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RESEARCH ARTICLE

ANTIMICROBIAL RESISTANCE PATTERNS AMONG BACTERIAL PATHOGENS ISOLATED FROM CLINICAL SAMPLES IN SANA'A HOSPITALS

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Abstract

Background and objectives: Yemen is among the developing nations where antimicrobial resistance (AMR) is posing a danger to public health. AMR can lead to increased morbidity and mortality from treatment failures and a lack of effective therapies. Particularly in the research arena, there is a dearth of knowledge about the antimicrobial resistance patterns of frequently isolated, locally occurring diseases. Therefore, the purpose of this study was to evaluate the diseases' microbiological profiles and resistance trends in Sana'a, Yemen.
Methods: In Sana'a, Yemen, a retrospective study was carried out at various governmental and private hospitals between June and September of 2020. Information about antibiotic susceptibilities and cultures was taken from the microbiology department's 2019 files. The data analysis method employed was descriptive statistics.
Results: This study includes 4156 pathogen isolates, with 58.2% of the isolates being Gram negative. Of all the isolates, urine (26.1 %, n=1086) and pus specimens (24.6 %, n = 1025) demonstrated the greatest detection rates. The most often isolated pathogens were *S. aureus* (35.6%, n=1479), *E. coli* (29.2%, n=1215), *P. aeroginosa* (14.1%, n=586), and *Klebsiella* species (10.7%, n=443). The highest rates of resistance were found for cephalosporins (cefixime 90%, cefadroxil 87.9%, cefepime 72%, and ceftriaxone 70%) and penicillins (carbincillin 87%, amoxacillin 80%, and amoxacillin/clavulanic acid 77%). Gram positive and Gram negative isolates showed minimal resistance to linezolid and vancomycin, with *Enterococcus* showing higher resistance. Colistin was most effective against Gram negative, while *E. coli*, *Klebseilla*, and *Proteus* showed high resistance.
Conclusions: The high rate of resistance discovered in the current study in both Gram-positive and Gram-negative organisms is alarming and highlights the necessity of routinely determining the prevalence of resistance in a given area in order to guide empirical therapy and choose the most effective course of antibiotic treatment.
Keywords: Antimicrobial resistance, bacterial isolates, clinical specimens, Multi-drug resistant (MDR), Sana'a hospitals.

INTRODUCTION

Among all prescription drugs, antibiotics are one of the most widely used. Antibiotic resistance (AR) has garnered attention in clinical settings globally recently because of its potential to increase healthcare expenses, patient morbidity, and mortality from infectious illnesses[1-5]. The impact is amplified in developing nations like Yemen because, despite a large volume of recent research published, much of it was focused in the country's capital, Sana'a, and information about the antibiotic susceptibility patterns of bacterial isolates in Yemen is still lacking[6-11]. It should be highlighted, nonetheless, that a number of significant variables, such as a failure to follow infection control protocols and an overuse or abuse of antibiotics as a result of misdiagnosis or illogical use, might promote the formation and spread of multi resistant organisms. Approximately 50% of all patient prescriptions for antibiotics[12,13]. Antibiotics are provided without the need for laboratory analyses to determine the cause, assess antibiotic susceptibility, or check for particular resistance markers. Antibiotic resistance is more likely to emerge now as many medications are widely available in pharmacies without a prescription. Yemen has a high concentration of each of the aforementioned elements[14-16]. Due to the violence and lack of funding in Yemen, the majority of medical professionals attempt to keep laboratory test costs down by treating patients using empirical medicine, or past clinical experience, rather than ordering diagnostic tests. A laboratory method should be used to provide a guide for choosing the right antibiotics, given the significant risk posed by multi-resistant pathogens. Efficient as opposed to depending on experimental therapy[14-16]. An increased rate of AR has been linked to an increase in the usage of antibiotics, according to several studies[17-20]. The percentage of prescriptions containing antibiotics was 84.2% in a 2015 study investigating how doctors write prescriptions in hospital outpatient departments in Aden, Yemen. This is significantly higher than the usual values recommended by the World Health Organization[21,22]. Counterfeit pharmaceuticals are another issue Yemen faces, and drug smuggling is pervasive. A recent study carried out in Yemen found that almost 40% of the medications that were brought into the nation illegally were either fake or of poor quality[23]. According to the World Health Organization, about 43% of counterfeit antibiotics have no effective effect. Components: 24% are low-quality, 21% have few active components, and 7% are the incorrect substances[24]. Because low-quality generic antibiotics may contribute to the growth of resistant microorganisms, antibiotic quality control is a critical concern[25]. The current study will give a summary of Sana'a City's resistance situation as of right now. The goal of this retrospective study was to identify the overall range of infections and profiles of antibiotic resistance in Sana'a, Yemen, using laboratory records from a variety of public and commercial hospitals.

MATERIALS AND METHODS

Study design: A retrospective study was done on clinical specimens that have been routinely received by the Microbiology Laboratory for culture and sensitivity. The study was conducted from March 2020 to September 2020 due to the availability of data for this period.

Study area: This study was conducted in five locations, comprising three public hospitals and three private hospitals in Sana`a city, Yemen. Public hospitals included Al-Thawra Modern General Hospital (ATH), Al-Jomhori Teaching Hospital (AJH), and 48 Hospital (48H), while private hospitals included Dr. Abdulkader Almutawakel Hospital (AMH) and the University of Science and Technology Hospital (USTH).

Study population: patient information from the Microbiology Laboratory Unit's computerized registration system. The study contained the Microsoft Excel spreadsheet report created by the system for the microbiology laboratory regarding the ASTs that were run on all isolated organisms in 2019. Fourth-year laboratory medicine students, who had received proper training, gathered data using a structured questionnaire.

Sample size: All culture reports from different clinical specimens during 2019 were collected.

Included data: This study collected all positive culture reports that provided details about the patient's age, the kind and source of the specimen, the isolated organism, and the number of ASTs that were conducted.

Excluded data: All entries with negative culture results or incomplete data that meet the criteria were excluded from this study.

Identification of pathogens: The bacterial and fungal isolates are obtained from the electronic registration system of microbiology laboratory units in the selected hospitals and microbiological laboratories.

Antimicrobial susceptibility testing: Antimicrobial susceptibility results were collected from the records of selected sites.

Data analysis: Data input and analysis were performed using the Statistical Package for Social Sciences (SPSS) version 21 (IBM Corp., released 2012; IBM SPSS Statistics for Windows, version 21.0, Armonk, NY: IBM Corp.). The distribution of specimens and the frequencies and percentages of isolated bacteria were ascertained using descriptive statistics. Every bacterial isolate as well as all bacterial isolates' rates of antibiotic resistance were computed. Additionally, rates of multidrug resistance were found.

Ethical considerations: The ethics research committee of the Faculty of Laboratory Medicine at 21 September University accepted the study, and the hospital laboratory management gave permission to use the data collected by the registration system. There were no personal identifiers in the study.

RESULTS

Three figures and seven tables with the study results are presented. Isolated pathogens: Gram-negative bacteria made up 58.2% (n = 2419) and Gram-positive bacteria made up 41.2% (n = 1714) of the 4156 pathogens; fungi made up the remaining 0.6% (n = 23). A total of 25 distinct pathogen species were identified from all of the clinical specimens. Fourteen pathogens are classified as Gram-negative bacteria, eleven as Gram-positive bacteria, and one as a fungal species. *S. aureus* (n=1479, 35.6%) and *Escherichia coli* (n= 1215, 29.2%) were the most frequently isolated bacteria, followed by *Pseudomonas aeroginosa* (n= 586, 14.1%) and *Klebsiella* spp. (n=443, 10.7%). Lower prevalence rates were shown by *Enterococcus* spp. (2.4%), *Proteus* spp. (1.7%), CNS (1.1%), and *Acinetobacter* spp. (0.9%). Out of 2419 Gram-negative bacteria, *Escherichia coli* accounted for 50.2% of all isolated pathogens, whereas *Staphylococcus aureus* represented 86.2% of 1714 Gram-positive bacteria.

Table 1: Frequency of various specimens.

Specimen	N (%)	Specimen	N (%)
Urine	1086 (26.1)	Stool	23 (0.6)
Pus	1025 (24.6)	CSF	26 (0.6)
Vaginal swab	854 (20.5)	Throat swab	15 (0.4)
Blood	497 (11.9)	Mitral valves	15 (0.4)
Sputum	266 (6.4)	Catheter tip	4 (0.1)
Seminal fluid	108 (2.6)	Urethral swab	1 (0.02)
Body fluid*	185 (4.4)	Nasal swab	1 (0.02)
Ear swab	50 (1.2)	Total	4156 (100)

*Body effusion specimens that included synovial, peritoneal, pleural and pericardial fluid.

Cefixime (90%) and cefadroxil (87.9%) had the highest overall resistance rate among the tested isolates, while vancomycin (17.4%), linezolide (16%), colistin (15%), amikacin (15.6%), imipenem (18%), chloramphenicaol (22%), and nitrofurantoin (21%) had the lowest resistance rates. Amoxacillin/Clavulanic Acid 77%, Cefepime 72%, Ceftriaxone 70%, Piperacillin 60%, and Piperacillin/Tazobactam 26% exhibit resistance overall.

Table 2: Distribution of isolates according to type.

Type	Organism	N (%)
GNB	*E. coli*	1215 (29.2)
	P. aeruginosa	586 (14.1)
	Klesbiella spp	443 (10.7)
	Proteus spp	71 (1.7)
	Acinetobacter spp	37 (0.9)
	Enterobacter spp	18 (0.4)
	Citobacter spp	4(0.1)
	Shigella spp	10 (0.2)
	Salmonella spp	2 (0.04)
	Burkholderia spp	1 (0.02)
	Serratia spp	1 (0.02)
	Undistinguished GNB	30 (0.7)
	GNB diplococcus	1 (0.02)
GPB	*S. aureus*	1479 (35.6)
	Enterococcus spp	99 (2.4)
	CNS	46 (1.1)
	A-Hemolytic Streptococci	41 (1)
	B-Hemolytic Streptococci	13 (0.3)
	Strept pyogenes	11 (0.26)
	Strept viridans	10 (0.26)
	Pneumococci	6 (0.1)
	Undistinguished GPB	5 (0.1)
	Strept agalactiae	3 (0.07)
	Staphylococcus spp	1 (0.02)
Fungi	*Candida* spp	23 (0.06)
	Total	4156 (100)

The resistance rate to imipenem and meropenem was low (18–24%), moderate with ertapenem (47%), moderate with tetracyclines (36–47%), moderate with fluoroquinolones (33–75%), and high with macrolides (56–84%) overall. Against the majority of studied infections, the overall resistance of ciprofloxacin (55%), erythromycin (56.5%), and co-trimoxazole (62%) was less effective. In third and fourth generations, the overall resistance rate varied from 36% to 90%, whereas in combinations involving B-lactamase inhibitor cephalosporins, it ranged from 25% to 87%.

Antifungal agent resistance rates: Among *Candida* spp., the overall susceptibility to antifungal drugs was 97.5%.

Multidrug-resistant bacteria: Bacteria that exhibit multidrug resistance (MDR) are resistant to at least three different types of antibiotics. These include aminoglycosides (amikacin, tobramycin, and/or gentamycin), carbapenems (imipenem and/or meropenem), quinolones (ciprofloxacin, levofloxacin, and/or moxifloxacin), and penicillins (piperacillin/ tazobacta and/or amoxicilin/clavulanic acid). 44.5% (1783) of the 4008 isolates of the most prevalent and significant bacteria were isolates with multidrug resistance. *Acinetobacter* spp. was the most prevalent (87.4%) multidrug-resistant pathogen, followed by *Proteus* spp. 50.7%, *Pseudomonas aeruginosa* 47.8%, and *Klesbiella* spp. 42.2%. The MDR S predominance. 46.5% (687/1479) of the MRSA strains were based on resistance to cefoxitin and/or oxacillin, whereas 61.2% (199/325) were based on this resistance. MDR is regarded as MRSA. After screening 1007 *S. aureus* isolates against vancomycin, it was discovered that 18.9% of them (190/1007) had resistance. Nonetheless, it was observed that these isolates resistant to vancomycin were susceptible to imepenem 34.3% (34/99), gentamicin 51.9% (69/133), meropenem 72.3% (16/22) and linezolid 41.7% (5/12). Out of 207 MRSA strains, only 166 were found to be resistant to vancomycin, with a resistance rate of 7.2% (12/166). It is important to note, nonetheless, that azithromycin susceptibility among these strains of vancomycin-resistant bacteria reached more than half, or 58% (7/12). Only 19 of the *Enterococcs* spp. were evaluated against vancomycin, and the results showed that the resistance level was 42.1% (8/19). The prevalence of MDR *Enterococcs* spp. was 36.4% (36/99). It is noteworthy nonetheless that two thirds of 62.5% (5/8) of the vancomycin-resistant bacteria were susceptible to gentamicin.

DISCUSSION

Antibiotic resistance (AR) can lead to a rise in mortality and morbidity as a result of inadequate treatments and treatment failures. Furthermore, as increased treatment costs deplete resources, the economic effects can be considerably more severe in a nation with limited resources like Yemen. The unavoidable result of the frequent and irresponsible use of broad spectrum antibiotics is the emergence of highly resistant bacteria. A quarter of Yemen's population suffers from malnutrition, with 3.2 million suffering from acute malnutrition as a result of the country's ongoing conflict that began in 2015. These individuals are more vulnerable to mortality and morbidity due to weakened immunity to infectious diseases[26-29]. Fathomer, internally displaced persons, that were 3.3 million in 2019, and war wounded among civilians and fighter facilities dissemination of resistant bacteria over the country[26,30,31].

Table 3: Overall susceptibility rates of the microorganisms.

Antibiotic Name	Sensitive N (%)	Moderate N (%)	Resistance N (%)	Total
Ampicillin/Sulbactam	381(27)	247 (18)	743 (54)	1371
Amikacin	1245 (54.5)	684 (30)	356 (15.6)	2285
Amoxacillin	96 (14)	45 (6.6)	536 (79)	677
Amoxacillin/Clavulanic acid	465 (21)	253 (11)	1740 (77)	2249
Ampicillin	142 (142)	134 (9.8)	1078 (80)	1354
Azirthromycin	526 (20)	492 (19)	1615 (61)	2633
Azteronam	146 (53)	32 (12)	98 (36)	276
Carbincillin	79 (5.6)	86 (6)	1218 (87)	1401
Cefaclor	253 (11)	238 (10)	1818 (79)	2309
Cefadroxil	71 (6.1)	71 (6.1)	1029 (87.9)	1171
Cefazolin	115 (18.7)	79 (12.8)	422 (68)	616
Cefepime	403 (17)	263 (10)	1739 (72)	2405
Cefixime	65 (4.8)	57 (4.2)	1231 (90)	1353
Cefoperazone	184 (49.5)	53 (14)	136 (36.5)	373
Cefotaxime	544 (21)	215 (8.3)	1826 (70.5)	2585
Cefoxitine	189 (41)	51 (11)	222 (48)	462
Ceftazidime	253 (22.7)	131 (11.8)	732 (65.5)	1116
Ceftizoxime	128 (29)	54 (12.5)	251 (58)	433
Ceftriaxone	583 (18.5)	333 (10.5)	2240 (71)	3156
Ceftriaone /Tazobactam	61 (50)	12 (10)	49 (40)	122
Cefuroxime	446 (18)	148 (6)	1870 (76)	2465
Cephalexin	131 (24.5)	88 (16.5)	313 (59)	532
Cephalothin	6 (22)	2 (7.5)	19 (70.5)	27
Cephradine	49 (25.5)	21 (11)	122 (63.5)	192
Chloramphenicaol	237 (71)	23 (7)	72 (22)	332
Ciprofloxacin	1013 (33)	369 (12)	1702 (55)	3084
Clarithromycine	144 (7.5)	162 (8)	1700 (84.5)	2006
Clindamycin	142 (19)	29 (4)	574 (77)	745
Cloxacillin	83 (14.5)	49 (8.5)	441 (77)	573
Colistin	87 (68.5)	21 (16.5)	19 (15)	127
Co-trimoxazole	100 (31.5)	21 (6.5)	198 (62)	319
Cefpodoxime	25 (34.7)	1 (1.3)	46 (64)	72
Ceftriaxone/Sulbactam	2 (5)	27 (66)	12 (29)	41
Cefoperazone/Sulbactam	21 (11)	3 (1.6)	169 (87.4)	193
Cefepime/Tazobactam	1 (25)	2 (50)	1 (25)	4
Cefodizime	80 (30)	33 (12.5)	152 (57.5)	265
Doxycyclin	440 (34.5)	238 (18.5)	598 (47)	1276
Ertapenem	22 (40)	7 (13)	26 (47)	55
Erythromycin	176 (34.5)	45 (9)	288 (56.5)	509
Enrofloxacin	8 (44.4)	4 (22.3)	6 (33.3)	18
Fosfomycin	209 (38.5)	136 (25)	199 (36.5)	544
Gentamycin	1366 (53)	434 (17)	792 (30)	2592
Imipenem	1129 (74)	123 (8)	274 (18)	1526
Kanamycin	18(53)	1 (3)	15 (44)	34
Levofolxacin	1189 (47.5)	438 (17.5)	874 (35)	2501
Lincomycin	18 (35)	4 (7)	30 (58)	52
Linezeolid	201 (76.7)	19 (7.3)	42 (16)	262
Lomefloxacin	41 (46)	12 (13.5)	36 (40.5)	89
Meropenem	1031 (65)	174 (11)	389 (24)	1594
Methicillin	98 (31)	35 (11)	186 (58)	319
Moxifloxacin	226 (28)	128 (15)	465 (57)	819
Mezlocillin	65 (97.1)	0.0 (0.0)	2 (2.9)	67
Minocycline	35 (59)	1 (2)	23 (39)	59
Nalidoxic acid	132 (17)	63 (8)	593 (75)	788
Nitrofurantoin	704 (66)	141 (13)	224 (21)	1069
Norfloxacin	266 (31.5)	85 (10)	493 (58.5)	844
Oxfloxacin	505 (35)	243 (17)	694 (48)	1442
Oxacillin	151 (31)	35 (8)	295 (61)	481
Penicillin	51 (13.5)	35 (9)	294 (77.5)	380
Pipracillin	145 (23)	106 (17)	383 (60)	634
Pipracillin/Tazobactam	1085 (56)	343 (18)	504 (26)	1932
Polymyxin B	63 (95.5)	2 (3)	1 (1.5)	66
Rifampicin	99 (48)	42 (20.5)	64 (31.5)	205
Streptomycin	122 (62)	38 (19.5)	36 (18.5)	196
Sulfamethoxazol	187 (15)	89 (7.5)	934 (77)	1210

Cont…

Teicoplanin	15 (27)	15 (27)	26 (46)	56
Tetracyciln	196 (48)	64 (15.5)	151 (36.5)	411
Tobramycin	77 (30)	44 (17)	137 (53)	258
Trimethoprim	52 (20)	16 (6)	191 (74)	259
Ticarcillin	4 (14)	1 (3)	24 (83)	29
Vancomycin	876 (75.1)	86 (5.8)	204 (17.4)	1166
Total	19498 (30.9)	7628 (12.1)	35982 (57.1)	63066

This study found the majority of isolates were gram-negative, which supports findings from previous studies in Yemen[28,32]. The distribution of bacterial isolates among the sample and the AMR patterns for various pathogenic isolates were disclosed by the study's findings. Pathogens causing the majority of infections from various specimens in the current study in Sana'a were identified as *S. aureus*, *Escherichia coli*, *Pseudomonas aeruginosa,* and *Klebsiella* species. The most important finding is that 35.2% of the primary specimens (urine, wound, vagina, blood, sputum, ear, etc.) included *S. aureus.* This result differs from one from a Yemeni study that found *E. coli* was the most common pathogen, followed by *K. pneumoniae*[30,32]. Furthermore, *P. aeruginosa* and *E. coli* dominated the isolates. Commensal bacteria like *E. coli* can be found in the natural flora of many regions of healthy people. But these germs have the potential to be harmful and spread easily. The high variety of pathogens isolated from different specimens supports the use of susceptibility tests before prescribing antibiotic therapy. In this study, urinary tract, wound, vaginal, and blood stream infections were responsible for the majority (80%) of all infections. Urine specimens dominated over other specimens, and *E. coli* was the most isolated bacteria.

Table 4: Antifungal agents with resistance patterns of *Candida* spp.

Group	Anti-fungal	Sensitive N (%)	Moderate N (%)	Resistance N (%)	Total
Polyenes group	Amphotericin B	19 (100)	0 (0)	0 (0)	19
Azoles-Imidazole group	Voriconazole	13 (100)	0 (0)	0 (0)	13
Polyenes group	Nystatine	18 (100)	0 (0)	0 (0)	18
Azoles-Imidazole group	Ketoconazole	18 (100)	0 (0)	0 (0)	18
Azoles-Imidazole group	Itraconazole	16 (88.8)	1 (6.1)	1 (6.1)	18
Azoles-Imidazole group	Fluconazole	17 (94.4)	0 (0)	1 (5.6)	18
Imidazoles	Clotrimazole	17 (100)	0 (0)	0 (0)	17
Total		118 (97.5)	1 (0.8)	2 (1.7)	121

These findings were in agreement with other respective studies conducted in Yemen and elsewhere[33,34]. As a result of war injuries and postsurgical wound infections, wound infections in Yemen present a significant clinical practice challenge. These infections typically result in sepsis, limb loss, extended hospital stays, increased costs, and contribute to rising global rates of morbidity and mortality[28,29]. *S. aureus* was the most prevalent pathogen among wound swab pathogens, which is consistent with prior research done in Yemen and other places[29,35]. Unlike our findings, which were confirmed by another investigation in which *E. coli* was the most prevalent pathogen[36]. On the other hand, septicemia is an important complication in health settings in developing countries and contributes to the rising number of morbidities and mortality. Despite the fact the fact that our study revealed that *E. coli* was the superior contributor to the occurrence of bloodstream infections, other studies in Yemen and Egypt demonstrated that *K. pneumoniae* (36.7%) and *S. aureus* (53.1%) were the predominant pathogens, respectively[36,37]. With regard to the resistance patterns, the current study exhibited high levels of resistance toward antimicrobial agents, which is consistent with several studies conducted previously in Yemen[1-11].

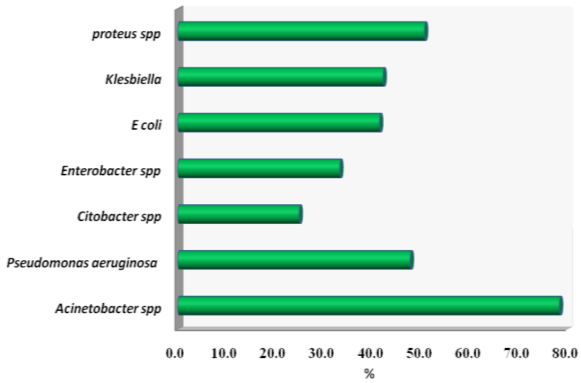

Figure 1: Multidrug resistance Gram negative bacteria.

In the present study, the highest incidence of resistance in both Gram positive and Gram negative isolates was recorded in the case of cefixime 90%, and high resistance was also documented toward amoxacillin 80%, amoxacillin/ clavulanic acid 77%, cefepime 72%, and ceftriaxone 70%. This resistance could be due to recurrent empirical therapy using new generations and strong broad-spectrum antibiotics for simple infectious or even viral diseases that leads to overuse of antibiotics and their consequences in widespread bacterial resistance to these antibiotics[14-17, 36].

Table 5: Antibiotic resistance patterns of isolated Gram negative bacteria.

Nalidixic Acid	74.4 349/469	70 47/67	81.8 9/11-	82.3 107/130	100 1/1-	100 3/3-	100 1/1-	NA	NA	NA
Amoxicillin	(137/155)	26/28)	(13/13)	(12/13)	NA	(3/3)	NA	NA	NA	NA
Amoxacillin/ Clavulanic Acid	71.40% (736/1030)	79.40% (293/369)	77% (50/65)	80.10% (309/386)	51.60% (16/31)	55.50% (5/9)	100% (4/4)	**50%** (1/2)	85.80% (6/7)	100% (1/1)
Ampicillin/ Sulbactum	59.20% (281/475)	70.10% (87/124)	73.30% (22/30)	70.20% (99/141)	72.20% (13/18)	83.30% (5/6)	50% (1/1)	NA	NA	NA
Amikacin	11.40% (87/762)	15% (31/206)	17.40% (8/46)	15% (53/355)	53.30% (8/15)	0% (0/6)	50% (1/2)	0% (0/2)	0% (0/7)	AN
Gentamicin	52 242/846	33.7 91/270	36.5 19/52	38.7 147/380	70 23/33	50 8/16-	50 1/2-	50 1/2-	22.2 2/9-	NA
Tobramycin	43 38/88	60 30/50	66.6 2/3-	65 35/54	NA	100 1/1-	NA	NA	NA	NA
Aztreonam	30.3 27/89	44.8 43/96	0 0/5	31.2 20/64	100 3/3-	0 0/2	50 1/2-	NA	NA	NA
Cefoxitin	33.5 48/143	49.6 62/125	28.5 2/7-	56.8 54/95	66.6 2/3-	100 2/2-	NA	NA	NA	100 1/1-
Cefuroxime	89.2 512/574	89 115/129	97 32/33	94.6 141/149	100 15/15	91.6 11/12-	NA	NA	66.6 4/6-	NA
Cefotaxime	77.5 (595/767)	76 (223/293)	69.3 (34/49)	81 (253/314)	66.70% (4/6)	66.70% (2/3)	100 (1/2)	**100** (1/1)	60 (3/5)	100 (1/1)
Ceftriaxone	75.5 763/1011))	79 259/328))	74 (43/58)	78.8 276/350))	92.6 (25/27)	81.8 (9/11)	66.6 (2/3)	**100** (2/2)	85.7 (6/7)	NA
Cefixime	88.4 442/500	91.9 91/99	97 32/33	93.2 123/132	NA	100 2/2	NA	NA	83.3 5/6	NA
Ceftazidime	63% (209/333)	73% (133/182)	47% (8/17)	67.50% (214/317)	96% (25/26)	58.30% (7/12)	75% (3/4)	NA	NA	100 (1/1)
Cefepime	69.5 555/799	72.8 207/284	69.7 30/43	71 255/359	90.6 29/32	54.5 6/11-	33.3 1/3-	**50** 1/2-	77.7 7/9-	100 1/1-
Imipenem	11 44/398	17.6 42/239	19.3 6/1-	13.9 47/339	71 22/31	41.6 5/12-	33.3 1/3-	NA	0 0/1	0 0/1
Meropenem	14 80/571	26 57/219	16 5/31-	23.7 57/240	83.3 25/30	33.3 3/9-	50 1/2-	NA	NA	NA
Ciprofloxacin	56.8 582/1023	54.7 151/276	58.6 34/58	56.8 248/436	91.6 11/12-	66.6 8/12-	100 1/1-	**100** 2/2-	30 3/10-	NA
Levofloxacin	32.3 254/787	42.5 93/219	34 16/47	34 112/331	65.5 19/29	40 6/15-	0 0/1	**50** 1/2-	33.3 2/6-	NA
Moxifloxacin	59.5 125/210	62.5 69/111	57 12/21-	56 51/91	85 17/20	71.4 5/7-	100 1/1-	NA	NA	NA
Ofloxacin	49.5 258/521	45.3 58/128	45.8 11/24-	53.1 93/175	33 1/3-	33.3 1/3-	NA	100 1/1-	33.3 2/6-	NA
Doxycycline	52.4 185/353	50 85/170	91 10/11-	65.8 112/170	66.6 18/27	35.7 5/14-	50 2/4-	NA	50 2/4-	100 1/1-
Chloramphenicol	11.7 11/94	22.8 16/70	20 1/5-	14.3 10/70	0 0/1	NA	NA	NA	0 0/1	NA
Colistin	7 3/43	12.5 5/40	50 1/2-	12.5 3/24-	10 1/10-	85.7 6/7*	0 0/1	NA	NA	NA
Carbincillin	93.5 (430/460)	94.3 (101/107)	93 (27/29)	95 (114/120)	NA	100 (2/2)	NA	100 (1/1)	75 (3/4)	100 (1/1)
SXT	69.2 72/104	71.4 30/42	66.7 2/3	74.4 29/39	81.8 9/11	87.5 7/8	100 2/2	NA	100 1/1	NA
Piperacillin	70.5 115/163	70.7 87/123	55.5 5/9-	51.3 118/230	75 3/4-	25 1/4-	100 2/2-	NA	NA	100 1/1-
Piperacillin/ Tazobactam	24.3 165/678	39 59/151	35 13/37	22.4 45/201	75 9/12-	20 1/5-	100 2/2-	0 0/2	20 1/5-	NA
Nitrofurantoin	12.5 79/630	29.5 33/112	50 8/16-	42.4 73/172	33.3 1/3-	0 0/3	0 0/2	NA	NA	NA

According to a Yemeni study reported, most therapy prescriptions were antibiotic prescriptions that exceeded the standard values suggested by the WHO[22].

The current study demonstrated that ciprofloxacin resistance (55%), erythromycin 56.5%, and co-trimoxazole (62%), were less effective against most tested pathogens. A study conducted in Yemen (2020) discovered that amoxicillin, amoxicillin/clavulanic acid, ciprofloxacin, erythromycin, and ceftriaxone were the most commonly utilized[26]. In Yemen, ciprofloxacin is the first-choice medication for a number of illnesses, including typhoid, GIT infections, and UTIs. The high levels of resistance observed[28] may have been influenced by the antimicrobials' broad use in the treatment of infections acquired in the community.

According to several studies conducted in African nations, bacterial resistance to widely used, reasonably priced medications typically exhibits broad-spectrum activity, such as ampicillin, tetracycline, and cotrimoxazole, which have been the cornerstones of antimicrobial treatment in the continent for decades[38].

Generally, we observed that the highest susceptibility rates were found to be for amikacin (15.6%), imipenem (18%), and chloramphenicaol (22%). This could be explained by the rare use of these aminoglycosides and chloramphenicol in our setting. Amikacin is a very expensive drug and is usually prescribed for serious infections[38]. Regarding chloramphenicaol, due to fear of the dangerous side effects associated with this agent, this might be one of the reasons for the relatively low levels of resistance. Our study observed that more than 71% of each *E. coli* and *Klebsiella* spp. showed resistance against amoxicillin and clavulanic acid, a finding consistent with results from previous studies in Yemen[32], while this drug is still effective among these pathogens, as documented in Ethiopia in one previous study[39]. When considering the rate of resistance to individual antibiotics with specific bacteria. In current study, this result is consistent with all previously discussed antibiotic results, and we therefore adhere to the previous discussion in the tables and do not discuss individual drug-resistant species due to unnecessary repetition and length of the discussion section.

The frequency of multidrug-resistant (MDR) microorganisms, which is regarded as a major therapeutic barrier to the management of common illnesses, was another significant finding in this study.

Table 6: Antibiotic resistance patterns of isolated Gram positive bacteria.

	S. aureus	***Enterococcus***	***CNS***	***S. pneumonia***	**AHS**	**BHS**	***S. agalactiae***	***S. pyogenes***
Pencillin	76.2 157/206	50 2/4*	72.7 8/11*	NA	50 3/6-	50 1/1-	50 1/2-	33.3 1/3
Amoxacillin	76% (334/440)	80% (8/10)	56.70% (21/37)	NA	0% (0/2)	0% (0/2)	50% (1/2)	
Amoxacillin/Clavulanic Acid	59.30% (251/423)	50% (2/4)	66.70% (4/6)	50% (2/4)	51.60% (16/31)	66.60% (6/9)	50% (1/2)	20 1/5
Cloxacillin	60.7 116/191	50 1/2-	71 5/7-	NA	40 2/5	60 3/5	NA	100 4/4
Oxacillin	57.9 117/202	NA	57.1 12/21	NA	4 0 2/5	66.6 2/3	50 1/2	66.6 2/3
Cefoxitin	60.6 37/61	NA	57.1 4/7-	NA	0 0/1	66.6 2/3	NA	100 2/2
Cefuroxime	73.5 490/666	83.3 45/54	NA	NA	NA	NA	0 0/1	60 3/5
Cefotaxime	64 (537/840)	81 (47/58)	41.6 (10/24)	20 (1/5)	42.8 (12/28)	36.4 (4/11)	50 (1/2)	28.5 2/7
Ceftriaxone	64 756/1177	73 62/85	23.3 7/30*	50 3/6	45.8 11/24	42.8 3/7	**100** 2/2	**33.3** 2/6
Cefepime	75.4 560/742	84.3 59/70	66.6 6/9	80 4/5	80 4/5	83.3 5/6	0 0/1	40 2/5
Carbincillin	81.2 (485/597)	63.5 (51/61)	NA	0 (0/1)	NA	NA	NA	50 1/2
Erythromycin	47.6 91/191	100 4/4	50 6/12*	NA	22.2 4/18-	28.5 2/7-	**50** 1/2-	**0** 0/5
Clarithromycin	78 706/904	85.4 70/82	50 3/6-	0 0/2	NA	NA	**0** 0/1	**0** 0/2
Azithromycin	66.5 (726/1091)	78 (67/86)	64.7 (11/17)	0 (0/3)	52 (13/25)	25 (2/8)	**33.3** (1/3)	**0** 0/5
Doxycycline	35 153/436	50 11/22-	17.8 5/28-	NA	25 1/4-	40 2/5-	50 1/2-	20 1/5
Tetracycline	27.2 31/114	0 0/1	50 3/6-	NA	0 0/3	33.3 1/3-	100 1/1-	0 0/2
Gentamicin	26 220/843	28 24/86	38.5 5/13-	0 0/2	18.2 2/11-	25 1/4-	**0** 0/1	**16.6** 1/6
Amikacin	19.4 (153/787)	20.7 (11/73)	22 (2/9)	NA	0 (0/2)	0 (0/1)	0 (0/1)	50 1/2
SXT	34.2 26/76	100 2/2*	60 6/10-	NA	80 4/5-	50 1/2-	NA	25 1/4
Clindamycin	75 399/532	86.6 39/45	42.8 3/7-	0 0/1	0 0/5	50 1/2-	100 1/1-	33.3 2/6
Ciprofloxacin	56.4 639/1133	60.2 50/83	21.8 7/1-	0 0/3	52.4 11/21-	30 3/10-	50 1/2-	20 1/5
Ofloxacin	47.5 236/497	47 25/53	19 4/21-	NA	100 2/2-	0 0/1	100 1/1-	NA
Levofloxacin	36.4 336/922	30 25/83	17.8 5/28-	0 0/3	16.6 1/6-	60 3/5-	0 0/2	16.6 1/6
Moxifloxacin	53 177/333	55.5 5/9*	0 0/4	0 0/2	NA	100 1/1-	100 1/1-	25 1/4
Vancomycin	18.8 190/1107	42 8/19*	13.3 2/15-	0 0/2	14.3 2/14-	66.6 2/3-	0 0/1	0 0/5
Teicoplanin	35.7 15/42	NA	NA	NA	50 1/2-	50 1/2-	NA	NA
Linezolid	17.5 41/234	0 0/3	10 1/10-	0 0/1	0 0/7	0 0/4	NA	0 0/3
Nirofurantoin	27.3 12/1-	20.6 14/68	50 1/2-	NA	0 0/3	33.3 1/3-	NA	NA

Overall, the prevalence of MDR was lower in our study than it was in Egypt, Ghana, and Ethiopia[38,40,41], although it was prevalent across the different isolates.

Table 7: Prevalence of multidrug resistance among bacterial agents last.

Pathogens	Total	Multidrug resistance N (%)
Acinetobacter spp	37	29 (78.4)
P. aeruginosa	586	280 (47.8)
Proteus spp	71	36 (50.7)
Klesbiella spp	443	187 (42.2)
E. coli	1215	504 (41.5)
Citobacter spp	4	1 (25)
Enterobacter spp	18	6 (33.3)
S. aureus	1479	687 (46.5)
Enterococcus spp	99	36 (36.4)
CNS	46	13 (28.3)
Shigella spp	10	4 (40)
Total	4008	1783 (44.5)

MDR is frequently transmitted within hospitals by patients, healthcare personnel, or the environment, especially in times of conflict when there is instability and disarray in the health care systems[33].

Limitations of the study

Data on antibiotic resistance are valuable but data in this study are still limited. It requires additional information about the sources of infection, assumes that some samples were collected after antibiotic treatment, uses disk diffusion methods to test for susceptibility, and is inconsistent in the number of antibiotics used, which may give unrealistic percentages in observed overall resistance. There is a need for extensive research in Yemeni cities to understand antimicrobial resistance across Yemen.

CONCLUSIONS

Sana'a, Yemen, has a high rate of antibiotic resistance patterns, according to the current study. According to this study, urine and pus specimens accounted for more than half of all clinical specimens, with *S. aureus* and *E. coli* being the most frequently isolated pathogens. The resistance of various bacteria to antibiotics was found to be high overall. The resistance to penicillins and cephalosporins was found to be the highest, while the resistance to amikacin, chloramphenicaol, and nitrofurantoin was the lowest. Moderate bacterial resistance to ciprofloxacin was also seen in the investigation. The most common kind of *S. aureus* was MRSA. Colistin was the most effective against Gram negative isolates as it recorded resistance, while *Enterococcus* species showed increased resistance to vancomycin and no resistance to linezolid.

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AUTHOR'S CONTRIBUTIONS

Al-Tahish GAA: supervision. **Measar MAH:** supervision. **Al-Safani MAH:** conceptualization, methodology. **Makeen MAN:** literature searches, research design. **Al-Moyed KA:** collecting data and analysis. **Al-Shamahy HA:** review, editing. **Al-Haddad AM:** data collection and processing. Final manuscript was read and approved by all authors.

DATA AVILIABILITY

The data will be available to anyone upon request from the corresponding author.

CONFLICT OF INTEREST

None to declare.

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