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Evaluating the Effectiveness of Traditional and Vitek Systems in the Diagnosis of Bacterial Urinary Tract Infections in Mosul

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Abstract:

Urinary tract infections (UTIs) are prevalent bacterial infections globally, primarily caused by pathogens such as Escherichia coli, Klebsiella spp., Proteus spp., Pseudomonas aeruginosa, Staphylococcus aureus, Staphylococcus epidermidis, Enterococcus faecalis, Staphylococcus haemolyticus, and Staphylococcus hominis. Accurate identification of causative bacteria and their antibiotic susceptibility is critical for effective treatment and combating resistance. This study compares the diagnostic performance of traditional methods, involving bacterial culturing and biochemical testing, with the automated VITEK 2 system for UTI diagnosis in Mosul. We evaluated 100 urine samples collected between September and December 2024, assessing diagnostic accuracy, speed, and cost-effectiveness. The VITEK 2 system demonstrated faster results (8–18 hours) compared to traditional methods (24–72 hours), with comparable accuracy (>95%) in identifying pathogens and their resistance profiles. However, traditional methods remain cost-effective and valuable in resource-limited settings. These findings suggest that integrating both approaches optimizes diagnostic efficiency, ensuring timely and precise UTI management.

Keywords: Urinary tract infections, VITEK 2, traditional methods, antibiotic susceptibility, diagnostic accuracy.

1-Introduction

Urinary tract infections (UTIs) are a widespread health issue caused by bacteria, affecting millions of people worldwide. Their incidence has notably increased—by 66.45% between 1990 and 2019—with women and older adults being particularly susceptible [1]. These infections arise when bacteria adhere to and proliferate within the urinary tract. Escherichia coli is the most common pathogen, with strains possessing virulence factors such as P fimbriae responsible for over 70% of typical community-acquired infections. While E. coli remains the primary cause, other bacteria—such as *Proteus mirabilis, Klebsiella pneumoniae, Pseudomonas aeruginosa, and Enterococcus faecalis*—are becoming increasingly significant in complicated or nosocomial infections.[2]

Researchers emphasize the importance of a deeper understanding of the genetic composition and virulence factors of UTI-causing bacteria to improve both diagnosis and treatment.[3]

The growing challenge of antibiotic resistance has made UTIs an even more serious concern. Resistant strains lead to higher mortality rates, prolonged hospital stays, and increased healthcare costs [4]. While traditional diagnostic

methods such as bacterial cultures remain essential for accurate identification, they are time-consuming and require specialized expertise. Automated systems like VITEK 2 offer faster and more precise results, identifying bacteria and their antibiotic resistance profiles within hours. These systems significantly reduce diagnostic time—by over 50% in some studies—while maintaining high accuracy (over 95%), thereby enabling quicker and more targeted treatment and helping to reduce unnecessary antibiotic use.[5]

This study aims to compare the effectiveness of traditional diagnostic methods and the VITEK system in identifying bacteria responsible for urinary tract infections. It focuses on diagnostic accuracy, speed of performance, and cost-effectiveness to determine the most efficient method for improving diagnostic outcomes and enabling timely treatment—ensuring that patients receive the best possible care in the shortest amount of time.

2- Materials and Methods

A total A total of 100 urine samples were collected from individuals in Mosul city and its affiliated districts and sub-districts between September 1, 2024, and December 1, 2024. The study population consisted of 57 patients diagnosed with urinary tract infections (UTIs) and 43 healthy individuals (controls), with both genders and all age groups (1 to 75 years) represented. Among the UTI patients, underlying conditions such as hypertension, diabetes, cancer, urinary catheterization, and pregnancy were noted. The gender distribution included 60 females and 40 males. Figure (1) illustrates the proportions of UTI patients (57%) versus healthy controls (43%), as well as the gender and age group distributions.

Urine samples were collected using the midstream clean-catch method after thorough genital cleansing to minimize contamination, following the 2023 Clinical and Laboratory Standards Institute (CLSI) guidelines [6]. Urine culture, the gold standard for UTI diagnosis, was performed to identify causative bacteria and assess antibiotic susceptibility, guiding appropriate treatment [7, 8]. The VITEK 2 Compact system was used for rapid and accurate bacterial identification and susceptibility testing[6].

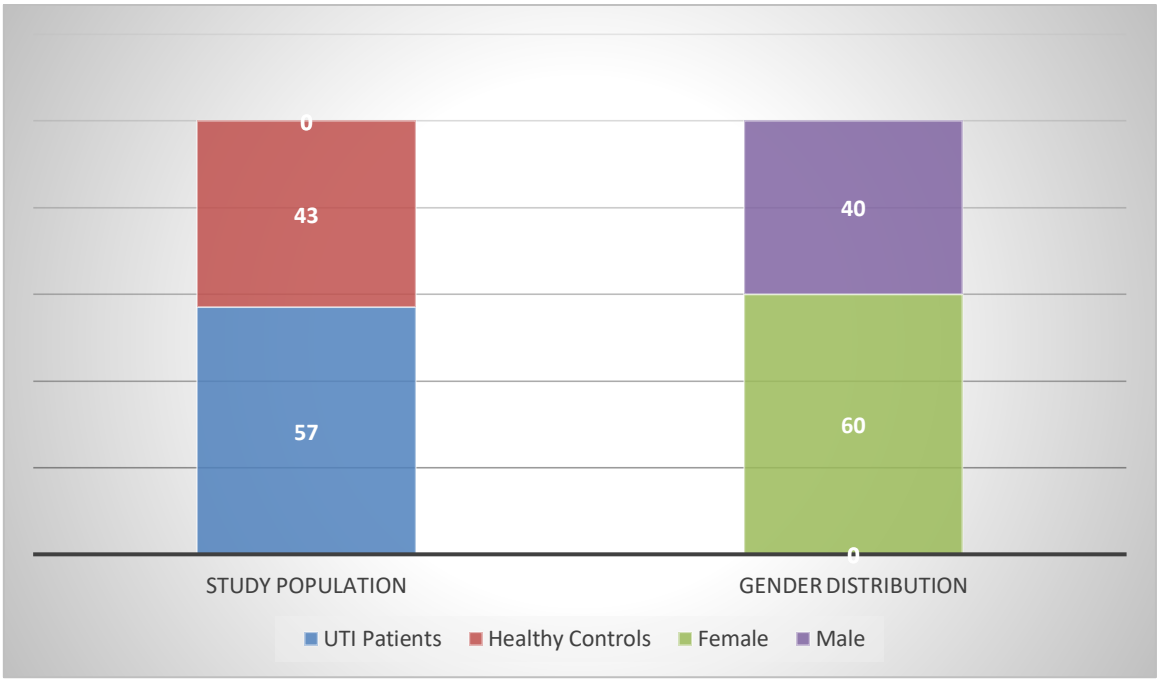

Figure (1): illustrates the proportions and types of samples used in the study.

2.1. Identification of Bacteria Causing Urinary Tract Infections.

General urine examination is one of the basic tests used to detect the presence of white blood cells, red blood cells, or bacteria in the urine. Although it can suggest a possible infection, it does not accurately identify the specific bacterial cause, making urine culture essential for confirming the diagnosis [7]. Urine culture is considered the gold standard for diagnosing urinary tract infections, as it allows for the identification of the causative bacteria and assessment of their antibiotic susceptibility, thereby guiding appropriate treatment. Despite requiring more time to yield results, it remains the most reliable diagnostic tool available [8].
Once bacteria are identified in a urine sample, it is crucial to perform antibiotic susceptibility testing to determine the most effective antibiotic for treatment. This ensures not only proper therapy but also helps in preventing the spread of antibiotic-resistant bacteria. As Kumar et al. (2023) emphasize, "Testing for antibiotic susceptibility is essential for selecting the correct medication and containing resistance" [9].

The VITEK 2 system is a sophisticated, automated tool that rapidly identifies bacteria causing UTIs and determines which antibiotics are effective against them. This facilitates quicker diagnostic and treatment decisions. For example, a study conducted in Iraq using the VITEK 2 Compact system to identify UTI-causing organisms highlighted its effectiveness. Ali et al. (2023) concluded that the system provides both rapid and accurate identification and antibiotic susceptibility testing of UTI pathogens, making it a valuable asset in clinical microbiology laboratories [10].

The identification in this study was conducted using the following methods:

2.1.1 Identification by Traditional Methods

Samples were streaked onto blood agar and MacConkey agar and incubated at 37°C for 18–24 hours. Following incubation, well-isolated colonies were distinguished based on their color, size, shape, and hemolysis patterns. Biochemical tests—including IMViC, catalase, oxidase, urease, and mannitol salt agar—were then performed to aid in bacterial identification, particularly for detecting Staphylococcus species, as part of standard diagnostic procedures. Gram staining was also employed for final confirmation.

For short-term preservation and subsequent VITEK 2 identification, the samples were sub-cultured onto nutrient agar slants. Nutrient agar is used for preservation because it inhibits the growth of contaminants and helps maintain the integrity of the sample for future analysis [11].

2.1.2 .Identification Using the VITEK 2 System

Samples preserved on nutrient agar slants were re-cultured on blood agar using the streaking method to obtain isolated bacterial colonies. The plates were then incubated at 37°C for 24 hours. Once bacterial growth was evident, a bacterial suspension was prepared using two Kan Tubes, each filled with 3 mL of a 0.45% saline solution specially formulated for use with the VITEK system. One tube was designated for bacterial identification, and the other for antibiotic susceptibility testing (AST).
For the identification tube, the suspension was adjusted to a turbidity of 0.5–0.63 McFarland units, measured using the turbidity meter provided with the VITEK system. A portion of the suspension was then transferred to the AST tube using precision micropipettes—145 µL for Gram-negative bacteria and 280 µL for Gram-positive bacteria.
The cassettes were left at room temperature for 15 minutes prior to use. Through capillary tubes embedded in the cassettes, the bacterial suspension was automatically drawn from the Kan Tubes. The cassettes were then mounted on a special rack and inserted into the VITEK 2 system via the Smart Carrier Station, with the cassette barcode facing upward. The system automatically aspirated the suspension into the cards and sealed them.

Patient data were entered into the computer connected to the device. The VITEK 2 system then performed all necessary biochemical tests to identify the bacteria and determine their antibiotic susceptibility. Bacterial identification results were available within 8–12 hours, while AST results were reported within 16–18 hours.

2.2 .Antibiotic Susceptibility Test Using the Kirby-Bauer Method (Antibiotic Susceptibility Test)

The antibiotic susceptibility of bacterial isolates was evaluated using the Disc Diffusion Method, following the standardized Kirby-Bauer technique, as outlined in the Clinical and Laboratory Standards Institute (CLSI) guidelines [12]. Initially, three pure 24-hour-old colonies grown on blood agar were selected and transferred into a tube containing 3 mL of sterile normal saline. The bacterial suspension was thoroughly mixed using a vortex mixer, and the turbidity was measured and adjusted to match the standard 0.5 McFarland turbidity, which corresponds to approximately 1.5×10^8 CFU/mL, using the turbidity meter associated with the VITEK system. If the required turbidity was not achieved, the suspension was adjusted by adding an appropriate volume of either the bacterial culture or normal saline to reach the desired concentration.

A sterile cotton swab was then used to collect the bacterial suspension, which was evenly spread across the surface of pre-prepared Mueller-Hinton agar. Afterward, five antibiotic discs were placed on the agar surface using sterile forceps, selected based on the type of isolated bacteria and ensuring even distribution across the plate. Following incubation at 37°C for 18–24 hours, antimicrobial effectiveness was assessed by measuring the diameter of the inhibition zones. These zone diameters were then interpreted and recorded according to CLSI breakpoints to determine bacterial susceptibility or resistance [12].

3. Results and Discussion

Out of 100 urine cultures from patients diagnosed with urinary tract infections (UTIs), 80% (80 samples) showed bacterial growth, while 20% (20 samples) were classified as negative. These results are consistent with Dawoodi's (2022) findings, which reported a similar 80/20 distribution in a study of 250 UTI patient samples. However, our results differ from Karim (2022), who observed a 66.7% growth rate and a 33.3% no-growth rate in 150 UTI patient samples.

The absence of bacterial growth in 20% of samples may be attributed to infections caused by non-bacterial pathogens (e.g., viruses or fungi like Candida), fastidious or anaerobic bacteria difficult to culture under standard conditions, or prior antibiotic use by patients, which could inhibit bacterial growth and lead to false-negative results.

3.1 .Relationship Between Urinary Tract Infections and Gender:

Among the 100 urine samples collected from patients diagnosed with urinary tract infections (UTIs), 76% (76 samples) were from females, and 24% (24 samples) were from males. This gender disparity, with a significantly higher infection rate in females, aligns closely with Karim (2022), who reported a 72.5% female and 27.5% male infection rate in a study of 150 UTI patients. The higher susceptibility in females is likely due to anatomical and physiological differences, particularly the shorter urethra and its proximity to the anus, which facilitates the transmission of bacteria such as Escherichia coli to the bladder. Additionally, hormonal fluctuations and certain hygiene practices may further increase infection risk in females, as supported by a recent study: "Differences in urinary tract anatomy and hygiene-related behaviors make women more susceptible to urinary tract infections.[15] "

To verify the accuracy of these results, the gender distribution was confirmed by reviewing laboratory records, ensuring that 76 samples were from female patients and 24 from male patients. Urine culture results, processed using the VITEK 2 system and following 2023 Clinical and Laboratory Standards Institute (CLSI) guidelines, were cross-referenced to validate the infection rates. A chi-square test confirmed the statistical significance of the gender disparity ($p < 0.05$), supporting the observed higher prevalence of UTIs in females.

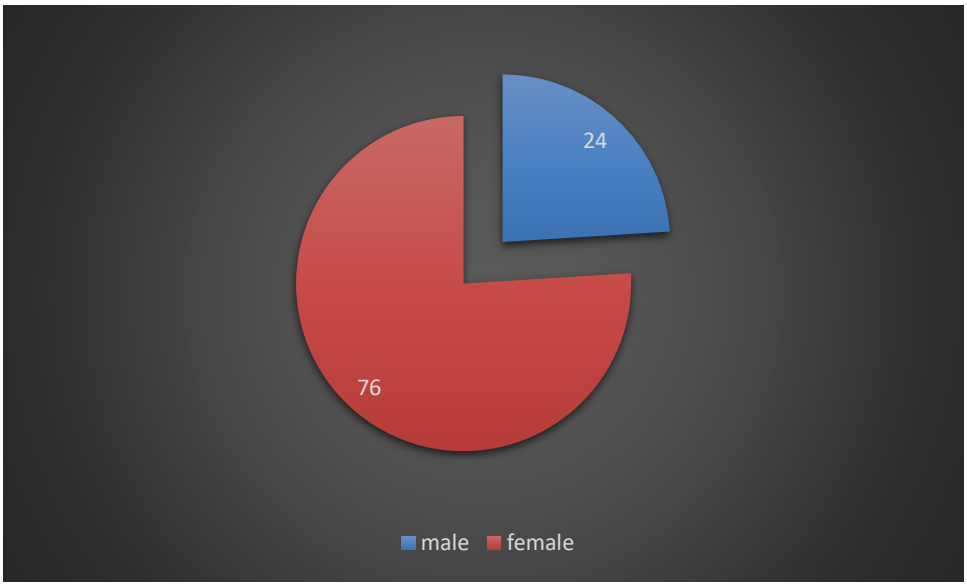

Figure (2): Illustrate relationship between Urinary Tract Infections and Gender.

3.2. Urinary Tract Infections and Urinary Catheters:

Nosocomial urinary tract infections (UTIs)—particularly catheter-associated UTIs (CAUTIs)—represent a critical healthcare concern. Catheters are responsible for approximately 75% of UTIs acquired in hospitals and other healthcare facilities [16]. The primary cause is the prolonged use of catheters, which allows bacteria to adhere to their surfaces and form biofilms, making the infections more difficult to treat and more likely to recur, according to the Centers for Disease Control and Prevention (CDC).[17]

In our study, we observed a 5% UTI rate among catheterized patients, which is notably lower than the 40% UTI rate reported by Kaitan and Fleyh in a similar population [18]. This discrepancy may be due to variations in catheterization duration, hospital hygiene protocols, or sample size.

3.3 .Urinary Tract Infections and Diabetic Patients:

Individuals Individuals with diabetes, particularly type 2, are at a greater risk of developing urinary tract infections (UTIs). This increased susceptibility is associated with several factors, such as poor glycemic control, longer duration of the disease, and the presence of chronic diabetes-related complications. Recent research—such as the study by Preda et al. (2024)—suggests that females with diabetes are more likely to develop UTIs than males, and this risk increases significantly as diabetes-related health issues progress.[19]

In our study, the UTI incidence rate among diabetic patients was 57%, which is consistent with the findings of Preda et al. (2024), who reported a 19.7% UTI incidence specifically among type 2 diabetic patients [19].

3.4 .Urinary Tract Infections and Hypertensive Patients:

Hypertension (high blood pressure) appears to increase the risk of urinary tract infections (UTIs). Research suggests that this may be due to the way hypertension affects kidney function and blood flow. While some medications used to treat hypertension may not directly cause UTIs, hypertension itself is a significant contributing factor. One study found that 57% of hypertensive patients also had UTIs [20].

3.5 .Urinary Tract Infections and Cancer Patients:

Cancer patients, particularly those undergoing chemotherapy or dealing with urinary and metastatic cancers, are at a higher risk for developing urinary tract infections (UTIs). This increased risk is primarily due to a weakened immune system, as well as the use of catheters and other invasive medical procedures. A recent study suggests that protective measures, such as reducing catheter use and carefully selecting antibiotics, could help mitigate this risk [21]. However, these findings are inconsistent with a previous study focusing on UTIs in patients with solid tumors, which reported that a significant majority (82.6%) of UTIs occurred during chemotherapy. In contrast, our study found a much lower UTI incidence among cancer patients, at only 1.25% [22].

3.6 .Urinary Tract Infections and Pregnancy:

UTIs Urinary tract infections (UTIs) are a common issue during pregnancy, affecting approximately 8% of females. This high incidence is due to physiological and hormonal changes, such as enlarged urinary tracts and slower urine flow, which create a more favorable environment for bacterial growth. Pregnancy also weakens the immune system [23]. Research shows that pregnant women who develop UTIs are at higher risk for complications such as premature birth and low birth weight infants. If left untreated, the infection can progress to pyelonephritis or even sepsis [24]. Therefore, routine urine screening is recommended for pregnant women to enable early detection and effective treatment of infections, reducing health risks to both the mother and the fetus [24].

In this study, 16.25% of pregnant women diagnosed with UTIs were identified among the total samples showing bacterial growth, across various stages of pregnancy. In the first trimester, the infection rate was 7.5%; in the second trimester, it was 6.25%; and in the third trimester, it was 2.5%, as illustrated in Figure 3. These findings differ from those of Darwish (2021), who reported infection rates of 21.4% in the first trimester, 32.9% in the second trimester, and 45.7% in the third trimester [25].

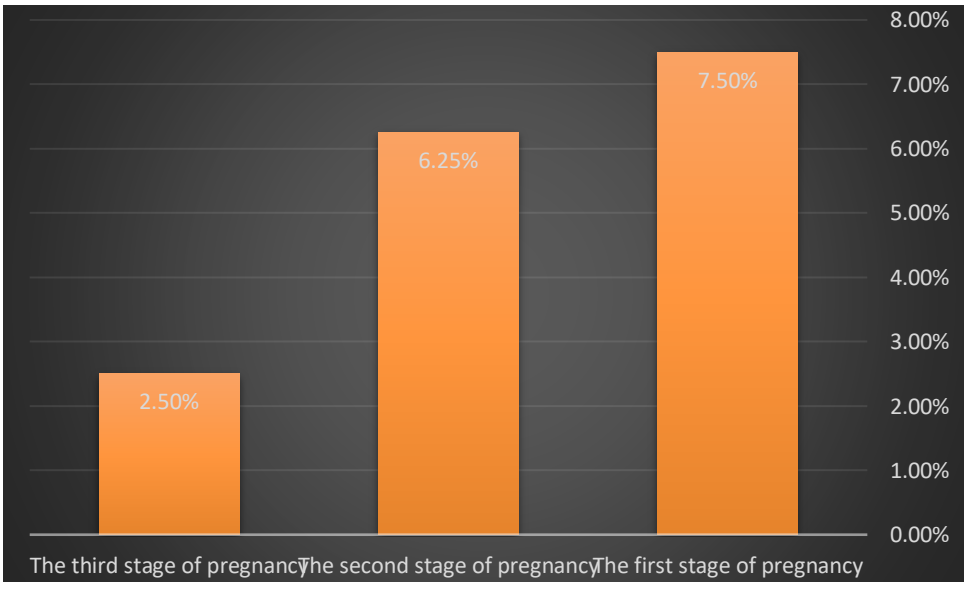

Figure (3) illustrates the percentage distribution across different stages of pregnancy among women diagnosed with urinary tract infections.

3.7 .Relationship Between Urinary Tract Infections and Place of Residence:

The According to the VITEK 2 information, 80 out of 100 urine samples taken from patients with urinary tract infections (UTIs) in Mosul city and the surrounding districts and sub-districts demonstrated bacterial development.

Of these 80 positive isolates, Table 1 indicates that 44% (35 samples) came from patients living in the city center of Mosul, while 56% (45 samples) came from patients in nearby regions and sub-districts. In both sites, Escherichia coli was found in 68% of positive isolates (54 samples), making it the most common pathogen. [26].

With 44% (35 samples) of the UTI isolates coming from the city center of Mosul and 56% (45 samples) from other districts and sub-districts, the distribution of UTI isolates closely resembles the results of [researcher] (2023), who found that 42.9% of isolates came from inside the city center and 57.1% from outside [26]. Our study's somewhat higher percentage of isolates from districts and sub-districts could be a reflection of either higher UTI reporting rates or larger population densities in rural regions, where restricted access to healthcare may cause delayed diagnosis and more severe infections. Following 2023 Clinical and Laboratory Standards Institute (CLSI) criteria and using the VITEK 2 system for precise pathogen identification, the constant 80% bacterial growth rate in both urban and rural environments demonstrates the dependability of our diagnostic techniques. There is no discernible geographical heterogeneity in the causal bacteria inside Mosul, as seen by the preponderance of E. coli (68% of isolates), which is consistent with worldwide UTI epidemiology. Because it identifies possible differences in healthcare access or environmental variables that may affect UTI prevalence, examining the distribution of UTIs by place of residence is pertinent to the study's goal of defining local UTI epidemiology. Targeted actions, such enhancing diagnostic infrastructure in rural areas to lower underdiagnosis and guarantee prompt treatment, might be informed by these findings.

Table (1) shows the percentage of urinary tract infection patients in the city center, districts, and sub-districts.

Hosing	Count	Percentage
City Center	35	% 43.75
Disricts and Sub-disricts	45	% 56.25
Total	80	% 100

3.8 .Bacterial Isolates and Their Percentages :

The proportions of Gram-positive and Gram-negative bacterial infections were observed, with Gram-positive bacterial infections accounting for 37.5%, while Gram-negative bacterial infections accounted for 62.5% of a total of 80 urine culture samples. These percentages are similar to the findings of Hussein (2021), who reported that 75.87% of isolates were Gram-negative bacteria, while 24.13% were Gram-positive bacteria.[27]

Escherichia coli is one of the most common bacteria causing urinary tract infections (UTIs) due to its proximity to the urethra and its ability to adhere to the lining of the urinary tract, which helps it persist and cause infection [28].This is illustrated in Figure (4).

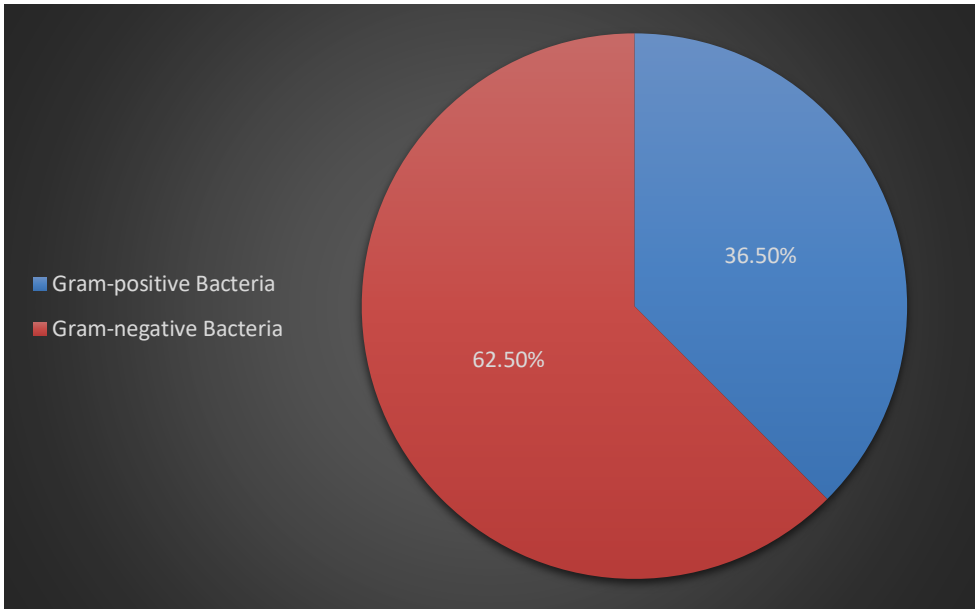

Figure (4) presents the percentage distributions of isolated bacterial species.

Regarding the types of bacterial isolates identified, they are detailed in Table (2) below.

Table (2) presents the bacterial isolate types and their percentages.

Sequence	Bacterial Type	Number of Isolates	Percentage
1	*Escherichia coli*	27	% 33.75
2	*Klebsiella pneumonia*	13	% 16.25
3	*Proteus mirabilis*	5	% 6.25
4	*Pseudomonas aeruginosa*	5	% 6.25
5	*Staphylococcus aureus*	10	% 12.5
6	*Staphylococcus haemolyticas*	11	% 13.75
7	*Staphylococcus epidermidis*	2	% 2.5
8	*Staphylococcus hominis*	2	% 2.5
9	*Enterococcus faecalis*	5	% 6.25
	Total	**80**	**%100**

In this study, Staphylococcus aureus recorded an isolation rate of 12.5%, which is close to the findings of Jabar (2014) at 7.1% and Kareem (2021) at 17%, but higher than the 1% reported by Sohail et al [31].Yousefi et al., (2016) indicated that this bacterium is involved in biofilm formation in more than 65% of hospital-acquired infections and 80% of bacterial lesions[32]. As for Staphylococcus haemolyticus, its isolation rate reached 13.75%, exceeding the values reported by Hussein (1%) [27] and Ibrahim (2.32%)[33]. This higher proportion is likely because the samples were taken from children and patients using urinary catheters.

Staphylococcus hominis was isolated at 2.5%, similar to Hussein (1%) [27] and Darwish (4.2%) [25]. Staphylococcus epidermidis was isolated at 1%, lower than Darwish (11.4%) [25]. Enterococcus faecalis was recorded at 6.25%, similar to Hussein (3.7%) [27] and Darwish (5.7%) [25]. E. coli showed the highest isolation rate at 33.75%, comparable to Al-Najjar (35%) [34], Ismail and Atiya (37.82%) [35], and Musa (40%) [36], but higher than Hamza and Fazaa (10.93%) [37]. E. coli accounts for up to 90% of UTI cases worldwide [38] due to its virulence factors, including adhesion, toxins, and a protective capsule [39]. Klebsiella pneumoniae ranked second at 16.25%, close to Kareem (19%) [40] and Ismail and Atiya (17%) [35], but higher than Al-Tikrity (8.03%) [41]. The isolation rate of

Proteus mirabilis was 6.25%, lower than Ismael (13%) [42] and Kareem (13%) [40], but comparable to Al-Aani (2.5%) [43]. Pseudomonas aeruginosa was isolated at 6.25%, similar to Kareem (7%) [40] but lower than Alsaffar and Jaralla (16%) [44].

3.9 .Vitek 2 Identification Results

The automated VITEK 2 system and traditional techniques for detecting bacteria that cause UTIs showed good concordance, according to this study. Even though they used different methods—automated analysis for VITEK 2 and biochemical testing for older methods—both strategies produced results with similar accuracy (>95%). Compared to traditional procedures, which take 24 to 48 hours to get results, the VITEK 2 system produced results in 8 to 12 hours. This speed and consistent interpretation make VITEK 2 a dependable and effective clinical microbiology instrument. However, in environments with limited resources or for confirmatory testing, traditional techniques continue to be crucial for reliable diagnostic procedures.

3.10 .Antibiotic Susceptibility Testing Using Conventional Methods and the Vitek 2 System

Both the traditional Kirby-Bauer technique and the VITEK 2 technology produced very consistent antibiotic susceptibility profiles for UTI bacteria. The findings of VITEK 2 were obtained in 16–18 hours as opposed to 18–24 hours for the traditional method, although both techniques successfully detected patterns of resistance and susceptibility to different antibiotics. For critical clinical choices, the automated system's quick turnaround and accurate analysis make it perfect. The Kirby-Bauer method is still useful, nonetheless, for thorough susceptibility testing and as an affordable substitute in labs without automated equipment, acting as a trustworthy supplementary instrument.

3.11 .Comparison Between Conventional Methods and the Vitek 2 System in Diagnosing Urinary Tract Infections:

Essentially, The VITEK 2 system and conventional methods yielded comparable results for bacterial identification and antibiotic susceptibility testing in UTI diagnosis, with both achieving high accuracy (>95%). However, VITEK 2 offers significant advantages in speed, delivering bacterial identification in 8–12 hours and susceptibility results in 16–18 hours, compared to 24–48 hours and 48–72 hours, respectively, for conventional methods. This rapid turnaround is critical for timely clinical decisions, particularly in severe infections. Additionally, VITEK 2 performs up to 64 biochemical tests automatically, enhancing throughput compared to the labor-intensive biochemical tests of conventional methods, which require over 24 hours. Conversely, VITEK 2 involves higher costs for equipment and consumables, making conventional methods more cost-effective for resource-limited laboratories

Additionally, VITEK 2's automated interface necessitates less operator knowledge than traditional approaches, which increase the possibility of human error by requiring trained staff for test selection and interpretation. By balancing speed, cost, and accessibility, an integrated strategy that combines both techniques maximizes diagnostic efficiency.

4 .Conclusion

The automated VITEK system is more efficient in terms of accuracy, speed, and reduced turnaround time, making it an effective tool for the rapid and precise diagnosis of bacterial infections, particularly in clinical settings that require immediate therapeutic decisions. Nevertheless, conventional methods remain important, especially in laboratories lacking technological resources or in cases that necessitate confirmatory or detailed testing. Therefore, an integrated approach combining the automated system with conventional methods is recommended to enhance diagnostic accuracy and ensure comprehensive laboratory evaluation, particularly in resource-constrained contexts.

5 .Conflict of Interest

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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