(IJRMST) 2023, Vol. No. 16, Jul-Dec **e-ISSN: 2455-5134 p-ISSN: 2455-9059**

Pathogenicity Characteristics of *Proteus Mirabilis* in Patients with UTI[1]

Noor Abd Al-Ameer Mazyed, Ahmed Khassaf Al Atya

Department of Biology, College of Science, University of Thi- Qar, Iraq.

DOI:10.37648/ijrmst.v16i01.005

Received: 12 April 2023; Accepted: 22 July 2023; Published:04 August 2023

ABSTRACT

A total of two hundred , and fifty urine samples are gathered from hospitals of Thi-Qar governorate over a six-month period, these samples were collected from Al- Nasiriyah teaching hospital, Al-Hussein Teaching Hospital, and Suq Al-Shuyoukh general hospital. Twenty-five *Proteus mirabilis* isolates were identified using their morphology, microscopic features, biochemistry, confirmatory APi 20 E tests, and VITEK II system. The twenty-five isolates were examined for antibiotic resistance against 18 different antibiotics. It was found that isolates' levels of antibiotic resistance varied. Amoxicillin-clavulanic acid, azithromycin, nitrofurantoin, and ampicillin were all reported to have high resistance among isolates (100 %) while the resistance to activity of trimethoprim, tetracycline, and cefotaxime was 96%. The resistance to nalidixic acid, cefepime, ceftriaxone, ciprofloxacin, ceftazidime, amikacin, cefixime, gentamicin, norfloxacin, imipenem, and meropenem were (88, 88, 84, 76, 72, 68, 68, 56, 52, 8, 16) % respectively.

Keywords: *Proteus mirabilis; UTI; Antibiotic resistance.*

INTRODUCTION

Proteus spp. It is a member of the Enterobacteriaceae family. Together with the genera Morganella and Providencia, it is classified with the tribe Proteeae (O'Hara et al., 2000). *Proteus mirabilis*, a Gram-negative, dimorphic, motile bacterium, has fascinated scientists for decades due to its ability to transform from small rods into lengthy, multinucleated swarmer cells with thousands of flagella (Armbruster & Mobley, 2012).

P. mirabilis is common in many habitats, including sewage, soil, and water as well as the gastrointestinal tracts of animals and humans.(Alqurashi et al., 2022). *Proteus mirabilis* in addition to being able to cause urinary tract infections such as cystitis, pyelonephritis, and asymptomatic bacteriuria, *Proteus mirabilis* infections can also result in bacteremia and life-threatening urosepsis. Moreover, *Proteus. mirabilis* can result in the production of urinary stones (Zafar et al., 2019). Patients with long-term indwelling catheters or complex UTIs are also susceptible to this opportunistic pathogen's infection.(Yuan *et al*., 2021) . Expression of virulence factors in this species, including adhesion molecules, urease, proteases, siderophores, and toxins, contributes to its pathogenicity (Danilo de Oliveira *et al*., 2021). The bacterium *Proteus mirabilis* is the third most common cause of urinary tract infections. It produces urease, which leads to the production of crystalline biofilm and is regarded one of the most significant virulence features of *P. mirabilis* strains, along with their capacity to swarm on solid surfaces (Filipiak *et al*., 2020) Clinical strains of *P. mirabilis*, like other Enterobacterales, have evolved significantly resistance to antimicrobial medicines over the past few decades (Literacka *et al*., 2019)

[1] *How to cite the article:* Mazyed N.A.A., Al-Atya A.K. (August 2023); Pathogenicity Characteristics of Proteus Mirabilis in Patients with UTI; *International Journal of Research in Medical Sciences and Technology;* Vol 16, 39-49, DOI: http://doi.org/10.37648/ijrmst.v16i01.005

MATERIALS AND METHODS

Collection of Samples

Between the 29th of August 2022 and the 29th of January 2023, 250 urine samples from both sex and various ages were collected from hospitals and private clinics in the province of Thi-Qar. The samples were obtained from the patients using sterile containers, and they were subsequently conveyed using Cary Blair swabs.

Cultivation of the samples

Swabs were streaked onto MacConkey's agar medium and blood agar medium. The inoculated medium was incubated aerobically at 37 °C for 24-48 hours, and then examined for bacterial growth.

Identification of the isolates:

A- Morphological characterization: Examination under the microscope revealed that the isolated bacterial cells were gram-negative, red cocco-bacilli of variable length that frequently occurred individually or in short chains (dimorphic) (Armbruster & Mobley, 2012).

B- Cultural characteristics

The Proteus isolates were recognized by their swarming behavior on blood agar and their pale appearance on MacConkey agar due to their inability to ferment lactose sugar. They also have a characteristic fish odor (Hassoon *et al*., 2021)

C-Biochemical tests

Catalase, Oxidase, Urease production, Triple Sugar Iron Agar, IMVC Test and API 20E (Tille, 2014).

D-VITEK II Compact system

VITEK-2 is an automated colorimetric system for the identification and susceptibility testing of the most clinically significant bacteria (Conejo *et al*., 2001).This system's mechanism of action measures the kinetics of bacterial growth using fluorescence-based technologies to detect metabolic changes within 6 hours (Ibrahim, 2019) **.**

Antibiotic Susceptibility Test (AST)

It was performed by Kirby-Bauer procedure on Muller Hinton agar . All isolates were tested against 18 antibiotics, and the results were interpreted according to clinical and Laboratory Standards Institute 2022. Ampicillin 25 µg, Amoxicillin –Clavulanic Acid 20 µg, Cefepime 5µg, Gentamicin 10µg, Amikacin10 µg, Meropenem 10µg, Impenim 10 µg, Ceftazidime 30 µg, Cefteriaxone 30 µg, Azithromicin 15 µg ,Tetracyclin 10 µg , Ciprofloxacin 10 µg , Nalidaxic acid 30 µg , Trimethoprime 10 µg, cefotaxime 30 µg , Cefixime 5 µg, Ntroforantoin 100 µg , Norfloxacin 30 µg (bioanalyse,Turkey). The inoculum was prepared by growing of *Proteus mirabilis* on dispersed agar plates, then the colonies grow in the plate transferred by loop into a test tube filled with 3 ml of normal saline. The suspensions density was adapted to 0.5 McFarland standards. The plate surface of Muller- Hinton agar (Himedia India) was inoculated with bacteria by a sterile swab. The swab was soaked into the suspension and pressed into the side of the test tube to discard exuberance fluid, then inoculate the Muller-Hinton agar by streaking method. Antibiotic discs were applied to the inoculated agar and, incubated at 37ºC overnight. The diameter of zone of growth inhibition observed was measured and compared to the chart of National Committee for Clinical Laboratory Standards (NCCLS)(CLSI, 2021).

Statistical Analysis

The data of the present study were statistically analysis by using SPSS (Statistical Package of Social Science version 26) based in using both descriptive and, non-parametric Chi-Square at p. value < 0.05.

RESULTS

The present study involved a 250 urine sample which collected from patients with UTI infection, among 250 urine sample the study revealed 25 (13.88%) infected with *P.mirabillis* the results also noted a significant difference according to type of infection at p. value < 0.05 as show in figure 1.

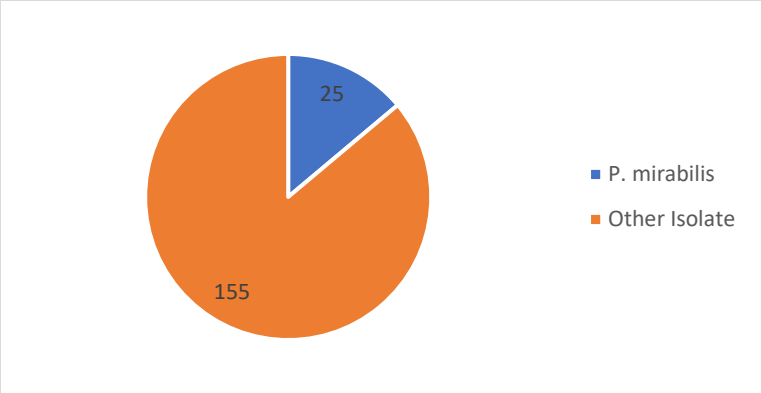

Figure 1: Ratio of *P. mirabillis* to other microorganism in patient with UTI.

CalX^2=160	**TabX^2=3.84**	**DF=1**	**p. value < 0.001^{Sig}**

The study noted 17 (68%) infection in male with *P.mirabilis* , while 8 (32%) infected in female with *P.mirabilis* , the results also noted a non-significant difference in availability of *P. mirabillis* according to sex at p. value < 0.05 as show in figure 2

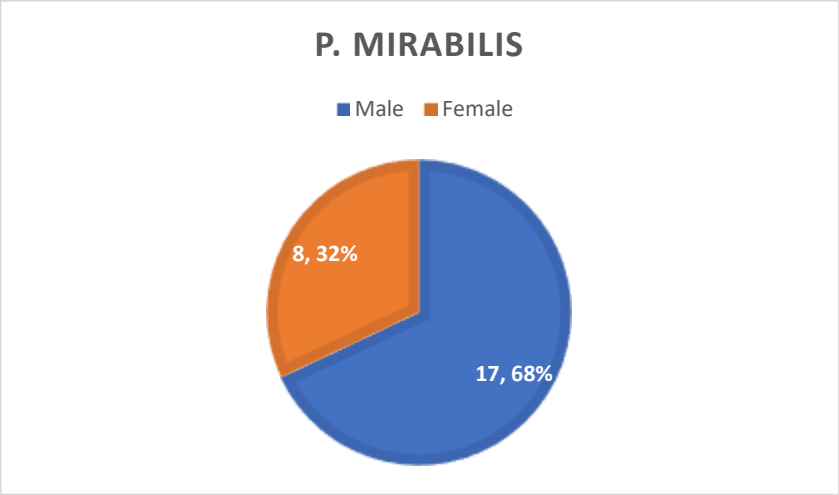

Figure 2: A comparison of *P. mirabillis* infection in patients with UTI according to sex.

CalX^2=3.24	**TabX^2=3.84**	**DF=1**	**p. value 0.072$^{Non-sig}$**

Identification of *Proteus mirabilis* was performed in accordance with (Tille, 2014) Based on the Colonial morphology (Shape, swarming, odor on MacConkey) and microscopic investigation of bacterial cell morphology, the shape, cell organization, and kind of Gram-Stain reaction were determined. After staining, various biochemical tests are performed on every isolate.

Table 1 Biochemical tests of the *P. mirabilis* isolates.

(-) a negative result, (+) a positive result, (V) variable according to strains.

No.	**Biochemical test**	***p.mirabilis***
1	Oxidase	-
2	Catalase test	+
3	Indole Production	-
4	Urease Production	+
5	production of H2S	+
6	lactose Fermentation	-
7	Maltose Fermentation	-
8	Methyl red	+
9	Voges-Proskauer	-
10	Simmons'Citrate	v

The isolated bacteria were tested against eighteen antibiotics with different mechanism of action, and the study showed 75.78% of isolated *P. mirabillis* were resistant for antibiotics, 7.55% of isolated bacteria were get moderate response for action of antibiotics, and 16.67% were suceptible for antibiotics activity, also noted all isolated *P. mirabillis* were resistant for activity of AMC, AZM, NIT, and AM, also noted 96% of isolated were resistant for activity of both TMP and CTX, also the study showed not isolated *P. mirabillis* were sensitive for AMC, AZM, TE, CTX, and NIT as show in figur3 and table 2 .

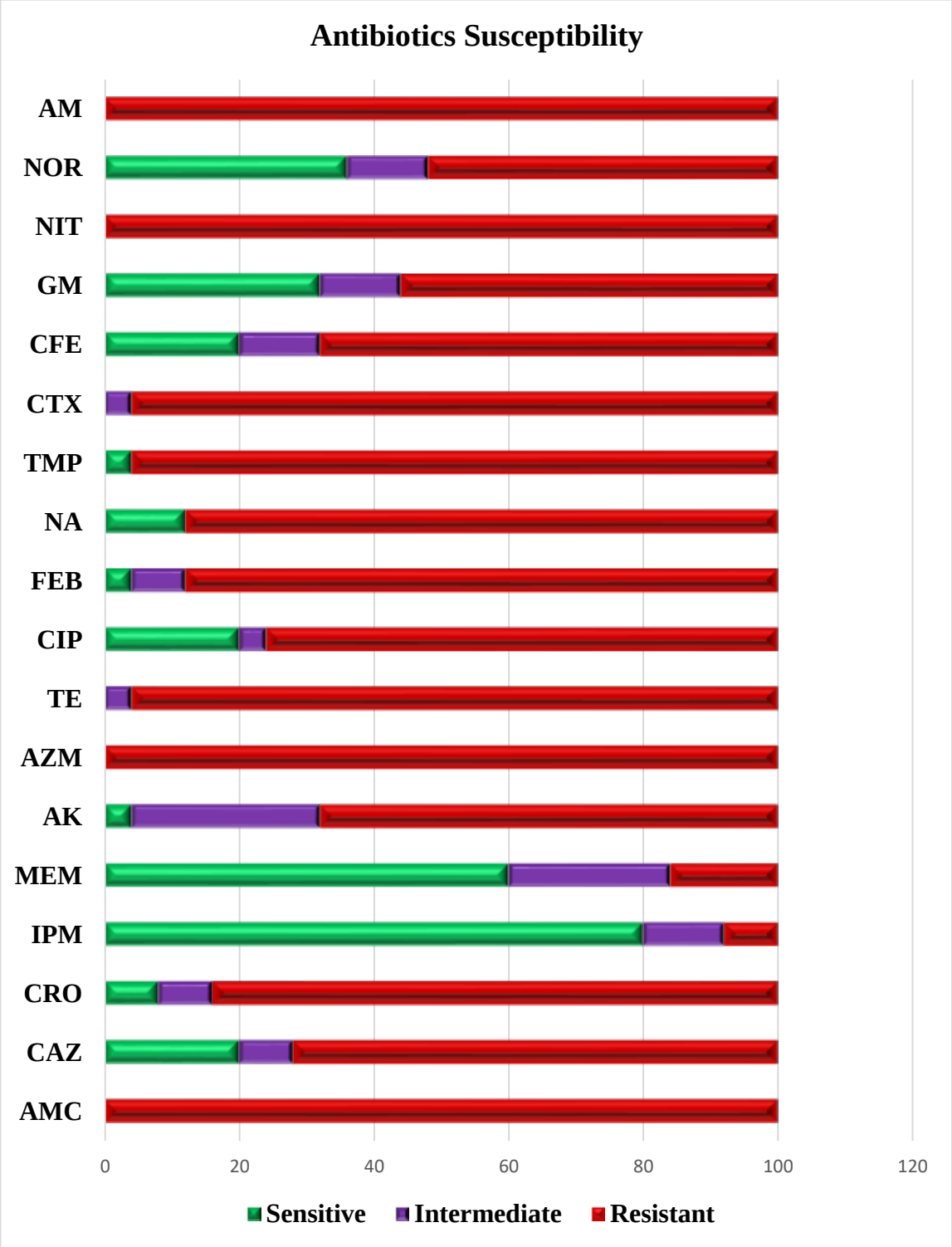

Figure 3: Antibiotics susceptibility of isolated *P. mirabillis*

Table 2: Antibiotics susceptibility of isolated *P. mirabilis.*

Antibiotics	**Sensitive**		**Intermediate**		**Resistant**	
	No.	**%**	**No.**	**%**	**No.**	**%**
AMC	0	0	0	0	25	100
CAZ	5	20	2	8	18	72
CRO	2	8	2	8	21	84
IPM	20	80	3	12	2	8
MEM	15	60	6	24	4	16
AK	1	4	7	28	17	68
AZM	0	0	0	0	25	100
TE	0	0	1	4	24	96
CIP	5	20	1	4	19	76
FEB	1	4	2	8	22	88
NA	3	12	0	0	22	88
TMP	1	4	0	0	24	96
CTX	0	0	1	4	24	96
CFE	5	20	3	12	17	68
GM	8	32	3	12	14	56
NIT	0	0	0	0	25	100
NOR	9	36	3	12	13	52
AM	0	0	0	0	25	100
Susceptibility %	**16.67**		**7.55**		**75.78**	
CalX^2=213.1	**TabX^2=48.96**		**DF= 34**	**p. value 0.072^{sig}**		

DISCUSSION

the prevalence rate of *P. mirabilis* was (13.88%) that slightly more when compared with findings of (Ram et al., 2019) who reported a prevalence rate of 10.7% in human urine samples and disagree with (Kareem et al., 2017)who reported a prevalence rate of *P.mirabilis* was (19.3%). Variation in the prevalence rate can be attributed to a variety of factors, including geographic region and antibiotic use (Ram et al., 2019) or it may be attributable to variations in sample size and the number of hospitals surveyed (Kamil & Jarjes, 2019).

The present study showed that there were no significant differences between males and females at getting the infection with *P. mirabilis* (P value 0.05). our results (68% for males) and (32% for females) converged with (Suhartono et al., 2022) who found that the pathogens were more frequently detected in men (70.24%) than women (28.92%), but, disagreed with (Abdelkreem et al., 2018), (Mirzaei et al., 2019) and (Owaied & Jabur, 2022) This is up to that the male patients predominance is on the base of the fact that males more susceptible to infection due to the fact that male exposure is greater as they are representing the majority of workforce , so they are exposed more to acquiring infectious diseases (Bahashwan & Shafey, 2013)and, the fact that the majority of the samples were taken from males with urinary catheters in intensive care wards.

The majority of the *P. mirabilis* strains isolated from our hospitals were resistant to the most of penicillins and cephalosporins that used in this study, which produced difficulties with the treatment of UTIs caused by *Proteus mirabilis*.The increasing prevalence of antibiotic resistance mechanisms, particularly beta lactamase and efflux pumps, makes treating UTIs more difficult (Foxman, 2010).

The β-lactam antibiotics are a class of bactericidal medicines whose chemical structure contains the β-lactam ring. These antibiotics are categorized as Penicillins, cephalosporins, monobactams, carbapenems, and penems (also called thiopenems), this classification is based on the molecular composition of the ring fused to the β- lactam pharmacophore unit, which produces a noncoplanar bicyclic scaffold. (Lima et al., 2020) All isolates show high resistance to penicillin group (ampicillin and amoxicillin- clavulanic acid).Were resistant (100%) to ampicillin that concent with(Al-shibly *et al*., 2017) and (Algburi et al., 2020) who found the resistant rate to ampicillin is (100%), but ,disagree with (Owaied, 2022), (Jawad & Al-ramahi, 2017) and, (Gomaa et al., 2019) who found the resistance rate to ampicillin(71.4 , 84.05 , 91.5) respectively. Our findings showed that the rate of resistance to (amoxicillin-clavulanic acid) was Absolute compatibility with (Al-shibly *et al*., 2017)and (Algburi et al., 2020) but dissent with (Mirzaei et al., 2022), (Owaied, 2022) and (Sokhn et al., 2020) who found the resistance rate (2.7 , 69 , 88) respectively . The results show that these antibiotics are being used inappropriately to treat bacterial infections (Algburi et al., 2020) Regarding extended-spectrum cephalosporins, ceftriaxone, cefotaxime, ceftazidime , cefixime, and cefepime substantially higher bacterial resistance (84, 96, 72, 68, 88) respectively was reported in this study .The result for Ceftriaxone was slightly agreed with (Owaied, 2022) from Thi-Qar province , (Algburi *et al*., 2020) and, (Rout et al., 2014) who demonstrated that (78.8%,90% ,90.3%) respectively of isolates were resistant. This study disagree with (Mirzaei et al., 2022),(Sokhn et al., 2020) and, (Kassim Ghaima et al., 2017b) their result was(10 , 95.8 , 58.8) respectively.

Our result of cefotaxime resistance was 96% this agree with (Algburi et al., 2020) that found the resistance rate to cefotaxime was (90%) but, the results of (FM et al.,2018), (Al-Shibly *et al*., 2017) and (Owaied, 2022) were (51.1% , 86% , 59.5%) differ with the study results .

The recent study revealed that the resistance to ceftazidime was 72 % that differ slightly with (Jawad & Al-ramahi, 2017)who found the resistance rate to ceftazidime was (66.66%), But contradicted with other studies by (Mirzaei *etal*., 2022), (Gomaa *et al*., 2019) and, (Kamil & Jarjes, 2019) (11.8 , 44.7, 97.8) respectively.

The study also reported a moderate resistance to cefixime (68%) this agree with (Kassim Ghaima *et al*., 2017) who found the cefixime resistance rate was (65.8%) but, contradicted with (Algburi *et al*., 2020)with (90%) resistance rate.

The study indicate the finding to cefepime resistance rate was corresponds with other studies such as (Owaied, 2022) and (Kamil & Jarjes, 2019) their results were(83.8% , 91%) respectively. But, contrast to previous investigations by (Rout et al., 2014), (Sokhn *etal*., 2020), (Gomaa *etal*., 2019) and (FM *etal*., 2018)their result were (67.7% , 96% , 72.3% , 53.2) respectively .

The most widely used antibiotics for treating a variety of diseases, including UTIs, are fluoroquinolones (FQs) (Nakano et al., 2019). Regarding the resistance to fluoroquinolones (ciprofloxacin 76%, norfloxacin 52%, nalidixic acid 88%). The resistance of ciprofloxacin disagree with the findings of (Wadee & Najm, 2021) , (Kamil & Jarjes, 2021) ,(Gomaa et al., 2019) and (Hammadi, 2023) their finding results were(100% , 91.4% , 53.2% , 38.9%) respectively and this not comparable with our result .

The study also revealed a high resistance to nalidixic acid (88%) compared to (Jawad & Al-ramahi, 2017), (Hassan, 2018), (Jamel *et al*., 2020) , (Hussein *et al*., 2020) and, (Alabi et al., 2017) they found the resistance rate of nalidixic acid (75.36%, 30%, 60%, 46%, 53.7%) respectively .

The outcomes of the current study showed a high resistance to norfloxacin (52%) compared to (Mirzaei et al., 2019), (Hussein et al., 2020) and (Jamel et al., 2020) who found the resistance rate to norfloxacin (13.6, 11.1, 8.4) These findings demonstrate the uncontrolled use of these antibiotics to treat bacterial infections (Algburi et al., 2020).

The aminoglycosides are commonly prescribed, broad-spectrum, bactericidal antibiotics for children, primarily for Gram-negative bacterial infections (Germovsek et al., 2016).

The recent study's findings demonstrated amikacin resistance (68%) approach the results of (Sokhn et al., 2020) who found (72%) of *P. mirabilis* isolates were resistant to Amikacin But contradicted with other studies by (Owaied, 2022), (FM et al., 2018), (Gomaa et al., 2019) and, (Al-shibly et al., 2017) their finding were(50% , 53.2% ,31.9% ,31.25%) respectively. While the resistance of *P. mirabilis* isolates to gentamicin (56%) this result agree with (Al-shibly et al., 2017) and (Gomaa et al., 2019) who found (54.86% , 53.2%)respectively, of *Proteus mirabilis* isolates were resistant to gentamicin . But disagree with (Hussein *et al*., 2020), (Hassan, 2018), (Jamel et al., 2020) and, (Al-Bassam & Al-Kazaz, 2013) their results were (20.6% ,65% , 60% ,50%) respectively .

The resistance to the carbapenems was shown by the resistance to imipenem and meropenem with percentage (8% ,16%) respectively, as a result of the infrequent use of imipenem and meropenem in our country, there is little increase in antibiotic resistance. Our finding imipenem resistance rate was conform with (FM et al., 2018), (Gomaa et al., 2019), (Algammal et al., 2021) and (Mirzaei et al., 2019) who found that (8.5% ,10.6% , 8.6% , 11.8%) respectively , of *Proteus mirabilis* isolates were resistant to imipenem. Our findings are in opposition to those of (Al-shibly et al., 2017), (Hammadi, 2023) and (Al-Bassam & Al-Kazaz, 2013) who found (18.75 %, 27.8 %, and 15 %) respectively.

meropenem resistance rate was in agreement with (Ibrahim, 2019) and (Al-shibly et al., 2017) reported that (20% and 15.62%) of *P. mirabilis* isolates subsequently were resistant to meropenem. These findings differ with some of the previous reports (Gomaa et al., 2019), (Owaied, 2022), (Algammal et al., 2021) and (Jawad & Al-ramahi, 2017) reported that (8.5% , 42.8% ,8.6% and 5.6%) of *P. mirabilis* isolates, respectively were resistant to meropenem.

In the recent study (100% ,96%) of *Proteus mirabilis* isolates were resistant to azithromycin and tetracycline respectively, this observation to azithromycin was in accordance with result of other study conducted by (AL-Jeelizy, 2022) who demonstrated that 90% of isolates were resistant to azithromycin but dissent with (Hassan, 2018) who found 18% of *P. mirabilis* isolates were resistant to azithromycin. The observation to tetracycline was in accordance with results of other studies conducted by (Gomaa et al., 2019) , (Jamel et al., 2020), (Kamil & Jarjes, 2021), (Talebi et al., 2023) , (FM et al., 2018) their results were(100%) and (Umar et al., 2016) who found (95%) of *Proteus mirabilis* isolates were resistant to tetracycline but diverge with (Jawad & Al-ramahi, 2017) ,(Raheem et al., 2017)and (AL-Jeelizy, 2022) their finding were (82.60% , 87.5% , 80%) respectively. likewise, in this study, result high resistance rate (96%) was reported against trimethoprim, the resistance rate was comparable with the study result with (Raheem et al., 2017) who show 100% of *Proteus mirabilis* isolates were resistant to trimethoprim while, this result dissent with(AL-Jeelizy, 2022), (Jawad & Al-ramahi, 2017) and (Hassan, 2018) who found (87.5% , 75.63% , 74%) of *Proteus mirabilis* isolates were resistant to trimethoprim .

The extra outer cytoplasmic membrane of Proteus isolates, which contains a lipid bilayer, lipoproteins, and lipopolysaccharides , may be responsible for their multidrug resistance. Resistance of Proteus to antibiotics was the result of selection for drug resistance, which has been linked to an increase in inappropriate antibiotic use. Iraq's use of antimicrobial agents is inconsistent (Al-Bassam & Al-Kazaz, 2013).

The existence of a single drug with activity against such a wide variety of resistances seems improbable. Responding to the challenges of Gram-negative resistance will require a multifaceted approach, including the use of current antimicrobial agents with caution, improved diagnostics (including the rapid detection of resistance) and, surveillance

better adherence to basic infection prevention measures, the development of new antibiotics, and research into non-antibiotic treatment and preventive strategies (Zowawi et al., 2015).

REFERENCES

1. Abdalnabi, A. (2019). *Molecular assessments of Proteus mirabilis virulence factors isolated from urinary tract infection patients*. *July*, 8–13. https://doi.org/10.31838/ijpr/2018.10.04.084
2. Abdelkreem, R. H., Abdelgadeir, L. M., & Elhassan, M. M. (2018). *Ciprofloxacin Susceptibility of Proteus Mirabilis Isolated From Sudanese Patients with Urinary Tract Infections*. *17*(4), 85–87. https://doi.org/10.9790/0853-1704118587
3. Al-Bassam, W. W., & Al-Kazaz, A.-K. (2013). The Isolation and Characterization of Proteus mirabilis from Different Clinical Samples Proteus mirabilis . *Journal of Biotechnology Research Center*, *7*(2), 24–30.
4. AL-Jeelizy, Z. (2022). *Molecular,Bacteriological,Phylogenetic tree and Biosynthesis Study of Nanoparticle of Proteus mirabilis from Urinary Tract Infection Patients in wasit province* (Issue October). https://doi.org/10.13140/RG.2.2.13645.72161
5. Al-shibly, M., Almousawi, A., & Dawood, N. (2017). Antimicrobial susceptibility and molecular characterization for some virulence factors of Proteus Mirabilis isolated from patients in Al-Qadisiyah Province/ Iraq. *Al-Qadisiyah Journal of Veterinary Medicine Sciences*, *16*(2), 1–7. https://doi.org/10.29079/vol16iss2art435
6. Alabi, O. S., Mendonça, N., Adeleke, O. E., & da Silva, G. J. (2017). Molecular screening of antibiotic-resistant determinants among multidrug-resistant clinical isolates of Proteus mirabilis from SouthWest Nigeria. *African Health Sciences*, *17*(2), 356–365. https://doi.org/10.4314/ahs.v17i2.9
7. Algammal, A. M., Hashem, H. R., Alfifi, K. J., Hetta, H. F., Sheraba, N. S., Ramadan, H., & El-Tarabili, R. M. (2021). atpD gene sequencing, multidrug resistance traits, virulence-determinants, and antimicrobial resistance genes of emerging XDR and MDR-Proteus mirabilis. *Scientific Reports*, *11*(1). https://doi.org/10.1038/s41598-021-88861-w
8. Algburi, A., Alazzawi, S. A., Al-ezzy, A. I. A., Weeks, R., Chistyakov, V., & Chikindas, M. L. (2020). *Potential Probiotics Bacillus subtilis KATMIRA1933 and Bacillus amyloliquefaciens B-1895 Co-Aggregate with Clinical Isolates of Proteus mirabilis and Prevent Biofilm Formation*.
9. Alqurashi, E., Elbanna, K., & Ahmad, I. (2022). *Antibiotic Resistance in Proteus mirabilis : Mechanism , Status , and Public Health Significance*. *16*(July), 1550–1561. https://doi.org/10.22207/JPAM.16.3.59
10. Armbruster, C. E., & Mobley, H. L. T. (2012). Merging mythology and morphology: The multifaceted lifestyle of Proteus mirabilis. *Nature Reviews Microbiology*, *10*(11), 743–754. https://doi.org/10.1038/nrmicro2890
11. Bahashwan, S. A., & Shafey, H. M. El. (2013). *ANTIMICROBIAL RESISTANCE PATTERNS OF PROTEUS ISOLATES FROM CLINICAL SPECIMENS*. *9*(27).
12. Barzegar, S., Arzanlou, M., Teimourpour, A., Esmaelizad, M., Yousefipour, M., MohammadShahi, J., & Teimourpour, R. (2022). Prevalence of the Integrons and ESBL Genes in Multidrug-Resistant Strains of Escherichia coli Isolated from Urinary Tract Infections, Ardabil, Iran. *Iranian Journal of Medical Microbiology*, *16*(1), 56–65. https://doi.org/10.30699/ijmm.16.1.56
13. CLSI. (2021). *M100 Performance Standards for Antimicrobiafile:///C:/Users/K/Downloads/Documents/2015_art_esprmartins1.pdfl*.
14. Conejo, A. D. E. L. C., Marti, L., Joyanes, P., Microbiol, C., Suppl, I., Horvat, R., Gen, A., & Am, M. (2001). *Evaluation of the VITEK 2 System for the Identification and Susceptibility Testing of Three Species of Nonfermenting Gram- Negative Rods Frequently Isolated from Clinical Samples*. *39*(9), 3247–3253. https://doi.org/10.1128/JCM.39.9.3247
15. Danilo de Oliveira, W., Lopes Barboza, M. G., Faustino, G., Yamanaka Inagaki, W. T., Sanches, M. S., Takayama Kobayashi, R. K., Vespero, E. C., & Dejato Rocha, S. P. (2021). Virulence, resistance and clonality of Proteus mirabilis isolated from patients with community-acquired urinary tract infection (CA-UTI) in Brazil. *Microbial Pathogenesis*, *152*(November). https://doi.org/10.1016/j.micpath.2020.104642
16. Filipiak, A., Chrapek, M., Literacka, E., Wawszczak, M., Głuszek, S., Majchrzak, M., Wróbel, G., Łysek-Gładysińska, M., Gniadkowski, M., & Adamus-Białek, W. (2020). Pathogenic Factors Correlate With Antimicrobial Resistance Among Clinical Proteus mirabilis Strains. *Frontiers in Microbiology*, *11*. https://doi.org/10.3389/fmicb.2020.579389
17. FM, S., HK, A., SE, G., & HA, A. (2018). *Antimicrobial resistance of clinical Proteus mirabilis isolated from different sources* (Vol. 27).
18. Foxman, B. (2010). rEvIEWS The epidemiology of urinary tract infection. *Nature Publishing Group*, *7*(12),

653–660. https://doi.org/10.1038/nrurol.2010.190

19. Germovsek, E., Barker, C. I., & Sharland, M. (2016). *What do I need to know about aminoglycoside antibiotics ?* 1–5. https://doi.org/10.1136/archdischild-2015-309069
20. Gomaa, S., Serry, F., Abdellatif, H., & Abbas, H. (2019). Elimination of multidrug-resistant Proteus mirabilis biofilms using bacteriophages. *Archives of Virology*, *164*(9), 2265–2275. https://doi.org/10.1007/s00705-019-04305-x
21. Govindan, R., Vijayan, R., Murugan, A., & MARIKANI, K. (2014). *AN ANTIMICROBIAL ACTIVITY OF THE BROWN SEAWEED PADINA TETRASTROMATICA EXTRACT IN DIFFERENT CONCENTRATION AGAINST International Journal of Advanced Life Sciences (IJALS) Isolation and identification of biofilm forming uropathogens from urinary tract infe*. *April*.
22. Hammadi, K. (2023). *Isolation and identification of Proteus mirabilis bacteria from urinary tract infections in humans and sheep*. *March 2022*.
23. Hassan, A. (2018). *Molecular and bacteriological pathogenicity assessment of proteus mirabilis in urinary tract infections*.
24. Hassoon, S., Mohamed, W., & Mohsen, A. (2021). *Isolation and Identification of Proteus bacteria from mouth to ethanol: aqueous extracts of pomegranate peel and Lantana cammara leaves.*
25. Hussein, E. I., Al-Batayneh, K., Masadeh, M. M., Dahadhah, F. W., Al Zoubi, M. S., Aljabali, A. A., & Alzoubi, K. H. (2020). Assessment of Pathogenic Potential, Virulent Genes Profile, and Antibiotic Susceptibility of Proteus mirabilis from Urinary Tract Infection. *International Journal of Microbiology*, *2020*. https://doi.org/10.1155/2020/1231807
26. Ibrahim, H. K. (2019). Screening and sensitivity of non-lactose fermenting bacteria to antibiotics by Vitek-2 compact system. *University of Thi-Qar Journal Of Science (UTsci)*, *7*(1), 1–5.
27. Jamel, A. N., Allami, R. H., & Hamza, S. J. (2020). Molecular study of rpob gene in proteus mirabilis isolated from urinary tract infection from different hospitals in Baghdad. *Plant Archives*, *20*(September 2017), 2379–2383.
28. Jawad, N., & Al-ramahi, S. (2017). *Diagnosis of Proteus mirabilis using PCR technique and determining their sensitivity to some antibiotics.*
29. Kamil, T. D., & Jarjes, S. F. (2019). Isolation, Identification, and Antibiotics Susceptibility Determination of Proteus Species Obtained from Various Clinical Specimens in Erbil City. *Polytechnic Journal*, *9*(2), 86–92. https://doi.org/10.25156/ptj.v9n2y2019.pp86-92
30. Kamil, T. D., & Jarjes, S. F. (2021). Evaluations Of Antibacterial Efficiency of Nife 2 o 4 Nanoparticles Alone and in Combination With Some Antibiotics Against Multidrug Resistant Proteus Mirabilis. *Polytechnic Journal*, *11*(2), 95–99. https://doi.org/10.25156/ptj.v11n2y2021.pp95-99
31. Kareem, A., Alatrash, M., & Al-yasseen, A. K. (2017). *DETECTION OF URER AND UREC AMONG PROTEUS MIRABILIS*. *10*(8), 8–11.
32. Kassim Ghaima, K., Hamid, H. H., & Hassan, S. F. (2017a). Biofilm formation, Antibiotic resistance and Detection of mannose-resistant Proteus-like (MR/P) fimbriae genes in Proteus mirabilis isolated from UTI Detection of virulence genes in non-typhoidal Salmonella (NTS) isolated from stool samples and chickens. . In *Article in International Journal of ChemTech Research*. https://www.researchgate.net/publication/317951771
33. Kassim Ghaima, K., Hamid, H. H., & Hassan, S. F. (2017b). Detection of virulence genes in non-typhoidal Salmonella (NTS) isolated from stool samples and chickens. View project Biofilm formation, Antibiotic resistance and Detection of mannose-resistant Proteus-like (MR/P) fimbriae genes in Proteus mirabilis isola. In *Article in International Journal of ChemTech Research*. https://www.researchgate.net/publication/317951771
34. Kwiecinska-Pirog, J., Skowron, K., Bartczak, W., & Gospodarek-Komkowska, E. (2016). The ciprofloxacin impact on biofilm formation by Proteus mirabilis and P. Vulgaris strains. *Jundishapur Journal of Microbiology*, *9*(4). https://doi.org/10.5812/jjm.32656
35. Kwiecińska-Piróg, J., Skowron, K., Zniszczol, K., & Gospodarek, E. (2013). The assessment of Proteus mirabilis susceptibility to ceftazidime and ciprofloxacin and the impact of these antibiotics at subinhibitory concentrations on Proteus mirabilis biofilms. *BioMed Research International*, *2013*. https://doi.org/10.1155/2013/930876
36. Lima, L. M., Nascimento, B., Barbosa, G., & Eliezer, J. (2020). β -Lactam antibiotics: an overview from a medicinal chemistry perspective. *European Journal of Medicinal Chemistry*, 112829. https://doi.org/10.1016/j.ejmech.2020.112829
37. Literacka, E., Schneider, A., Urbanowicz, P., Herda, M., Hryniewicz, W., Izdebski, R., Baraniak, A., & Gniadkowski, M. (2019). *Proteus mirabilis Producing the OXA-58 Carbapenemase in Poland*. *March*, 1–2.
38. Mirzaei, A., Habibi, M., Bouzari, S., & Asadi, M. R. (2022). *Characterization of Antibiotic-Susceptibility*

Patterns , Virulence Factor Profiles and Clonal Relatedness in Proteus mirabilis Isolates from Patients with Urinary Tract Infection in Iran Characterization of Antibiotic-Susceptibility Patterns , Virulence F. https://doi.org/10.2147/IDR.S230303

39. Mirzaei, A., Habibi, M., Bouzari, S., & Karam, M. R. A. (2019). Characterization of antibiotic-susceptibility patterns, virulence factor profiles and clonal relatedness in proteus mirabilis isolates from patients with urinary tract infection in Iran. *Infection and Drug Resistance*, *12*, 3967–3979. https://doi.org/10.2147/IDR.S230303
40. Nakano, R., Nakano, A., Abe, M., Nagano, N., Asahara, M., Furukawa, T., Ono, Y., Yano, H., & Okamoto, R. (2019). Prevalence and mechanism of fluoroquinolone resistance in clinical isolates of Proteus mirabilis in Japan. *Heliyon*, *5*(3), e01291. https://doi.org/10.1016/j.heliyon.2019.e01291
41. O'Brien, V. P., Hannan, T. J., Nielsen, H. V., & Hultgren, S. J. (2016). Drug and Vaccine Development for the Treatment and Prevention of Urinary Tract Infections. *Microbiology Spectrum*, *4*(1). https://doi.org/10.1128/microbiolspec.uti-0013-2012
42. O'Hara et al., 2000. (2000). *Classification of Proteus vulgaris biogroup 3 with recognition of Proteus hauseri sp. nov., nom. rev. and unnamed Proteus genomospecies 4, 5 and 6*. 1869–1875.
43. Owaied, H. Q. (2022). Antibiotic susceptibility of P . mirabilis isolated from clinical samples in Thi- Qar province. *University of Thi-Qar Journal of Science (UTJsci), 2*.
44. Owaied, H. Q., & Jabur, S. G. (2022). *Molecular Research of The Difference between Chromosome and Plasmid at Harboring Some Virulence and Antibiotic Resistance Genes in P . Mirabilis Collection of Samples*. *89*(October), 7950–7957.
45. Raheem, A. A., Sajjad, A., & Hussein, K. (2017). *Epidemiological study of the bacterium Proteus mirabilis isolated from clinical cases and investigate the molecular basis of resistance to antibiotics*.
46. Ram, P., Rao, V., Rao, S., Subramanyam, K. V, & Srinivas, K. (2019). Prevalence and virulence gene profiles of Proteus mirabilis isolated from animal, human and water samples in Krishna District, Andhra Pradesh, India. *~ 19 ~ The Pharma Innovation Journal*, *8*(6), 19–23. www.thepharmajournal.com
47. Rout, S., Sc, M., Dubey, D., Sc, M., Panigrahy, R., & D, M. (2014). Surveillance of extended-spectrum b - lactamase producing bacteria in an Indian teaching hospital. *Journal of Taibah University Medical Sciences*, *9*(4), 274–281. https://doi.org/10.1016/j.jtumed.2014.01.009
48. Sokhn, E. S., Salami, A., El Roz, A., Salloum, L., Bahmad, H. F., & Ghssein, G. (2020). Antimicrobial Susceptibilities and Laboratory Profiles of Escherichia coli, Klebsiella pneumoniae, and Proteus mirabilis Isolates as Agents of Urinary Tract Infection in Lebanon: Paving the Way for Better Diagnostics. *Medical Sciences (Basel, Switzerland)*, *8*(3), 1–11. https://doi.org/10.3390/medsci8030032
49. Suhartono, S., Mahdani, W., & Khalizazia, K. (2022). Prevalence and Antibiotic Susceptibility of Proteus mirabilis Isolated from Clinical Specimens in the Zainoel Abidin General Hospital, Banda Aceh, Indonesia. *Open Access Macedonian Journal of Medical Sciences*, *10*(A), 1532–1537. https://doi.org/10.3889/oamjms.2022.10695
50. Talebi, A., Momtaz, H., & Tajbakhsh, E. (2023). *Frequency distribution of virulence factors and antibiotic resistance genes in uropathogenic Proteus species isolated from clinical samples*. *January*, 1–8.
51. Tille, P. M. (2014). *Bailey & Scott's Microbiology Diagnostic 13 edition*.
52. Umar, M., Yaya, A. ., Yusuf, G., Tafinta, I. ., Aliko, A. ., Jobbi, D. Y., & Lawal, G. (2016). *Biochemical characterization and antimicrobial susceptibility trends of Proteus mirabilis isolated from patients suspected with urinary tract infections attending Sickbay Hospital, Zaria, Kaduna, Nigeria*. *4*(2), 1–8.
53. Wadee, S., & Najm, R. S. (2021). *Evaluations Of Antibacterial Efficiency of Nife 2 o 4 Nanoparticles Alone and in Combination With Some Antibiotics Against Multidrug Resistant Proteus Mirabilis*. *January 2022*.
54. Yuan, F., Huang, Z., Yang, T., Wang, G., Li, P., Yang, B., & Li, J. (2021). Pathogenesis of Proteus mirabilis in Catheter-Associated Urinary Tract Infections. In *Urologia Internationalis* (Vol. 105, Issues 5–6, pp. 354–361). S. Karger AG. https://doi.org/10.1159/000514097
55. Zafar, U., Taj, M., Hussain, A., Hassani, I., & Samreen, Z. (2019). Proteus mirabilis as a pathogenic organism. *International Journal of Biosciences (IJB)*, *14*(03), 443–450. https://doi.org/10.12692/ijb/14.3.443-450
56. Zowawi, H. M., Harris, P. N. A., Roberts, M. J., Tambyah, P. A., Schembri, M. A., Pezzani, M. D., Williamson, D. A., & Paterson, D. L. (2015). The emerging threat of multidrug-resistant Gram-negative bacteria in urology. *NATURE REVIEWS | UROLOGY*, 1–15. https://doi.org/10.1038/nrurol.2015.199