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Antimicrobial Resistance in Wadi Hadramout: A Study on Prevalence and Patterns (2022-2023)

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Abstract
Background: Antimicrobial resistance is a global problem which threatens the public health. New resistance patterns emerge daily, getting through the international boundaries and spreading fast.
Aim: To determine the prevalence of antimicrobial resistance of pathogenic bacteria isolated from clinical samples in Wadi Hadramout, Yemen.
Methodology: A cross-sectional study was carried out in Wadi Hadramout estimating the prevalence of antimicrobial resistance. The clinical samples collected in the period from June 2022 to June 2023 and positive cultures were tested for antimicrobial sensitivity by standard culturing methods and sensitivity toward various antimicrobials.
Results: A total of 552 samples (vaginal swab 197, midstream urine142, wound swab124, and others) were collected. The most common pathogens isolated were Staphylococcus aureus 206 (37.3%), Escherichia coli (E coli) 152(27.5%), Pseudomonas aeruginosa 74 (13.4%) and Klebsiella spp 61(11.1%). Staphylococcus aureus had 100% resistance to Amoxycillin, penicillin, and erythromycin with an average of 72% resistance to all tested antibiotics. E coli had 100% resistance to Amoxycillin, penicillin, cefadroxil, and erythromycin, and 94 % to Clarithromycin, Cefixime, Cefalexin, Cefuroxime, trimethoprim, Ceftriaxone, and Vancomycin, with an average resistance of 73% to all tested antibiotics.
Conclusion: the prevalence of antibiotic resistance is very high in Wadi Hadramout, and it seems higher than in the other cities in Yemen.

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Keywords
antimicrobial resistance, bacteria, staphylococcus aureus, Escherichia coli, wadi Hadramout

Introduction:

Antimicrobial Resistance (AMR) threatens the public health worldwide. New resistance patterns emerge daily, getting through international boundaries and spreading fast (Abushaheen et al., 2020; Baekkeskov et al., 2020). The global number of Hospital-Associated Infections (HARIs) was estimated to be 136 million per year (Balasubramanian et al., 2023), and about 4.95 million were associated with AMR bacteria in 2019 (Murray et al., 2022). Deaths associated with the 33 bacterial pathogens were estimated to comprise 13.6% of all global deaths and 56.2% of all sepsis-related deaths in 2019. Almost half of which is due to the leading pathogens, mainly *Staphylococcus aureus*, *Escherichia coli*, *Klebsiella pneumoniae*, *Streptococcus pneumoniae*, and *Pseudomonas aeruginosa* (Ikuta et al., 2022). Low- and middle-income countries (LMICs) have poor antimicrobial stewardship. And in most of those countries, over-the-counter sales of antibiotics are the norm rather than the exception. Patients from LMICs are exposed to healthcare-associated infections at least 2-fold higher than in high-income countries (HICs) (Balasubramanian et al., 2023). AMR was studied in different regions in Yemen whose findings were: in Aden, 40-80 % (ALhlale et al., 2020; Almehdar et al., 2024; Badulla et al., 2020; Orubu et al., 2021), in Mukalla, 37-70 % (Al-Haddad et al., 2010; Hameed, 2016), in Sanaa, 67-85% (Al-Yosaffi et al., 2023; Edrees &

Anbar, 2021), and in Taiz, 45-85% (Al-Jendy et al., 2018). There is no data about AMR in Wadi Hadramout. This is the first study, to the best of the researchers' knowledge, that aims to investigate the prevalence of AMR in Wadi Hadramout.

Methods and materials:

This is a cross-sectional study. The results of the clinical samples tested for bacterial culture and sensitivity were gathered from June 2022 to June 2023 at a private microbiology laboratory database in Seiyun City, Hadramout, Yemen. Results of 552 clinical specimens, which appear to be positive for pathogenic bacteria and tested for antibiotic sensitivity, were included in the study, vaginal swab 197, midstream urine142, wound swab124, and others (Table 1). Standard microbiological methods were applied to identify the bacterial species. The disk diffusion method was used for antimicrobial susceptibility, and the diameter of zone inhibition was measured. Data analysis was performed using Statistical Package for the Social Sciences (SPSS v26). The frequencies of different bacteria and the rate of AMR were calculated. This study did not directly involve human subjects.

Results:

Five hundred and fifty-two specimens were tested for antibiotic sensitivity. The most common pathogens isolated were *Staphylococcus aureus* 206 (37.3%), *E coli* 152 (27.5%), *Pseudomonas aeruginosa* 74 (13.4%), and *Klebsiella spp*. 61(11.1%), as shown in (Table 1). The results of microbial sensitivity tests revealed that *Staphylococcus aureus* had 100% resistance to Amoxycillin, penicillin, and erythromycin, with an average of 72% resistance to all tested antibiotics, as given in (Fig 1). *E coli* had 100% resistance to Amoxycillin, penicillin, cefadroxil, and erythromycin, and 94 % to Clarithromycin, Cefixime, Cefalexin, Cefuroxime, trimethoprim, Ceftriaxone, and Vancomycin, with an average resistance of 73% to all tested antibiotics as shown in (fig 2). *Pseudomonas aeruginosa* had 100% resistance to Amoxycillin, penicillin, Cefadroxil, Piperacillin, trimethoprim, Lincomycin, and erythromycin, with an average resistance of 77% to all tested antibiotics. *Klebsiella spp*. had 100% resistance to Norfloxacin, Cefixime, Lincomycin, Amoxycillin, penicillin, and erythromycin, averaging 73 % to all tested antibiotics as presented in (Table 2). Other types of bacteria isolated in smaller numbers with almost the same sensitivity results.

Table 1: Types of bacteria and types of specimens

Type of bacteria AND type of specimen												
	type of specimen											Total
Type of bacteria	Midstream urine	Wound swab	Semen	Sputum	Ear swab	Vaginal swab	Throat swab	Pus aspiration	Pleural fluid	Synovial fluid	Stool	
Escherichia coli	**60**	**14**	**3**	**0**	**0**	**67**	**0**	**4**	**0**	**0**	**4**	**152**
Staphylococcus aureus	**31**	**58**	**7**	**1**	**12**	**86**	**0**	**9**	**0**	**2**	**0**	**206**
Pseudomonas aeruginosa	**11**	**37**	**0**	**1**	**5**	**19**	**0**	**1**	**0**	**0**	**0**	**74**
Klebsiella spp.	**30**	**11**	**2**	**1**	**1**	**11**	**1**	**3**	**0**	**0**	**1**	**61**
Enterobacter spp.	**5**	**0**	**0**	**0**	**0**	**12**	**0**	**0**	**0**	**0**	**0**	**17**

Streptococcus pyogenes	**0**	**0**	**0**	**1**	**0**	**0**	**18**	**0**	**1**	**0**	**0**	**20**
Proteus spp.	**5**	**4**	**0**	**0**	**9**	**2**	**0**	**0**	**0**	**0**	**0**	**20**
salmonella typhi	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**2**
Total	**142**	**124**	**12**	**4**	**27**	**197**	**19**	**17**	**1**	**2**	**7**	**552**

Table 2: The Common bacteria isolated and its antibiotic sensitivity results.

bacteria / Antibiotic	*Staphylococcus aureus*			*Escherichia coli*			*Pseudomonas aeruginosa*			*Klebsiella spp.*		
	Resistance (72 %)	Intermediate sensitive	sensitive	Resistance (73 %)	intermediate sensitive	sensitive	Resistance (77 %)	intermediate sensitive	sensitive	Resistance 73%	intermediate sensitive	sensitive
Nitrofurantoin	79	127	0	29	123	0	52	22	0	39	21	1
Norfloxacin	165	40	0	83	67	2	51	21	0	38	23	0
Cefixime	201	5	0	148	3	0	73	1	0	60	0	0
Cefalexin	95	11	0	78	2	0	46	1	0	39	0	0
Azithromycin	178	28	0	135	16	1	58	15	0	49	11	1
Co–trimoxazole	145	60	1	112	36	5	55	18	0	39	21	1
Levofloxacin	119	76	1	63	82	0	33	40	1	19	39	0
Ofloxacin	114	67	0	73	70	0	39	29	0	32	27	0
Vancomycin	106	59	0	136	4	0	63	6	0	58	1	0
Cefuroxime	113	17	0	95	3	0	52	1	0	43	2	0
Amoxiclav	123	62	18	115	35	1	63	11	0	49	11	0
Clarithromycin	179	27	0	149	3	0	72	2	0	58	3	0
Ceftriaxone	114	44	1	103	12	0	52	7	0	38	11	0
Moxifloxacin	86	117	3	80	72	0	39	29	0	30	30	1
Amikacin	129	73	1	93	58	0	38	35	0	32	28	0
Cefepime	158	34	0	124	23	0	66	4	0	52	9	0
Lincomycin	199	4	0	151	0	0	73	0	0	61	0	0
Gentamicin	102	90	1	67	77		38	35	1	30	28	0
Ciprofloxacin	60	30	1	85	29	3	17	8	1	12	19	0
Meropenem	140	56	17	12	58	18	12	31	10	7	25	4
Imipenem	2	18	31	2	22	22	0	13	3	0	12	0
Piperacillin-Tazobactam	59	125	12	33	108	0	30	42	0	23	30	1
Piperacillin	47	5	0	36	0	0	12	0	0	11	0	0
Trimethoprim	49	5	0	41	4	0	17	0	0	15	2	0
Tetracycline	93	21	0	78	12	0	39	6	0	35	7	0
Amoxycillin	23	0	0	16	0	0	2	0	0	15	0	0
penicillin	23	0	0	17	0	0	3	0	0	16	0	0
Cefadroxil	18	5	0	18	0	0	3	0	0	14	1	0

Erythromycin	22	0	0	17	0	0	3	0	0	16	0	0

Fig 1: ***Staphylococcus aureus* antibiotic sensitivity**

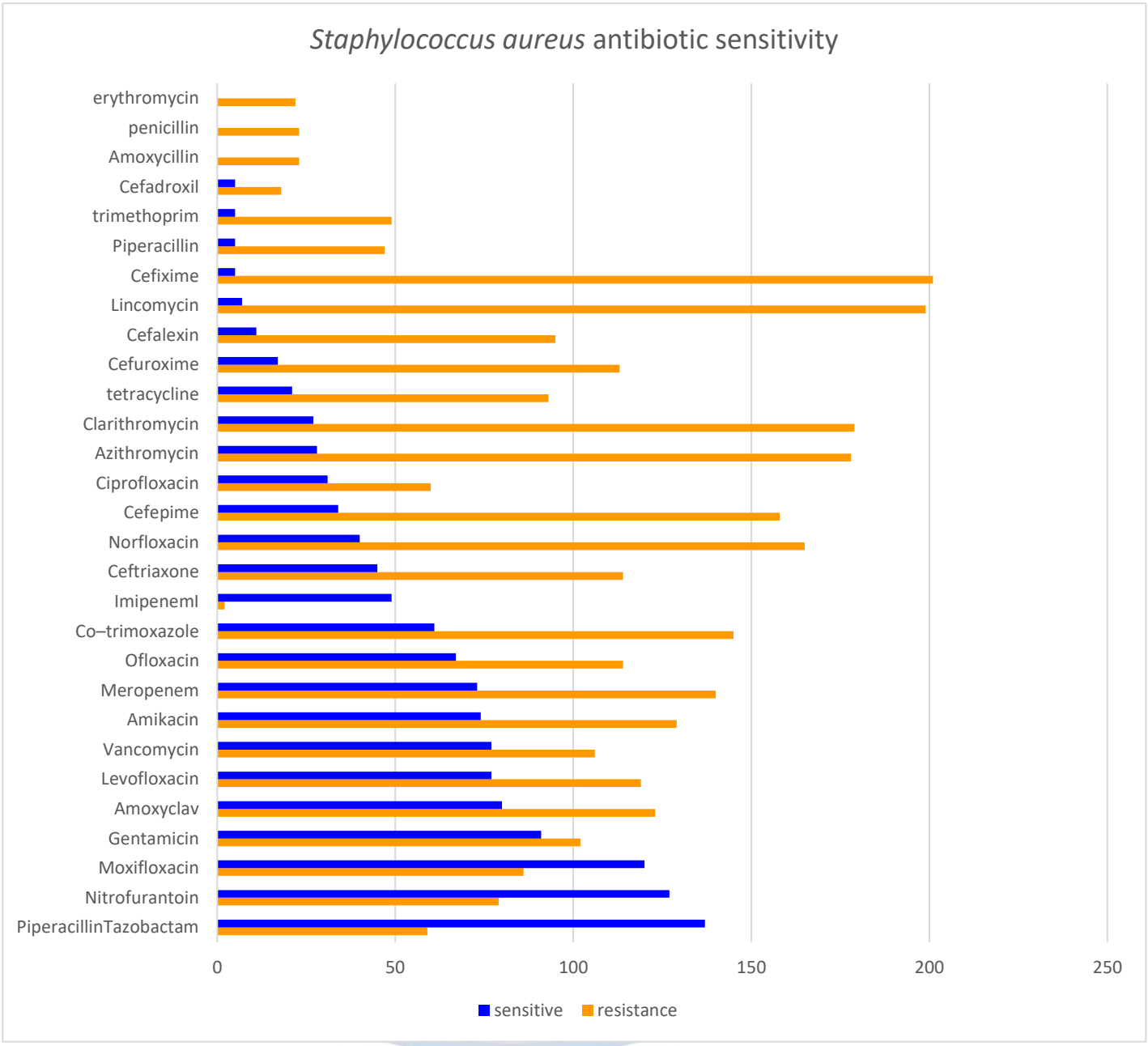
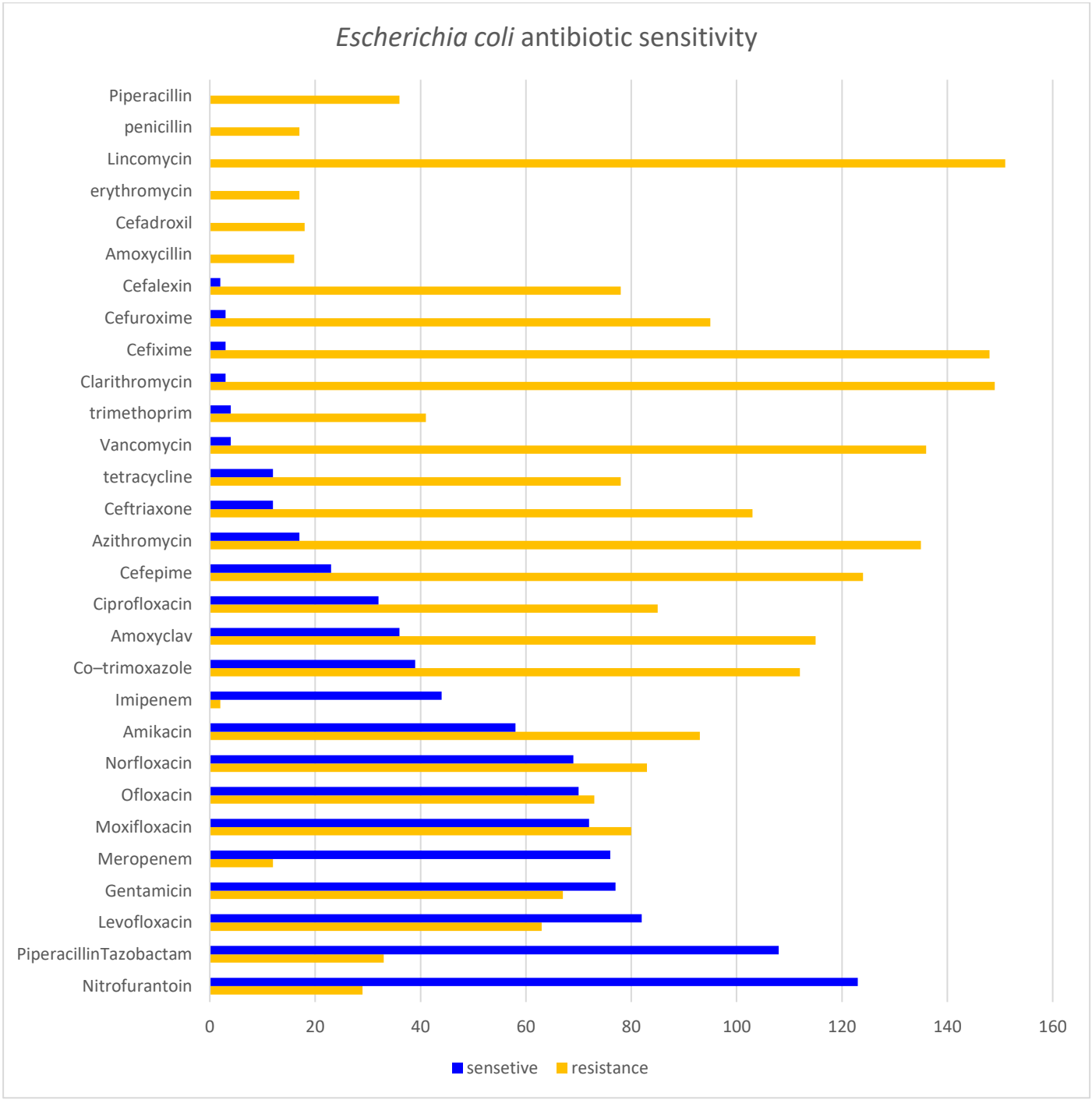


Fig 2: ***Escherichia coli*** **antibiotic sensitivity**



Discussion: One of the major issues facing global public health in the twenty-first century is still AMR. If AMR is not sufficiently faced and dealt with properly, there could be severe consequences, including a return to the pre-antibiotic era, when common infections from childbirth, surgery, and open fractures could be fatal (Tang et al., 2023). To mitigate this

growing threat, robust surveillance systems and enhanced antimicrobial stewardship programs are urgently needed across both developed and developing nations (Ajulo & Awosile, 2024). A systematic review conducted by the Antimicrobial Resistance Collaborators highlighted alarming rates of resistance globally. They found Methicillin-resistant *Staphylococcus aureus* was 60-80% in Asia (except Russia), Africa, Eastern Mediterranean, Peru and Chile, while Third-generation cephalosporin-resistant *Escherichia coli* was 70-80% in Southeast Asia and the Persian Gulf and Fluoroquinolone-resistant *Escherichia coli* >80 in Yemen and Thailand, while Third-generation cephalosporin-resistant *Klebsiella pneumoniae* 70-80% in Balkan Peninsula, Russia, and Africa (Murray et al., 2022). Yahya A. Almutawif in Saudia Arabia found high resistance rates in uropathogens, the Gram-negative bacteria, to ampicillin (78.8%) and cephalexin (68.5%). *Enterococcus spp*. , (> 62.3%) against ciprofloxacin, gentamicin, and tetracycline, while gram-positive *Streptococcus spp*. showed substantial resistance rates (> 76.6%) toward colistin and trimethoprim/ sulfamethoxazole (Almutawif & Eid, 2023). In the Eastern Mediterranean Region, 17.4%–79.6% for methicillin-resistant *staphylococcus aureus*, 28.2%–95.0% *K. pneumoniae*, and 32.6%–88.6% *E. coli* resistant to 3rd generation cephalosporin (Talaat et al., 2022).

Our study revealed even more concerning trends. Resistance rates soared to (89- 100%) for several widely prescribed antibiotics including: Amoxycillin, penicillin, cefadroxil, erythromycin, Clarithromycin, Cefixime, Cefalexin, Cefuroxime, trimethoprim, Ceftriaxone, and Vancomycin. Imipenem emerged as the least resisted antibiotic, yet resistance still stood at 3.7%. These findings surpass previous reports from other governorates in Yemen like Aden 40-80 % (ALhlale et al., 2020; Almehdar et al., 2024; Badulla et al., 2020; Orubu et al., 2021), and Mukalla 37-70 % (Al-Haddad et al., 2010; Hameed, 2016), Sanaa 67-85% (Al-Yosaffi et al., 2023; Edrees & Anbar, 2021), and Taiz 45-85% (Al-Jendy et al., 2018).The prevalence of *Staphylococcus aureus* in vaginal swabs in our study was 43.6% which is similar to the study done in Iraq 44.4% and 44.3% (Mahmmod & AlHadban, 2022; Mohammad et al., 2024). These results raise a red flag and shed the light on a critical problem where 4 of the most common pathogenic bacteria were resistant to 11 of the most commonly prescribed antibiotics. Murray et al estimated 1.27 million preventable deaths were caused by drug-resistant bacteria worldwide in 2019, mainly due to *Escherichia coli, Staphylococcus aureus, Klebsiella pneumoniae, Streptococcus pneumoniae, Acinetobacter baumannii*, and *Pseudomonas aeruginosa*. WHO and other groups and researchers conclude that the spread of AMR is an urgent issue that needs a global, coordinated action plan to address. Information about the magnitude of the burden and trend of bacterial AMR in different parts of the world and the leading pathogens is mandatory. If left unchecked, AMR could make many bacterial pathogens spread and become much more lethal in the future (Murray et al., 2022). Great challenges in LMICs include a lack of an antimicrobial stewardship program, the availability of antibiotics over-the-counter, Self-Medication, the spread of counterfeit medications, with weak leadership and governance from health policy decision-makers (Alfadly et al., 2017; Almehdar et al., 2024). In an era of limited resources, LMICs are facing major problems that divert attention away from this pandemic, which is silently spreading, reaching not only the individual but also the society, the nation, and the entire global ecosystem (Sartelli et al., 2020).

Conclusion and Recommendations: Our study revealed that *Staphylococcus*, followed by *E. coli, Pseudomonas*, and *Klebsiella pneumoniae* were the most widespread pathogenic bacteria in several isolates. Alarmingly, the prevalence of antibiotic resistance is very high in Wadi Hadramout, and it seems to be higher than in other cities in Yemen, which needs immediate action by local health authorities.

There is a need for further studies about antibiotic abuse, self-medication, and microbiological surveillance, as well as an action plan by the health authority, mainly education at the local level to the general population and health workers community. For safe empirical antibiotic prescription, a regular study of antimicrobial resistance must be conducted.

Limitation

This study depends on the database of the laboratory with no direct contact with the patients or the laboratory techniques.

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مقاومة مضادات الميكروبات في وادي حضرموت: دراسة في مدى انتشارها وأنماطها (2022–2023)

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الملخص

الخلفية: مقاومة مضادات الميكروبات مشكلة عالمية تهدد الصحة العامة. تظهر أنماط مقاومة جديدة يوميًا تخترق الحدود الدولية وتنتشر بسرعة.

االهدف : تحديد انتشار مقاومة مضادات الميكروبات من العينات السريرية في وادي حضرموت

المنهجية: دراسة مقطعية لتقدير انتشار مقاومة مضادات الميكروبات، وقد تم اختبارحساسية مضادات الميكروبات للزراعة الإيجابية بالطرق القياسية للزراعة والحساسية تجاه مضادات الميكروبات المختلفة.

النتائج: إجمالي 552 عينة (مسحة مهبلية 197، فحص البول 142، مسحة جرح 124، وغيرها). كانت أكثر البكتيريا شيوعًا هي المكورات العنقودية الذهبية 206 (37.3٪) و الإشريكية القولونية (27.5٪) 152و الزائفة الزنجارية 74 (13.4٪) و كليبسيلا (11.1٪).61 كان لدى المكورات العنقودية الذهبية مقاومة بنسبة 100٪ للأموكسيسيلين والبنسلين والإريثروميسين بمتوسط مقاومة 72٪ لجميع المضادات الحيوية المختبرة. كان لدى الإشريكية القولونية مقاومة بنسبة 100٪ للأموكسيسيلين والبنسلين والسيفادروكسيل والإريثروميسين و 94٪ لكلاريثروميسين وسيفيكسيم وسيفاليكسين وسيفوروكسيم وتريميثوبريم وسيفترياكسون وفانكومايسين بمتوسط مقاومة 73٪ لجميع المضادات الحيوية المختبرة

الاستنتاج : انتشار مقاومة المضادات الحيوية مرتفع جدًا في وادي حضرموت ويبدو أعلى من المدن الأخرى في اليمن.

معلومات البحث

تاريخ الاستلام: 2025/01/22
تاريخ القبول: 2025/02/03
تاريخ النشر : 2025/07/08

الكلمات المفتاحية

مقاومة المضادات الحيوية، البكتيريا، المكورات العنقودية الذهبية، الإشريكية القولونية، وادي حضرموت