.0**	**44.5**	**15.0**	**25.0**	**35.1**	**14.4**	**13.3**	**4.8**	**32.1**	**31.1**	**24.4**
Cefotaxime/ ceftriaxone	556	296	414	221	150	151	107	104	129	111	113	92	105	54	47	45
	31.7	**35.8**	**56.3**	**33.0**	**41.3**	**39.7**	**40.2**	**15.4**	**24.8**	**35.1**	**14.2**	**12.0**	**5.7**	**31.5**	**29.8**	**26.7**
Ceftazidime	563	290	412	221	149	150	109	105	128	111	113	89	105	54	46	44
	32.5	**36.9**	**55.8**	**33.0**	**41.6**	**40.0**	**39.4**	**16.2**	**25.0**	**35.1**	**14.2**	**12.4**	**3.8**	**33.3**	**30.4**	**27.3**
Ciprofloxacin	553	244	416	221	151	151	107	107	129	111	112	90	105	54	46	45
	56.6	**65.2**	**79.6**	**55.2**	**72.8**	**74.2**	**50.5**	**43.0**	**57.4**	**61.3**	**63.4**	**62.2**	**85.7**	**59.3**	**56.5**	**57.8**
Ertapenem	559	287	426	205	151	150	110	79	103	112	112	88	104	50	42	35
	86.8	**93.7**	**99.1**	**92.2**	**99.3**	**96.7**	**90.0**	**97.5**	**100.0**	**98.2**	**97.3**	**100.0**	**99.0**	**100.0**	**100.0**	**100.0**
Gentamicin	550	289	415	221	151	151	108	105	120	111	113	91	105	54	47	45
	32.2	**47.8**	**62.7**	**43.4**	**49.7**	**53.0**	**55.6**	**27.6**	**27.5**	**37.8**	**18.6**	**25.3**	**7.6**	**55.6**	**40.4**	**37.8**
Imipenem	564	298	422	218	148	151	110	109	130	111	112	87	105	53	46	45
	91.5	**92.3**	**99.8**	**86.2**	**99.3**	**98.0**	**96.4**	**79.8**	**86.9**	**99.1**	**95.5**	**100.0**	**100.0**	**100.0**	**93.5**	**77.8**
Meropenem	558	298	426	220	153	149	109	105	130	112	113	90	106	52	46	46
	91.9	**92.6**	**99.3**	**85.0**	**99.3**	**97.3**	**96.3**	**80.0**	**86.2**	**97.3**	**94.7**	**98.9**	**97.2**	**100.0**	**91.3**	**78.3**
Piperacillin/ tazobactam	564	296	423	220	152	151	109	108	130	110	111	63	103	54	47	45
	57.8	**60.8**	**66.7**	**27.3**	**75.7**	**78.8**	**49.5**	**45.4**	**45.4**	**33.6**	**43.2**	**74.6**	**34.0**	**50.0**	**78.7**	**62.2**

Note: *AST patterns for carbapenems varied for sentinel hospitals located in KwaZulu-Natal: KEH, IALCH, GH, RKKH and MGH.

Table 5: Number and percentage of susceptible *Escherichia coli* isolates per antimicrobial agent from 16 sentinel hospitals across South Africa, January 1, 2016 to December 31, 2016

Antimicrobial agent	CHBH	CMJAH	DGMH	SBAH	GSH	TH	HJH	KEH	IALCH	UH	GH	FH	NMAH	LH	RKKH	MGH
	n	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Amikacin	373	221	79	124	186	171	138	83	68	67	51	47	43	59	57	44
	98.7	**98.2**	**81.0**	**74.2**	**98.9**	**91.8**	**99.3**	**71.1**	**69.1**	**89.6**	**84.3**	**91.5**	**86.0**	**86.4**	**89.5**	**93.2**
Amoxicillin-clavulanic acid	372	220	78	124	185	173	137	81	67	66	52	46	45	58	57	43
	52.4	**68.2**	**56.4**	**54.8**	**73.0**	**71.1**	**63.5**	**42.0**	**47.8**	**74.2**	**40.4**	**82.6**	**46.7**	**67.2**	**56.1**	**65.1**
Ampicillin/ amoxicillin	363	215	74	123	185	171	134	81	67	67	52	48	43	59	57	44
	4.4	**16.7**	**10.8**	**21.1**	**22.7**	**21.6**	**10.4**	**4.9**	**7.5**	**22.4**	**3.8**	**18.8**	**14.0**	**23.7**	**14.0**	**4.5**
Cefepime	368	221	75	123	185	172	143	79	56	67	52	47	43	59	52	33
	74.2	**89.6**	**58.7**	**71.5**	**73.5**	**77.9**	**83.2**	**48.1**	**48.2**	**91.0**	**55.8**	**83.0**	**46.5**	**78.0**	**63.5**	**60.6**
Cefotaxime/ ceftriaxone	369	218	78	124	185	171	141	82	66	66	52	45	40	59	57	44
	72.9	**81.7**	**59.0**	**71.8**	**74.1**	**78.4**	**80.9**	**48.8**	**51.5**	**90.9**	**57.7**	**82.2**	**50.0**	**78.0**	**63.2**	**61.4**
Ceftazidime	365	221	76	123	187	172	142	81	65	67	52	46	44	59	56	44
	73.7	**87.8**	**57.9**	**71.5**	**73.3**	**77.9**	**82.4**	**51.9**	**50.8**	**91.0**	**57.7**	**84.8**	**47.7**	**78.0**	**62.5**	**61.4**
Ciprofloxacin	364	185	77	122	184	169	141	82	67	67	51	47	44	58	57	45
	70.9	**79.5**	**61.0**	**69.7**	**65.8**	**72.2**	**80.1**	**54.9**	**47.8**	**83.6**	**52.9**	**78.7**	**75.0**	**79.3**	**64.9**	**53.3**
Ertapenem	375	222	77	122	184	173	140	77	58	66	52	45	42	54	51	34
	94.9	**99.5**	**100.0**	**99.2**	**100.0**	**100.0**	**99.3**	**98.7**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
Gentamicin	367	220	77	123	185	170	141	81	59	66	52	47	43	59	56	43
	79.6	**83.6**	**76.6**	**86.2**	**81.1**	**86.5**	**83.7**	**69.1**	**61**	**86.4**	**69.2**	**89.4**	**81.4**	**93.2**	**76.8**	**58.1**
Imipenem	376	224	78	124	186	173	142	83	67	66	52	47	41	59	53	
	97.9	**99.1**	**100.0**	**98.4**	**100.0**	**100.0**	**98.6**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
Meropenem	371	223	78	123	185	172	143	82	67	67	52	47	42	59	58	40
	97.6	**99.1**	**100.0**	**98.4**	**100.0**	**100.0**	**98.6**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
Piperacillin/ tazobactam	369	220	79	124	187	173	141	82	68	67	52	-	43	59	58	45
	87.0	**86.4**	**77.2**	**62.9**	**93.0**	**90.8**	**85.1**	**82.9**	**88.2**	**76.1**	**78.8**	**-**	**81.4**	**94.9**	**94.8**	**95.6**

Note: Data were omitted for those sentinel hospitals that tested fewer than 30 ESKAPE pathogens for a particular antimicrobial agent.

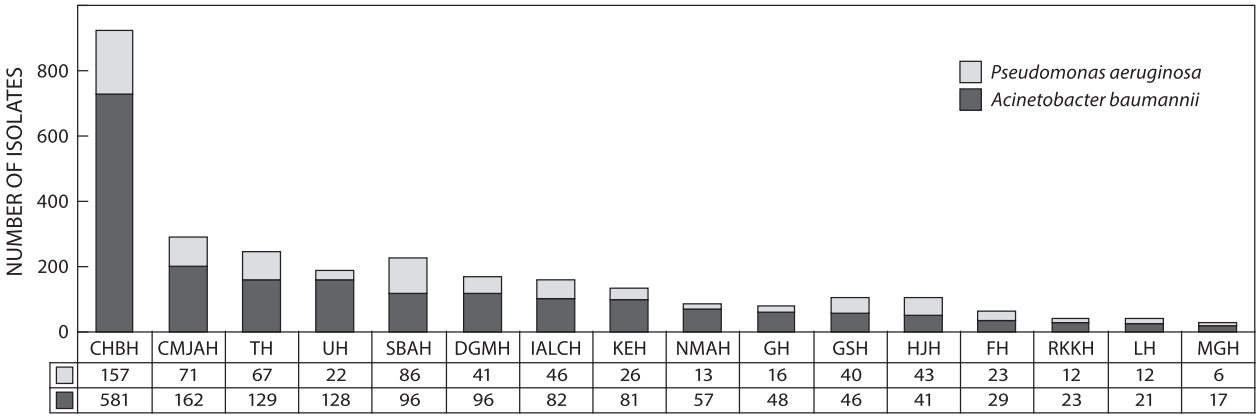

Figure 3: Number of non-fermenters: *Acinetobacter baumannii* ($n = 1\,637$) and *Pseudomonas aeruginosa* ($n = 681$) reported from 16 sentinel hospitals across South Africa, January 1, 2016 to December 31, 2016.

Table 6: Antimicrobial susceptibility patterns of non-fermenters isolated from blood cultures reported from 16 sentinel hospitals across South Africa, January 1, 2016 to December 31, 2016

Antimicrobial agent	*Acinetobacter baumannii*				*Pseudomonas aeruginosa*			
	Non-susceptible		Susceptible		Non-susceptible		Susceptible	
	n	%	*n*	%	*n*	%	*n*	%
Amikacin	791	59.9	529	40.1	–	–	–	–
Gentamicin	1140	72.0	443	28.0	–	–	–	–
Imipenem	1294	81.0	304	19.0	172	26.1	488	73.9
Meropenem	1290	81.3	296	18.7	164	24.8	498	75.2
Minocycline	21	87.5	3	12.5	–	–	–	–
Tigecycline	53	7.5	652	92.5	–	–	–	–
Cefepime	–	–	–	–	139	21.75	500	78.2
Ceftazidime	–	–	–	–	134	20.12	532	79.9
Piperacillin/tazobactam	–	–	–	–	151	23.45	493	76.6

Notes: number of isolates (*n*), percentage (%), not reported (–).

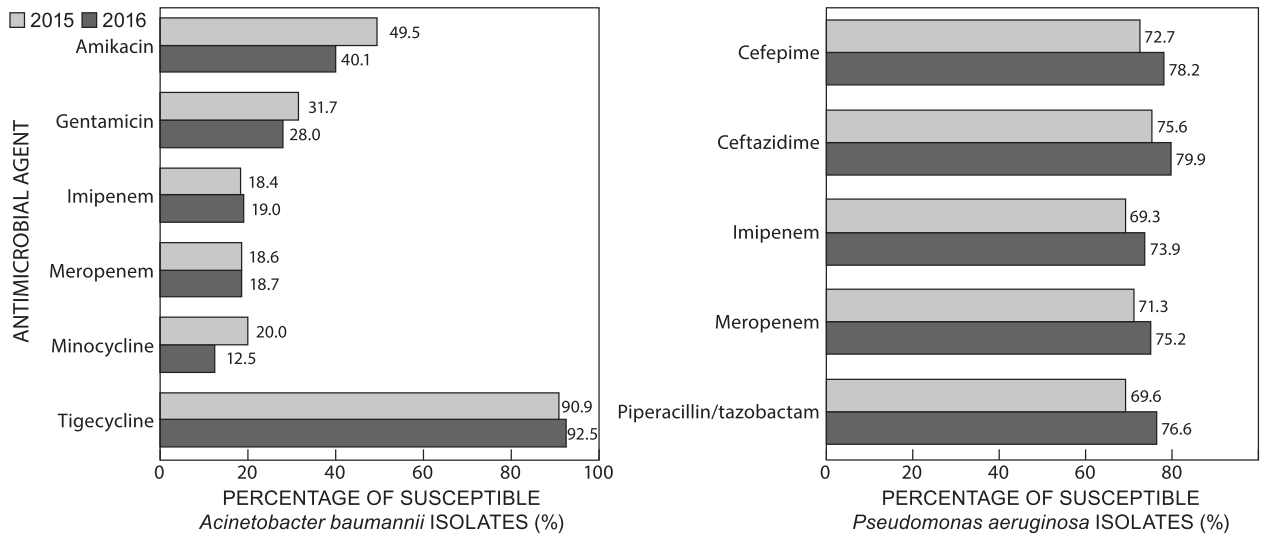

Figure 4: Percentage of susceptible *Acinetobacter baumannii* and *Pseudomonas aeruginosa* isolates, 2015 to 2016.

Approximately 80% and 75% of *Pseudomonas aeruginosa* isolates were susceptible to cephalosporins and carbapenems (Table 6). Antimicrobial susceptibility to imipenem ($p = 0.21$), cefepime ($p = 0.57$) and piperacillin/tazobactam ($p = 0.39$) increased in *Pseudomonas aeruginosa*; however, this was not statistically significant over the two-year period (Figure 4). Almost 50% of *Pseudomonas aeruginosa* isolates reported from Tygerberg Hospital showed reduced susceptibility to carbapenems (Table 8).

Gram-positive bacteria

Of the 3 369 Gram-positive bacteria, 20% (785/3 369) were identified as *Enterococcus faecalis*, 21% (846/3 369) were identified as

Table 7: Number and percentage of susceptible *Acinetobacter baumannii* isolates per antimicrobial agent from 16 sentinel hospitals across South Africa, January 1, 2016 to December 31, 2016

Antimicrobial agent	CHBH	CMJAH	DGMH	SBAH	GSH	TH	HJH	KEH	IALCH	UH	GH	FH	NMAH	LH	RKKH	MGH
	n	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Amikacin	561	110	91	–	44	119	36	47	68	120	43	–	–	–	–	–
	32.6	**43.6**	**34.1**	**–**	**70.5**	**41.2**	**41.7**	**70.2**	**72.1**	**20.8**	**39.5**	**–**	**–**	–	–	–
Gentamicin	557	155	96	96	44	125	40	77	75	125	48	–	56	–	–	–
	16.5	**35.5**	**21.9**	**21.9**	**75.0**	**44.8**	**37.5**	**41.6**	**42.7**	**10.4**	**43.8**	**–**	**23.2**	–	–	–
Imipenem	567	157	94	96	46	125	40	77	78	125	48	–	56	–	–	–
	6.7	**12.1**	**24.5**	**17.7**	**58.7**	**26.4**	**12.5**	**33.8**	**33.3**	**9.6**	**20.8**	**–**	**46.4**	–	–	–
Meropenem	558	157	94	96	43	126	38	77	78	126	47	–	57	–	–	–
	6.1	**12.1**	**25.5**	**17.7**	**58.1**	**25.4**	**15.8**	**32.5**	**33.3**	**9.5**	**21.3**	**–**	**47.4**	–	–	–
Tigecycline	–	136	**86**	95	44	–	–	76	75	–	47	–	54	–	–	–
	–	**94.9**	**95.3**	**100.0**	**95.5**	–	–	**93.4**	**84.0**	**–**	**87.2**	**–**	**96.3**	–	–	–

Note: Data were omitted for those sentinel hospitals that tested fewer than 30 ESKAPE pathogens for a particular antimicrobial agent.

Table 8: Number and percentage of susceptible *Pseudomonas aeruginosa* isolates per antimicrobial agent from 16 sentinel hospitals across South Africa, January 1, 2016 to December 31, 2016

Antimicrobial agent	CHBH	CMJAH	DGMH	SBAH	GSH	TH	HJH	KEH	IALCH	UH	GH	FH	NMAH	LH	RKKH	MGH
	n	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Cefepime	154	69	39	88	38	65	42	–	34	–	–	–	–	–	–	–
	87.0	**73.9**	**87.2**	**76.1**	**78.9**	**63.1**	**95.2**	–	**58.8**	–	–	–	–	–	–	–
Ceftazidime	153	69.0	40.0	88	37	65	43	–	44	–	–	–	–	–	–	–
	86.3	**75.4**	**92.5**	**76.1**	**81.1**	**66.2**	**93.0**	–	**72.7**	–	–	–	–	–	–	–
Imipenem	153	70	38	88	39	64	42	–	45	–	–	–	–	–	–	–
	70.6	**72.9**	**92.1**	**65.9**	**74.4**	**48.4**	**88.1**	–	**77.8**	–	–	–	–	–	–	–
Meropenem	152	70	38	88	38.0	65	41	–	45	–	–	–	–	–	–	–
	70.4	**74.3**	**89.5**	**67.0**	**76.3**	**52.3**	**92.7**	–	**77.8**	–	–	–	–	–	–	–
Piperacillin/ tazobactam	154	67	40	84	38	62	42	–	45	–	–	–	–	–	–	–
	79.2	**71.6**	**87.5**	**76.2**	**76.3**	**79.0**	**85.7**	–	**71.1**	–	–	–	–	–	–	–

Note: Data were omitted for those sentinel hospitals that tested fewer than 30 ESKAPE pathogens for a particular antimicrobial agent.

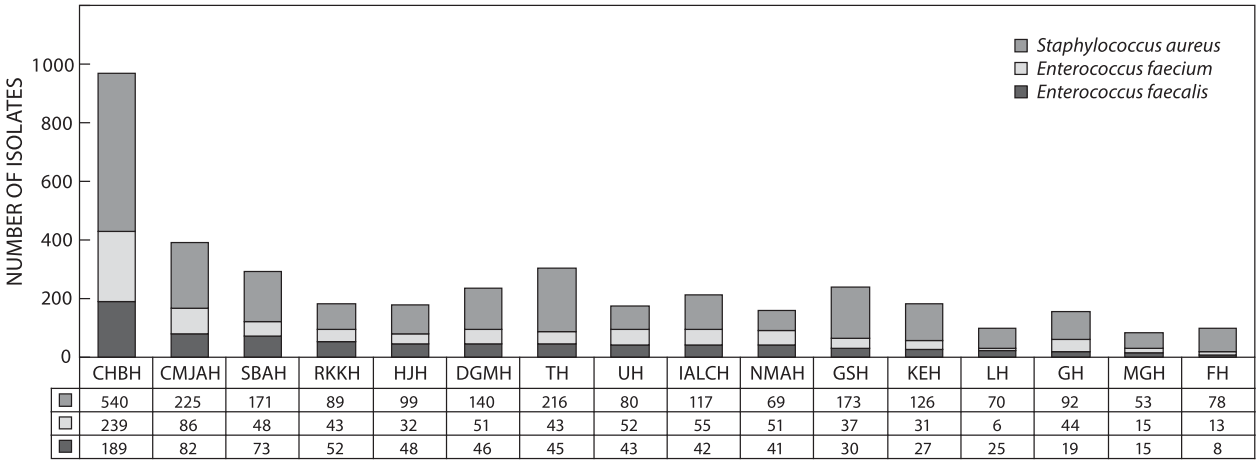

Figure 5: Number of Gram-positive bacteria: *Enterococcus faecalis* ($n = 785$), *Enterococcus faecium* ($n = 846$) and *Staphylococcus aureus* ($n = 2\ 338$) reported from 16 sentinel hospitals across South Africa, January 1, 2016 to December 31, 2016.

Table 9: Antimicrobial susceptibility patterns of Gram-positive bacteria isolated from blood cultures reported from 16 sentinel hospitals across South Africa, January 1, 2016 to December 31, 2016

Antimicrobial agent	*Enterococcus faecalis*				*Enterococcus faecium*				*Staphylococcus aureus*			
	Non-susceptible		Susceptible		Non-susceptible		Susceptible		Non-susceptible		Susceptible	
	n	%	*n*	%	*n*	%	*n*	%	n	%	*n*	%
Linezolid	3	0.4	687	99.6	5	0.7	734	99.3	–	–	–	–
Penicillin/ ampicillin	33	9.7	306	90.3	383	97.5	10	2.5	–	–	–	–
Teicoplanin	5	1.2	409	98.8	12	2.7	426	97.3	–	–	–	–
Vancomycin	8	1.0	759	99.0	45	5.4	796	94.6	–	–	–	–
Cloxacillin	–	–	–	–	–	–	–	–	709	30.8	1590	69.2

Notes: number of isolates (*n*), percentage (%), not reported (–).
Vancomycin was not reported for *Staphylococcus aureus* as non–susceptibility is rare.

Enterococcus faecium and 59% (2 338/3 369) were identified as *Staphylococcus aureus*. All three pathogens were reported from all 16 sentinel hospitals in South Africa. Approximately 29% (968/3 369) of all three pathogens were reported from Chris Hani Baragwanath Hospital (Figure 5).

Of the panel of antimicrobial agents that were tested, more than 90% of *Enterococcus faecalis* and *Enterococcus faecium* isolates were shown to be susceptible to oxazolidinones and glycopeptides (Table 9). In comparison with 2015, AST patterns for the particular antimicrobial agents remained similar in both *Enterococcus faecalis* and *Enterococcus faecium* isolates over the two-year period (Figure 6). There were no unusual AST patterns reported for *Enterococcus faecalis* isolates (Table 10). Approximately 48% of *Enterococcus faecium* isolates from Universitas Hospital were shown to be non-susceptible to

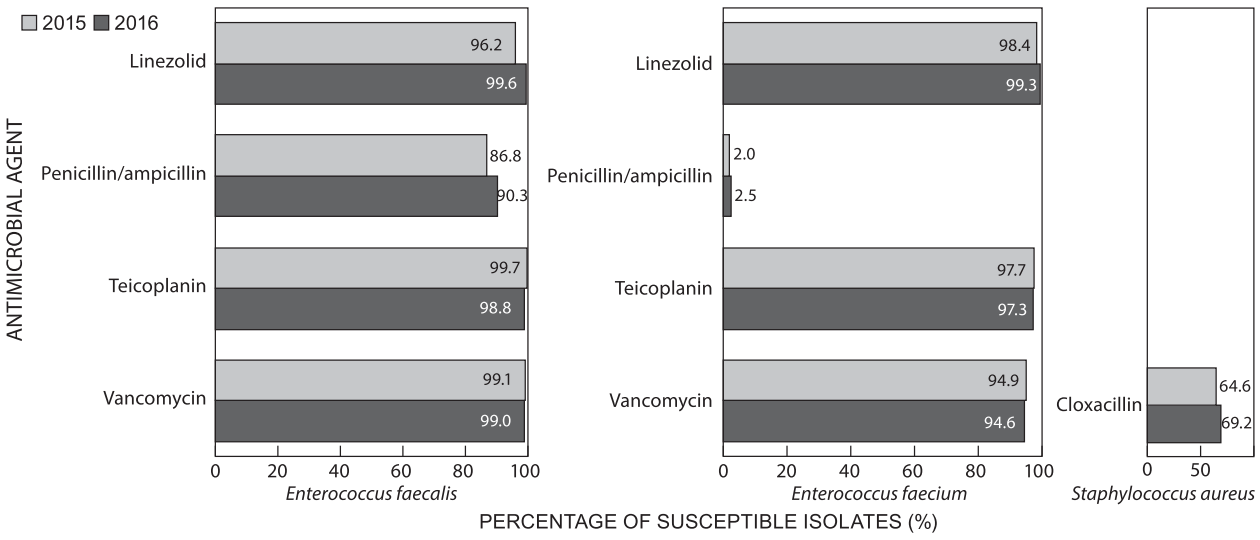

Figure 6: Percentage of susceptible *Enterococcus faecalis*, *Enterococcus faecium* and *Staphylococcus aureus* isolates, 2015 to 2016.

Table 10: Number and percentage of susceptible *Enterococcus faecalis* isolates per antimicrobial agent from 16 sentinel hospitals across South Africa, January 1, 2016 to December 31, 2016

Antimicrobial agent	CHBH	CMJAH	DGMH	SBAH	GSH	TH	HJH	KEH	IALCH	UH	GH	FH	NMAH	LH	RKKH	MGH
	n	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Linezolid	188	79	43	73	–	40	45	–	40	43	–	–	–	–	36	–
	100.0	**100.0**	**97.7**	**100.0**	–	**100.0**	**97.8**	–	**100.0**	**100.0**	–	–	–	–	**100.0**	–
Penicillin/ ampicillin	–	62	–	69	–	–	–	–	39	–	–	–	–	–	46	–
	–	**91.9**	–	**98.6**	–	–	–	–	**100.0**	–	–	–	–	–	**91.3**	–
Teicoplanin	–	64	41	72	–	42	–	–	40	–	–	–	–	–	38	–
	–	**100.0**	**97.6**	**100.0**	–	**100.0**	–	–	**100.0**	–	–	–	–	–	**97.4**	–
Vancomycin	189	79	43	72	–	45	43	–	42	43	–	–	39	–	53	–
	99.5	**100.0**	**100.0**	**100.0**	–	**100.0**	**100.0**	–	**100.0**	**95.3**	–	–	**94.9**	–	**96.2**	–

Note: Data were omitted for those sentinel hospitals that tested fewer than 30 ESKAPE pathogens for a particular antimicrobial agent.

Table 11: Number and percentage of susceptible *Enterococcus faecium* isolates per antimicrobial agent from 16 sentinel hospitals across South Africa, January 1, 2016 to December 31, 2016

Antimicrobial agent	CHBH	CMJAH	DGMH	SBAH	GSH	TH	HJH	KEH	IALCH	UH	GH	FH	NMAH	LH	RKKH	MGH
	n	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Linezolid	232	84	51	43	37	39	32	–	49	52	39	–	–	–	–	–
	100.0	**98.8**	**94.1**	**100.0**	**100**	**97.4**	**100.0**	–	**100.0**	**100.0**	**100.0**	–	–	–	–	–
Penicillin/ ampicillin	–	79	–	43	37	–	–	–	53	–	41	–	–	–	38	–
	–	**2.5**	–	**2.3**	**0.0**	–	–	–	**1.9**	–	**7.3**	–	–	–	**2.6**	–
Teicoplanin	–	81	47	45	37	40	–	30	52	–	39	–	–	–	–	–
	–	**96.3**	**93.6**	**97.8**	**100.0**	**100.0**	–	**100.0**	**98.1**	–	**100.0**	–	–	–	–	–
Vancomycin	236	87	51	46	37	44	30	31	55	52	44	–	51	–	43	–
	96.2	**95.4**	**96.1**	**97.8**	**100.0**	**100.0**	**100.0**	**100.0**	**98.2**	**51.9**	**100.0**	–	**96.1**	–	**97.7**	–

Note: Data were omitted for those sentinel hospitals that tested fewer than 30 ESKAPE pathogens for a particular antimicrobial agent.

Table 12: Number and percentage of susceptible *Staphylococcus aureus* isolates per antimicrobial agent from 16 sentinel hospitals across South Africa, January 1, 2016 to December 31, 2016

Antimicrobial agent		CHBH	CMJAH	DGMH	SBAH	GSH	TH	HJH	KEH	IALCH	UH	GH	FH	NMAH	LH	RKKH	MGH
		n	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*	*n*
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Cloxacillin		535	214	137	172	172	213	97	122	113	80	90	77	65	71	88	53
		50.1	**72.9**	**71.5**	**84.9**	**82.0**	**70.4**	**89.7**	**66.4**	**76.1**	**71.3**	**66.7**	**63.6**	**58.5**	**81.7**	**85.2**	**75.5**

vancomycin; however, this finding should be interpreted with caution as AST testing for these non-susceptible isolates may not have been confirmed using additional testing (Table 11).

Approximately 69% of *Staphylococcus aureus* isolates were susceptible to cloxacillin (Table 9). In comparison with 2015, susceptibility to cloxacillin ($p = 0.23$) increased from 65% to 69%; however, this was not statistically significant (Figure 6). In addition, 50% of *Staphylococcus aureus* isolates reported from Chris Hani Baragwanath Hospital were shown to be non-susceptible to cloxacillin (Table 12).

Carbapenemase-producing Enterobacteriaceae

In 2016, AMRL/CHARM identified 1 182 CPE isolates from clinically significant sites (blood and urine were the most common specimen types). Approximately 72% (846/1 182) of CPE isolates were identified as *Klebsiella pneumoniae*. Approximately 34% (400/1 182) and 63% (741/1 182) of CPE isolates were shown to be positive for $bla_{\text{NDM-1}}$ and $bla_{\text{OXA-48}}$-like encoding genes (Table 13). In 2016, CPE isolates encoding for $bla_{\text{OXA-48}}$-like genes were shown to be most prevalent compared with 2015.[6]

Limitations

Interpretation of results

The results of this report should be interpreted with caution. A number of factors might have introduced bias, resulting in either an overestimation or underestimation of AST reporting.

1. Data may have been incomplete due to missing cases not captured on the LIS or non-standardised coding of ESKAPE pathogens and antimicrobial agents at diagnostic laboratories. Testing methods and microbiological practice may have varied between sentinel hospitals and this could account for variations in the results presented in this report.
2. Confirmatory AST methods may not have been performed or recorded for any of these ESKAPE pathogens as the results presented here were reported as captured on the LIS by diagnostic laboratories. We have not been able to report on colistin AST as new methods have been recommended by CLSI and the European Committee on Antimicrobial Susceptibility Testing (EUCAST) guidelines, which have not yet been implemented by diagnostic laboratories.
3. For some sentinel hospitals, ESKAPE pathogens may not all have been represented. This may be due to ESKAPE pathogens not being isolated at a particular sentinel hospital in 2016.
4. Data were omitted for those sentinel hospitals that tested fewer than 30 ESKAPE pathogens for a particular antimicrobial agent.
5. Vancomycin resistance for *Staphylococcus aureus* requires confirmatory testing, which may not have been available at routine laboratory level. All *Staphylococcus aureus* isolates that are non-susceptible to vancomycin should be referred to AMRL/CHARM at the NICD.
6. Results for CPE may not be representative as not all CRE isolates are referred to CHARM for CPE confirmatory testing.

Table 13: Total number of confirmed Carbapenemase-producing Enterobacteriaceae, January 1, 2016 to December 31, 2016

	Carbapenemase class						
CPE	GES	IMP	KPC	OXA-48 and variants	NDM	VIM	Total
Citrobacter amalonaticus	–	–	–	2	–	–	2
Citrobacter braakii	–	–	–	1	1	–	2
Citrobacter freundii	–	–	1	8	9	–	18
Citrobacter koseri	–	–	–	1	–	–	1
Citrobacter sedlakii	–	–	–	–	1	–	1
Enterobacter aerogenes	–	–	–	8	1	–	9
Enterobacter cloacae	1	–	2	57	32	2	94
Enterobacter gergoviae	–	–	–	1	–	–	1
Enterobacter kobei	–	–	–	1	2	–	3
Escherichia coli	–	–	–	90	11	–	101
Klebsiella oxytoca	1	–	–	6	2	–	9
Klebsiella pneumoniae	11	–	3	531	287	14	846
Klebsiella species	–	–	–	6	–	2	8
Morganella morganii	–	–	–	2	6	–	8
Proteus mirabilis	–	–	–	2	–	–	2
Proteus vulgaris	–	–	–	–	1	–	1
Providencia rettgeri	–	–	–	1	17	–	18
Salmonella species	–	–	–	–	1	–	1
Serratia marcescens	3	–	–	24	29	1	57
Total	**16**	**0**	**6**	**741**	**400**	**19**	**1 182**

Notes: imipenemase (IMP), Guiana extended-spectrum carbapenemase (GES) *Klebsiella pneumoniae* carbapenemase (KPC), oxacillinase (OXA), New Delhi metallo-beta-lactamase (NDM) and veronica integron metallo-beta-lactamases types (VIM).

Conclusion

In this report, data showed that antimicrobial susceptibility patterns for *Klebsiella pneumoniae* remained the same over the two-year period. Antimicrobial resistance to third and fourth generation cephalosporins increased for *Escherichia coli*. Carbapenem resistance in *Acinetobacter baumannii* is of concern as there are limited antimicrobial options available for treatment of significant infections. Although a large proportion of vancomycin-resistant *Enterococcus faecium* was reported from Universitas Hospital, these isolates need laboratory confirmation as this may have been an unidentified outbreak. In most pathogens, the AST patterns remained unchanged. There has been a large increase in the number of CPEs identified across South Africa over the two-year period. Enhanced surveillance together with effective antimicrobial stewardship programmes and strict infection control practices are needed to combat AMR in both ESKAPE pathogens and CPEs. The limitations highlighted in this report emphasise the need for continuous improvement in quality of data obtained by electronic surveillance.

Disclaimer

Data are reported as received through the CDW. No demographic, epidemiological, clinical or molecular data were available to distinguish between hospital-associated and community-associated infections.

Acknowledgements – The authors would like to thank the following: Ms Sue Candy and her team for preparing the data; Dr Ashika Singh-Moodley for providing 2016 CPE data; the SASCM editorial committee (Prof. O Perovic, Dr W Lowman, Prof. N Govender, Dr C Sriruttan, Dr K Moodley, Dr C Govind, Dr I Zietsman, Dr B Magazi, Dr R Kularatne, Dr M Maloba, Dr C Bamford, Dr K Sweswe-Han and Dr Y Mahabeer) for comments and suggestions.

Disclosure statement – No potential conflict of interest was reported by the authors.

References

1. De Rosa FG, Corcione S, Pagani N, et al. From ESKAPE to ESCAPE, from KPC to CCC. CID. 2015;60(8): 1289–1290. 10.1093/cid/ciu1170
2. Dik JH, Sinha B. Challenges for a sustainable financial foundation for antimicrobial stewardship. Infect Dis Rep. 2017;9: 32–34.
3. Patel JB, Cockerill FR, Eliopoulos GM, et al. CLSI. Performance Standards for Antimicrobial Susceptibility Testing. 26th ed. CLSI supplement M100S. 2016;36(1): 1–12. Wayne, PA: Clinical and Laboratory Standards Institute.
4. Bamford C, Brink A, Govender N, et al. Part V. Surveillance activities. *SAMJ*. 2011;101: 1–8.
5. Performance Standards for Antimicrobial Susceptibility Testing. *Clinical and Laboratory Standards Institute (CLSI)*, 2016; M100–S26.
6. Perovic O, Chetty V [Internet]. Antimicrobial Resistance Surveillance from sentinel public hospitals, South Africa. 2015 [Updated August 2016; cited 05 July 2017]. Available from: http://www.fidssa.co.za/Content/images/2015_SASCM_Public_Sector_ReportFINAL.pdf

Received: 8-12-2017 Accepted: 24-04-2018