

Surveillance and comparison of antimicrobial susceptibility patterns of ESKAPE organisms isolated from patients with bacteraemia in South Africa, 2016 - 2017

H Ismail,¹ BSc, BSc Hons, PhD, MPH; W Lowman,^{2,3,4} MB BCh, FC Path (SA) (Microbiol), MMed (Microbiol); C N Govind,^{5,6} MB ChB, FC Path (SA) (Microbiol); K Swe Swe-Han,^{6,7} MBBS, DTM&H, PDIC, FC Path (SA) (Microbiol), MMed (Microbiol), PhD (Med Microbiol); M R B Maloba,⁸ MB ChB, DTM&H, FC Path (SA) (Microbiol); C Bamford,^{9,10} MB ChB, FC Path (SA) (Microbiol), MMed (Microbiol); O Perovic,^{1,2} MD, DTM&H, FC Path (SA) (Microbiol), MMed (Microbiol)

¹ Centre for Healthcare-Associated Infections, Antimicrobial Resistance and Mycoses, National Institute for Communicable Diseases, National Health Laboratory Service, Johannesburg, South Africa

² Department of Clinical Microbiology and Infectious Diseases, School of Pathology, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa

³ Vermaak and Partners/Pathcare Pathologists, Johannesburg, South Africa

⁴ Wits Donald Gordon Medical Centre, Johannesburg, South Africa

⁵ Lancet Laboratories, Durban, South Africa

⁶ College of Health Sciences, University of KwaZulu-Natal, Durban, South Africa

⁷ School of Laboratory Medicine and Medical Sciences, Inkosi Albert Luthuli Central Hospital Academic Complex, Durban, South Africa; and National Health Laboratory Service, Durban, South Africa

⁸ Faculty of Health Sciences, University of the Free State, Bloemfontein, South Africa; and National Health Laboratory Service, Universitas Academic Laboratory Complex, Bloemfontein, South Africa

⁹ PathCare, East London, South Africa

¹⁰ Division of Medical Microbiology, Department of Pathology, Faculty of Health Sciences, University of Cape Town, South Africa

Corresponding author: O Perovic (olgap@nicd.ac.za)

Background. In South Africa (SA), the National Department of Health has developed an Antimicrobial Resistance National Strategy Framework document to manage antimicrobial resistance (AMR). One of the strategic objectives is to optimise surveillance and early detection of AMR. At the National Institute for Communicable Diseases (NICD), an analysis of selected organisms and antimicrobial agents from both the public and the private sectors was conducted.

Objectives. The relevance of surveillance for AMR is increasingly recognised in the light of global action plans to combat resistance. In this report, we present an overview of ESKAPE (*Enterococcus faecium*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, *Enterobacter* spp.) organisms and *Escherichia coli* reported from public and private sector laboratories in SA for the period 2016 - 2017.

Methods. Antimicrobial susceptibility testing (AST) profiles on selected ESKAPE organisms and *E. coli* isolated from blood cultures from the public and private sectors in 2016 and 2017 were analysed. AST data were extracted from a web-based electronic platform created by the NICD. Drug-bug combinations following the World Health Organization's Global Antimicrobial Surveillance System guidelines were included in the analysis.

Results. A total of 28 920 ESKAPE organisms and *E. coli* were reported in 2016 and 32 293 in 2017 across the two health sectors. Proportions of some organisms differed between the two health sectors, such as *E. coli* (19% in the public sector and 36% in the private sector), *A. baumannii* (14% public and 4% private), *P. aeruginosa* (7% public and 11% private) and *S. aureus* (27% public and 17% private). Susceptibility data indicated changing patterns in both sectors towards an increase in non-susceptibility to carbapenems in *K. pneumoniae* ($p < 0.01$). However, we demonstrated an increase in susceptibility to cloxacillin in *S. aureus* ($p < 0.01$) in both sectors.

Conclusions. The key clinically important finding is the rapidly decreasing carbapenem susceptibility among Enterobacteriaceae reported in SA, irrespective of sector. In addition, the analysis provides information that could be used to monitor the effectiveness of interventions implemented at a national level under the guidance and direction of the national AMR framework.

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Antimicrobial resistance (AMR) among both Gram-positive and Gram-negative bacteria has increased in recent years.^[1] Bacteria in the ESKAPE group (*Enterococcus faecium*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, *Enterobacter* spp.) account for two-thirds of all healthcare-associated infections and have been shown to display high rates of

AMR.^[2] Gram-negative ESKAPE organisms are of concern owing to their multidrug-resistant phenotypes, which generally present clinicians with few treatment options.^[3] Surveillance for AMR is pivotal to understanding the extent of resistance at individual facilities and at the national level. Surveillance reports provide guidance for antibiotic treatment at local and national levels. Surveillance is an

important strategy in the South African (SA) National Department of Health and features in the Antimicrobial Resistance National Strategy Framework document as one of the strategic objectives to optimise surveillance and early detection of AMR. At the National Institute for Communicable Diseases (NICD), an analysis of selected organisms and antimicrobial agents from both the public and the private health sectors was conducted.

Objectives

To describe the spectrum of selected ESKAPE organisms as well as *Escherichia coli* isolated from patients with bacteraemia reported from the two health sectors in SA and to compare their antimicrobial susceptibility testing (AST) profiles over a 2-year period.

Methods

Secondary data analysis was conducted from January 2016 to December 2017. AST data were extracted from a secure web-based electronic platform created by the Surveillance Information Management Unit at the NICD. These data were available on the AMR dashboard from the NICD website (<http://www.nicd.ac.za>). The study population included all patients who had a blood culture submitted either to the public National Health Laboratory Service or to one of the four accredited private pathology laboratories (Ampath, Lancet Laboratories, PathCare and Vermaak and Partners). Positive blood cultures with any one of the ESKAPE organisms or *E. coli* were included in the analysis. A working group of the South African Society for Clinical Microbiology made a decision in 2015 not to include surveillance of *Enterobacter* spp. owing to concerns about lack of standardisation in the testing and reporting of susceptibility profiles between different laboratories. In line with the GERMS-SA laboratory-based surveillance programmes, duplicate isolates obtained from the same patient within 21 days were excluded in order to avoid bias due to over-representation of sicker patients undergoing multiple investigations. AST and interpretation of results were performed by individual laboratories according to current Clinical and Laboratory Standards Institute (CLSI) guidelines,^[4] or European Committee on Antimicrobial Susceptibility Testing (EUCAST) guidelines^[5] at one private laboratory. There were only a few minor changes in the breakpoint interpretation in EUCAST during the 2 years of the study (for example, cefepime zone sizes were changed from 19 mm to 21 mm), and no changes in CLSI have been indicated for drug-bug combinations analysed in this article. Data were omitted for hospitals that tested <30 organisms for a particular antimicrobial agent. In the secondary data analysis, AST results were grouped based on categorical data as provided by the submitting laboratories. Results were reported as susceptible or non-susceptible, which includes the intermediate and resistant categories. Reporting of susceptibility profiles for drug-bug combinations was based on the Global Antimicrobial Surveillance System (GLASS) early implementation manual.^[6] Absolute frequencies, percentages, bar charts and tables were used to describe the data. The χ^2 test was used to compare differences among AST patterns over the 2-year period, with the level of significance set at $p < 0.05$.

Results

A total of 28 920 ESKAPE organisms and *E. coli* were reported in 2016 and 32 293 in 2017 across the two health sectors in SA. The proportion of *E. coli* was 19% in the public sector and 36% in the private sector, that of *K. pneumoniae* was 27% in the public sector and 30% in the private sector, that of *A. baumannii* was 14% in the public sector and 4% in the private sector, that of *P. aeruginosa* was 7% in the public sector and 11% in the private sector, that of *E. faecium* was 8%

in the public sector and 4% in the private sector, and that of *S. aureus* was 27% in the public sector and 17% in the private sector (Fig. 1).

Enterobacteriaceae

E. coli

The bacterial profile for *E. coli* reported over the 2-year period showed notable differences in the proportions across the two health sectors. For the public sector, the proportion was similar over the 2 years, 19% (3 981/20 630) in 2016 and 19% (4 085/21 124) in 2017. However, in the private sector, there was an increase in the proportion of reported *E. coli* from 34% (2 781/8 290) in 2016 to 37% (4 187/11 169) in 2017 (Fig. 1). Comparison of the AST profiles for the fluoroquinolone ciprofloxacin showed no change in the public sector (74%), but in the private sector there was a significant decrease in susceptibility from 69% to 65% ($p < 0.01$). Although no significant changes were noted for the third-generation cephalosporins cefotaxime/ceftriaxone and ceftazidime and the fourth-generation cephalosporin cefepime, higher susceptibility was noted for isolates reported from the private sector compared with the public sector. High proportions of isolates ($\geq 99\%$) reported from both health sectors were susceptible to the carbapenems ertapenem, imipenem and meropenem. No significant changes in susceptibility profiles were observed for the beta-lactam and beta-lactamase inhibitor piperacillin-tazobactam in either health sector (Table 1).

K. pneumoniae

The bacterial profile for *K. pneumoniae* reported over the 2-year period was similar for the two health sectors: 27% (5 533/20 630) in the public sector in 2016 and 26% (5 440/21 124) in 2017, and 30% (2 466/8 290) in the private sector in 2016 and 29% (3 204/11 169) in 2017 (Fig. 1). AST profiles for ciprofloxacin reported from both health sectors showed a significant decrease in susceptibility, from 66% to 64% in the public sector ($p = 0.04$) and from 60% to 54% in the private sector ($p < 0.01$). Significant decreases in susceptibilities were noted for the carbapenems in both health sectors. In the public sector, ertapenem decreased from 96% to 92% ($p < 0.01$), imipenem from 95% to 91% ($p < 0.01$) and meropenem from 94% to 91% ($p < 0.01$), and in the private sector, ertapenem decreased from 85% to 77% ($p < 0.01$), imipenem from 90% to 85% ($p < 0.01$) and meropenem from 91% to 86% ($p < 0.01$). No significant changes in susceptibility to piperacillin-tazobactam were noted for isolates reported from the public sector, but isolates reported from the private sector showed a significant decrease from 43% to 37% ($p < 0.01$) (Table 2).

Non-fermentative Gram-negative bacteria

A. baumannii

The bacterial profile for *A. baumannii* reported over the 2-year period showed a ~10% difference in the proportion of isolates reported by the two health sectors: 13% (2 736/20 630) in 2016 and 15% (3 139/21 124) in 2017 in the public sector and 4% (304/8 290) in 2016 and 4% (458/11 169) in 2017 in the private sector (Fig. 1). A significant decrease in susceptibility to the aminoglycosides (amikacin from 44% to 37% ($p < 0.01$) and gentamicin from 32% to 23% ($p < 0.01$)) was observed in isolates reported from the public sector. Although a decrease in susceptibility was noted for isolates reported from the private sector (amikacin from 63% to 57% ($p = 0.08$) and gentamicin from 53% to 46% ($p = 0.06$)), these differences were not significant ($p \geq 0.05$) (Table 3). Significant decreases in susceptibilities were noted for the carbapenems reported from both health sectors: imipenem from 27% to 19% ($p < 0.01$) and meropenem from 25% to 19% ($p < 0.01$) in the public sector and imipenem from 46% to 38% ($p = 0.03$) and meropenem from 44% to 38% ($p = 0.09$) in the private sector (Table 3).

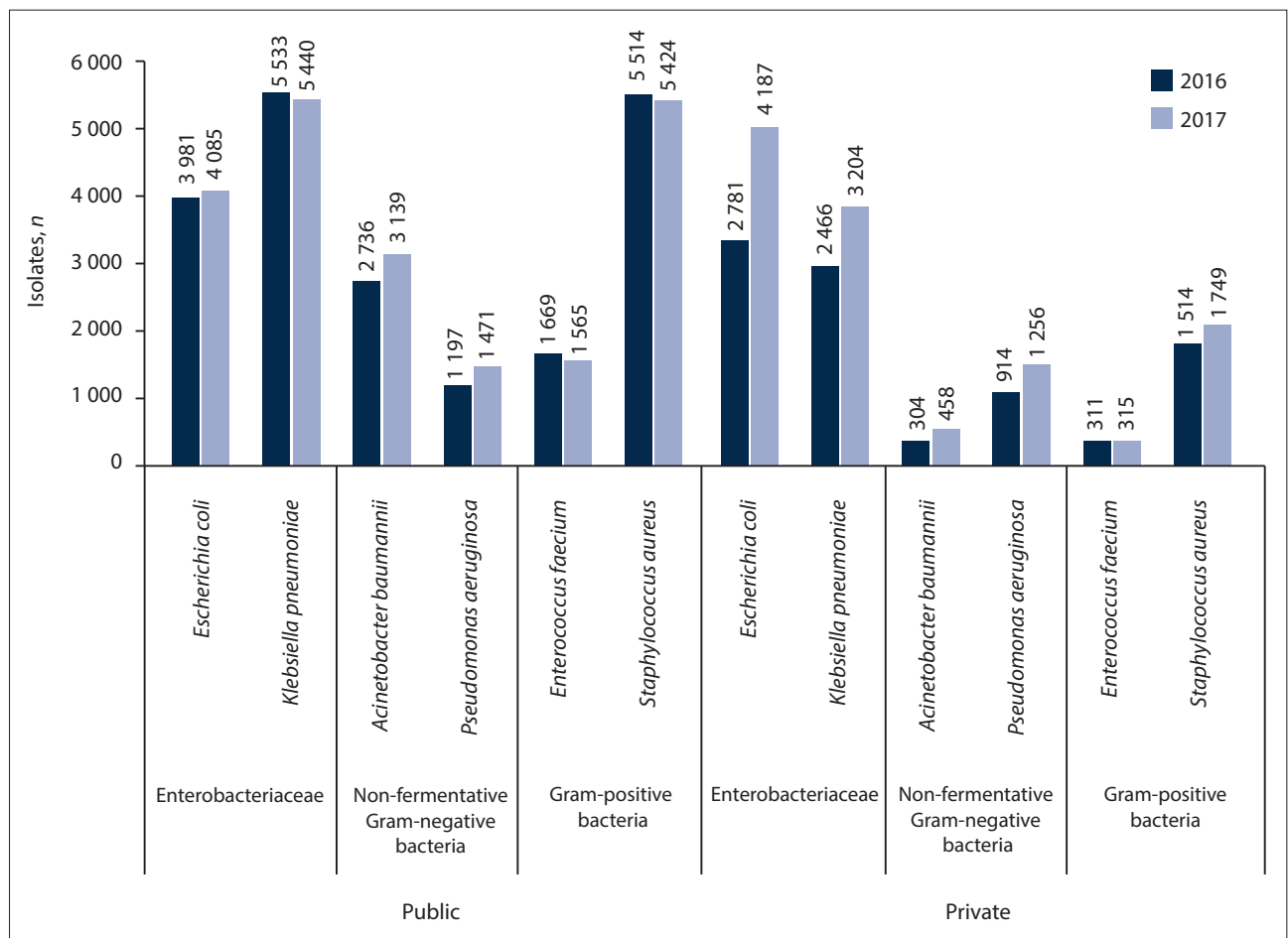


Fig. 1. Bacterial profile for ESKAPE organisms (*Enterococcus faecium*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, *Enterobacter spp.*) and *Escherichia coli* identified from blood cultures from public and private health sectors in South Africa, 2016 - 2017.

P. aeruginosa

The bacterial profile for *P. aeruginosa* reported over the 2-year period showed a ~5% difference in the proportion of isolates reported by the two health sectors. The absolute numbers of reported cases were approximately the same: 6% (1 197/20 630) in 2016 and 7% (1 471/21 124) in 2017 in the public sector and 11% (914/8 290) in 2016 and 11% (1 256/11 169) in 2017 in the private sector (Fig. 1). A significant increase in susceptibility to ceftazidime from 79% to 84% was noted for isolates reported from the public sector ($p < 0.01$). Isolates reported from the public sector showed no significant changes in susceptibility to imipenem and meropenem. However, a significant decrease in susceptibility was observed for isolates reported from the private sector: imipenem from 62% to 58% ($p = 0.04$) and meropenem from 64% to 60% ($p = 0.03$). Although isolates reported from the private sector displayed similar susceptibility patterns to piperacillin-tazobactam, isolates reported from the public sector showed a significant increase in susceptibility from 73% to 81% ($p < 0.01$) (Table 4).

Gram-positive bacteria

E. faecium

The bacterial profile for *E. faecium* reported over the 2-year period showed notable differences in proportions across the two health sectors. For the public sector, the proportion was similar, 8% (1 669/20 630) in 2016 and 7% (1 565/21 124) in 2017, and was shown to be higher than in the private sector, where it was 4%

(311/8 290) in 2016 and 3% (315/11 169) in 2017 (Fig. 1). Although a high proportion of isolates reported from both health sectors were susceptible to both vancomycin and teicoplanin, a significant decrease in susceptibility to teicoplanin was noted for isolates in the public sector, from 97% to 94% ($p < 0.01$). No changes in susceptibility patterns were noted for linezolid during the 2 years (Table 5).

S. aureus

The bacterial profile for *S. aureus* reported over the 2-year period showed notable differences in the proportions across the two health sectors. For the public sector the proportion was similar, 27% (5 514/20 630) in 2016 and 26% (5 424/21 124) in 2017, and the figures were lower in the private sector, 18% (1 514/8 290) in 2016 and 16% (1 749/11 169) in 2017 (Fig. 1). A significant increase in susceptibility to the penicillinase-stable penicillin cloxacillin was observed in both sectors, from 72% to 77% in the public sector ($p < 0.01$) and from 74% to 85% in the private sector ($p < 0.01$). A general observation was that a greater proportion of cloxacillin-susceptible *S. aureus* isolates was reported in the private sector compared with the public sector in 2017 (Table 6).

Discussion

This report describes and compares AST profiles for ESKAPE organisms and *E. coli* isolated from blood cultures over a 2-year period in the public and private health sectors in SA. The majority of isolates were reported from the public sector (71% (20 630/28 920)

Table 1. Antimicrobial susceptibility patterns of *Escherichia coli* isolates identified from blood cultures in South Africa, 2016 - 2017

Health sector	Drug	2016		2017		p-value
		Total isolates tested, N	Susceptible, n (%)	Total isolates tested, N	Susceptible, n (%)	
Public	Amikacin	3 842	3 478 (91)	3 885	3 522 (91)	0.84
	Amoxicillin-clavulanic acid	3 845	2 462 (64)	3 870	2 456 (63)	0.60
	Ampicillin/amoxicillin	3 834	614 (16)	3 823	595 (16)	0.59
	Cefepime	3 668	2 785 (76)	3 750	2 825 (75)	0.55
	Cefotaxime/ceftriaxone	3 752	2 798 (75)	3 835	2 874 (75)	0.71
	Ceftazidime	3 780	2 869 (76)	3 791	2 848 (75)	0.43
	Ciprofloxacin	3 815	2 818 (74)	3 720	2 756 (74)	0.83
	Co-trimoxazole	NT	NT	NT	NT	-
	Doripenem	NT	NT	NT	NT	-
	Ertapenem	3 552	3 518 (99)	3 659	3 645 (100)	<0.01*
	Gentamicin	3 864	3 168 (82)	3 872	3 175 (82)	0.99
	Imipenem	3 727	3 705 (99)	3 774	3 757 (100)	0.40
	Meropenem	3 716	3 691 (99)	3 810	3 791 (100)	0.32
	Piperacillin-tazobactam	3 485	3 020 (87)	3 736	3 237 (87)	0.99
Private	Amikacin	2 781	2 598 (93)	4 040	3 725 (92)	0.06
	Amoxicillin-clavulanic acid	2 780	1 945 (70)	4 171	2 791 (67)	0.01
	Ampicillin/amoxicillin	1 998	425 (21)	2 310	466 (20)	0.38
	Cefepime	2 778	2 283 (82)	4 040	3 254 (81)	0.09
	Cefotaxime/ceftriaxone	2 777	2 253 (81)	4 171	3 329 (80)	0.18
	Ceftazidime	2 148	1 755 (82)	2 804	2 231 (80)	0.06
	Ciprofloxacin	1 997	1 378 (69)	3 534	2 301 (65)	<0.01
	Co-trimoxazole	1 746	657 (38)	2 298	839 (37)	0.47
	Doripenem	2 753	2 748 (100)	4 013	4 007 (100)	0.75
	Ertapenem	2 779	2 769 (100)	4 041	4 026 (100)	0.94
	Gentamicin	2 779	2 368 (85)	4 045	3 448 (85)	0.97
	Imipenem	2 777	2 772 (100)	4 043	4 033 (100)	0.61
	Levofloxacin	792	593 (75)	1 229	868 (71)	0.04
	Meropenem	2 780	2 777 (100)	4 042	4 034 (100)	0.54
Piperacillin-tazobactam	2 774	2 212 (80)	3 677	2 868 (78)	0.09	

NT = not tested.

*Significance was based on low number of non-susceptible isolates.

in 2016 and 65% (21 124/32 293) in 2017), demonstrating the public laboratory coverage of ~80% of the general population; however, this ratio still reflects under-utilisation of blood culture diagnostics in the public sector.

Gram-negative bacteria were reported more commonly than Gram-positive ones in both the public sector (65% (13 447/20 630) in 2016 and 67% (14 135/21 124) in 2017) and the private sector (78% (6 465/8 290) in 2016 and 82% (9 105/11 169) in 2017). We also observed a different bacterial profile for the two sectors. In the public sector, higher proportions of *E. faecium*, *A. baumannii* and *S. aureus* were reported, while in the private sector there were higher proportions of *P. aeruginosa* and *E. coli*. The present report only described the susceptibility profiles of organisms, and not demographic or clinical data. It was therefore not possible to determine the reasons for this difference. Possible causes may include differences in specimen-taking practices, differences in infection control practices and different patient populations.

In the Enterobacteriaceae group, *E. coli* showed no noteworthy differences in susceptibility profile in the public sector. However, a significant decrease in susceptibility to ciprofloxacin and amoxicillin-clavulanic acid was observed in the private sector, possibly owing

to excessive use of these agents in treatment of the most common urinary and respiratory infections.

K. pneumoniae demonstrated decreased susceptibility to many antibiotics ($p < 0.01$) in both sectors, suggesting possible overuse of broad-spectrum antibiotics or lack of infection prevention and control. The most striking finding was a decrease in susceptibility to the carbapenems, with both sectors showing a significant difference just a year apart ($p < 0.01$). This increase in carbapenem-resistant Enterobacteriaceae (CRE) is largely attributable to the increase in isolates harbouring carbapenemase-producing genes.^[7] A number of factors may have influenced this change, including poor infection prevention and control measures targeting CRE, lack of effective antimicrobial stewardship programmes, or possible emergence of a successful clone.^[8]

Antimicrobial susceptibility of *A. baumannii* indicated a significant decrease in susceptibility to aminoglycosides and carbapenems in the public sector, possibly owing to use of these agents in the treatment of infections by *K. pneumoniae* and other Enterobacteriaceae. In contrast, the only observed significant change in antimicrobial susceptibility of *A. baumannii* in the private sector was decreased susceptibility to the carbapenem imipenem.

Table 2. Antimicrobial susceptibility patterns of *Klebsiella pneumoniae* isolates identified from blood cultures in South Africa, 2016 - 2017

Health sector	Drug	2016		2017		p-value
		Total isolates tested, N	Susceptible, n (%)	Total isolates tested, N	Susceptible, n (%)	
Public	Amikacin	5 288	4 278 (81)	5 130	4 164 (81)	0.73
	Amoxicillin-clavulanic acid	5 284	1 763 (33)	5 085	1 542 (30)	<0.01
	Cefepime	5 164	1 687 (33)	5 012	1 548 (31)	0.05
	Cefotaxime/ceftriaxone	5 192	1 631 (31)	5 008	1 483 (30)	0.05
	Ceftazidime	5 201	1 661 (32)	5 042	1 523 (30)	0.06
	Ciprofloxacin	5 280	3 479 (66)	4 893	3 128 (64)	0.04
	Co-trimoxazole	NT	NT	NT	NT	-
	Doripenem	NT	NT	NT	NT	-
	Ertapenem	4 769	4 562 (96)	4 696	4 333 (92)	<0.01
	Gentamicin	5 308	2 083 (39)	5 125	1 992 (39)	0.70
	Imipenem	5 071	4 800 (95)	4 929	4 492 (91)	<0.01
	Levofloxacin	48	35 (73)	38	22 (58)	0.14
	Meropenem	5 068	4 772 (94)	4 967	4 537 (91)	<0.01
	Piperacillin-tazobactam	4 967	2 799 (56)	4 951	2 718 (55)	0.15
Private	Amikacin	2 444	1 964 (80)	3 162	2 392 (76)	<0.01
	Amoxicillin-clavulanic acid	2 450	975 (40)	3 175	1 133 (36)	<0.01
	Cefepime	2 435	1 070 (44)	3 167	1 231 (39)	<0.01
	Cefotaxime/ceftriaxone	2 442	1 052 (43)	3 169	1 203 (38)	<0.01
	Ceftazidime	1 760	789 (45)	2 307	895 (39)	<0.01
	Ciprofloxacin	2 068	1 231 (60)	2 824	1 528 (54)	<0.01
	Co-trimoxazole	1 853	789 (43)	2 625	1 027 (39)	0.02
	Doripenem	2 376	2 185 (92)	3 047	2 683 (88)	<0.01
	Ertapenem	2 419	2 056 (85)	3 124	2 403 (77)	<0.01
	Gentamicin	2 442	1 405 (58)	3 169	1 727 (54)	0.02
	Imipenem	2 410	2 175 (90)	3 121	2 647 (85)	<0.01
	Levofloxacin	509	382 (75)	551	378 (69)	0.02
	Meropenem	2 431	2 206 (91)	3 123	2 679 (86)	<0.01
	Piperacillin-tazobactam	2 443	1 050 (43)	3 169	1 184 (37)	<0.01

NT = not tested.

Table 3. Antimicrobial susceptibility patterns of *Acinetobacter baumannii* isolates identified from blood cultures in South Africa, 2016 - 2017

Health sector	Drug	2016		2017		p-value
		Total isolates tested, N	Susceptible, n (%)	Total isolates tested, N	Susceptible, n (%)	
Public	Amikacin	2 064	913 (44)	2 052	765 (37)	<0.01
	Doripenem	NT	NT	NT	NT	-
	Gentamicin	2 629	837 (32)	2 955	668 (23)	<0.01
	Imipenem	2 581	684 (27)	2 865	558 (19)	<0.01
	Meropenem	2 602	654 (25)	2 928	549 (19)	<0.01
	Minocycline	30	6 (20)	33	9 (27)	0.56
	Tigecycline	1 279	1 176 (92)	1 745	1 585 (91)	0.28
Private	Amikacin	288	182 (63)	439	249 (57)	0.08
	Doripenem	275	120 (44)	435	172 (40)	0.28
	Gentamicin	303	161 (53)	458	212 (46)	0.06
	Imipenem	304	139 (46)	458	174 (38)	0.03
	Meropenem	303	133 (44)	458	173 (38)	0.09
	Minocycline	NT	NT	NT	NT	-
	Tigecycline	212	190 (90)	326	285 (87)	0.44

NT = not tested.

Table 4. Antimicrobial susceptibility patterns of *Pseudomonas aeruginosa* isolates identified from blood cultures in South Africa, 2016 - 2017

Health sector	Drug	2016		2017		p-value
		Total isolates tested, N	Susceptible, n (%)	Total isolates tested, N	Susceptible, n (%)	
Public	Cefepime	1 076	884 (82)	1 324	1 119 (85)	0.12
	Ceftazidime	1 150	906 (79)	1 404	1 173 (84)	<0.01
	Doripenem	NT	NT	NT	NT	-
	Imipenem	1 102	845 (77)	1 362	1 040 (76)	0.85
	Meropenem	1 123	873 (78)	1 372	1 063 (77)	0.88
	Piperacillin/tazobactam	1 118	812 (73)	1 369	1 112 (81)	<0.01
Private	Cefepime	908	652 (72)	1 240	862 (70)	0.25
	Ceftazidime	892	657 (74)	1 228	876 (71)	0.24
	Doripenem	883	601 (68)	1 208	762 (63)	0.02
	Imipenem	911	567 (62)	1 243	719 (58)	0.04
	Meropenem	912	588 (64)	1 244	745 (60)	0.03
	Piperacillin/tazobactam	902	582 (65)	1 226	780 (64)	0.67

NT = not tested.

Table 5. Antimicrobial susceptibility patterns of *Enterococcus faecium* isolates identified from blood cultures in South Africa, 2016 - 2017

Health sector	Drug	2016		2017		p-value
		Total isolates tested, N	Susceptible, n (%)	Total isolates tested, N	Susceptible, n (%)	
Public	Daptomycin	NT	NT	NT	NT	-
	Linezolid	1 380	1 369 (99)	1 236	1 224 (99)	0.64
	Penicillin/ampicillin	837	30 (4)	813	46 (6)	0.05
	Teicoplanin	1 033	1 001 (97)	908	853 (94)	<0.01
	Vancomycin	1 636	1 560 (95)	1 509	1 436 (95)	0.80
Private	Daptomycin	65	63 (97)	104	102 (98)	0.64
	Linezolid	215	210 (98)	191	190 (99)	0.22
	Penicillin/ampicillin	38	3 (8)	27	0	0.26
	Teicoplanin	295	283 (96)	299	282 (94)	0.36
	Vancomycin	309	295 (95)	312	294 (94)	0.49

NT = not tested.

Table 6. Antimicrobial susceptibility patterns of *Staphylococcus aureus* isolates identified from blood cultures in South Africa, 2016 - 2017

Health sector	Drug	2016		2017		p-value
		Total isolates tested, N	Susceptible, n (%)	Total isolates tested, N	Susceptible, n (%)	
Public	Cloxacillin	5 118	3 705 (72)	5 108	3 951 (77)	<0.01
Private	Cloxacillin	1 283	950 (74)	1 508	1 283 (85)	<0.01

P. aeruginosa demonstrated significant increases in susceptibility to piperacillin/tazobactam and ceftazidime in the private sector, which may be explained by the infrequent use of these agents as empirical treatment.

Equally, we are seeing changing patterns in susceptibility to penicillinase-stable penicillins in *S. aureus* in both sectors, with subsequent reduced rates of methicillin-resistant *S. aureus* (MRSA). Absolute numbers of *S. aureus* did not decline, suggesting that the decrease in MRSA proportions may be due to a strain replacement with Gram-negative organisms in the proportion of hospital-acquired infections, a decrease in the prevalence of particularly pathogenic MRSA clones, or a combination of these two factors. The widening gap in MRSA proportions between the two sectors over the 2 years

suggests that these factors are operating to different extents in the two sectors.

The second GLASS report presented AMR data from nine countries in the African region. Nigeria reported data on *E. coli* and *K. pneumoniae* showing <25% susceptibility to third-generation cephalosporins from three sentinel sites, similar to our results for *K. pneumoniae* but not for *E. coli*. In contrast, susceptibility to third-generation cephalosporins in the UK is much higher, at 90% for both organisms in 2017.^[9] AST findings for the ESKAPE organisms reported from the public sector in the present study were comparable to findings from an SA study published in 2018.^[10] In the present study, *K. pneumoniae* showed decreased susceptibility to carbapenems over the 2-year period, but susceptibility in isolates

reported from secondary and tertiary health facilities from 2015 to 2016 remained constant.^[10] *A. baumannii* showed a notable decrease in susceptibility to the aminoglycosides: amikacin from 50% in 2015 to 40% in 2016 and gentamicin from 32% in 2015 to 28% in 2016.^[10] A decrease in susceptibility to teicoplanin was noted for *E. faecium* in the present study; however, susceptibility in isolates reported from the earlier study showed no change (97%) from 2015 to 2016.^[10] Changing AST patterns to penicillinase-stable penicillins were also noted for *S. aureus* isolates. Both the present study and the earlier study showed increased susceptibility.^[10,11]

This report indicates the importance of antimicrobial resistance surveillance for clinical treatment guidelines at the national level. At facility level there is a need for local antimicrobial susceptibility data to address antibiotic treatment appropriately. Specimen submission practices are important when addressing and analysing antimicrobial susceptibility patterns at each facility.

Study limitations

Findings from this study should be interpreted with caution. Its limitations have been highlighted in previous reports.^[9,10] Briefly, these include:

- Data may have been incomplete owing to missing information not captured on the laboratory information system or non-standardised coding of ESKAPE organisms and antimicrobial agents at diagnostic laboratories.
- Testing methods and microbiological practice may have varied between laboratories, which could account for variations in the results presented in this report.
- Confirmatory AST methods were not performed or recorded for any of the ESKAPE organisms, as the results presented here were reported as captured on the laboratory information system by diagnostic laboratories. We have not been able to report on colistin AST, as new methods have been recommended by the CLSI and EUCAST guidelines, which were not universally implemented by all diagnostic laboratories during the period of the study.
- Data from the private sector represent a small (25 - 30%) proportion of the general population and may not be directly comparable with the much greater proportion in the public sector owing to factors such as selective testing, specimen-taking practices, infection control practices and patient populations that may differ between the two sectors.
- Vancomycin non-susceptibility for *S. aureus* requires confirmatory testing, which is not available at routine laboratory level. All *S. aureus* isolates that are non-susceptible to vancomycin should be referred to reference laboratories for confirmation.
- Results for carbapenemase-producing Enterobacteriaceae are not available in this report, as not all CRE isolates are tested for carbapenemase-producing genes.
- AST results for *Enterobacter* spp. were not reported in this study.

Conclusions

This study provides important laboratory data to monitor AST profiles of ESKAPE organisms. The key clinically important finding is the rapidly decreasing carbapenem susceptibility among

Enterobacteriaceae reported in SA, irrespective of sector. High numbers and rates of resistance in *A. baumannii* are alarming in the public sector as this drives the use of colistin, the last resource for treatment of multidrug-resistant organisms. In addition, the study provides baseline surveillance data that can be used to monitor the effectiveness of interventions implemented at a national level under the guidance and direction of the national AMR framework.

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Conflicts of interest. None.

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