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Original Article

Morbidity and mortality associated with ESBL *Klebsiella pneumoniae* infection in different administration routes in albino rats

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Abstract

Klebsiella pneumoniae is a non-motile, encapsulated, environmental gram-negative bacterium. Once the bacteria have infiltrated the body, they can display substantial degrees of resistance to drugs and virulence. Extended Spectrum Beta-Lactamases (ESBLs) are most typically seen in *K. pneumoniae*. The objective of this study was to investigate the morbidity and mortality associated with ESBL *K. pneumoniae* infection in different albino rat administration route groups. Four cohorts of albino rats were acquired and categorized into the subsequent groups: inhalation, oral administration via food, water, and control group. Each group was infected independently and the isolate administration lasted 6 days. The clinical diagnosis revealed the presence of *K. pneumoniae* infection. Within one day of infection, the inhalation group exhibited the initial clinical signs and symptoms, such as red eyes, coughing, and closed eyelids. Subsequently, the infection was verified through the process of sample cultivation. Additionally, blood clinical findings, including blood tests such as CBC, lipid profile, CRP, and kidney and liver function tests, further supported the confirmation of the infection. The *K. pneumoniae* isolates had a severe influence on the CBC, liver, and kidney functioning causing elevated liver enzymes, and high RBC levels with impaired kidney functioning. Due to *K. pneumonia's* affinity for lung tissue, it had the greatest impact in the albino rat inhalation group.

Keywords: Blood parameters, Clinical signs, COVID-19, *Klebsiella pneumonia,* Lung infection

1. Introduction

K. pneumoniae is a non-motile, gram-negative bacterium. It is a rod-shaped bacterium that pertains to the *Enterobacteriaceae* family. A polysaccharide capsule is essential for *K. pneumonia's* capacity to cause disease and to evade engulfment by immune cells through a process known as phagocytosis [1]. *K. pneumoniae* can exist as a commensal organism in several environments, such as soil, water, plants, insect species, birds, and animals. It is frequently present in the oral and dermal cavities, respiratory and urogenital systems, as well as the intestines of both humans and animals [2]. It is a component of the indigenous microorganisms that inhabit the oral and gastrointestinal tracts of humans. *K. pneumoniae* is the predominant and medically important pathogenic species among *Klebsiella* bacteria [3]. This bacterium has the ability to create biofilms at multiple locations throughout the body [4]. *K. pneumoniae* infections can be disseminated through the consumption of food or drink that has been contaminated and are commonly linked to illnesses acquired in the community or through person-to-person or animal-to-person transmission in healthcare settings [5], *K. pneumoniae* is a notable human pathogen that is commonly linked to hospital-acquired infections, especially in individuals with weakened immune systems [6], It accounts for 33% of Gram-negative bacterial infections in healthcare facilities [7]. In addition to sepsis, pneumonia, urinary tract infections, infections of the circulation, wounds or infections at the surgical site, meningitis, and hepatic abscesses, it has the potential to set off a wide variety of other ailments as well [8]. Humans are the primary reservoir for *K. pneumoniae.* In the general population, the organism is found in feces in approximately 5% to 38% of cases, while its presence in the nasopharynx ranges from 1% to 6% [9]. The SENTRY Antimicrobial Surveillance Program conducted a comprehensive analysis of data from 1997 to 2016, revealing that *K. pneumoniae* ranks as the third particularly prevalent source of bloodstream infections worldwide, after *Staphylococcus aureus* and *Escherichia coli* [10]. *K. pneumoniae* possesses an extensive accessory genome consisting of plasmids and chromosomal gene loci. These genetic elements play a vital role in deciding the fate of the pathogen [11], The strains are commonly referred to as opportunistic, hypervirulent (hyKp), or multidrug-resis-

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tant (MDR) [12]. There is an increasing number of reports indicating the isolation of *K. pneumoniae* from different sources, and many of these isolates show features of being resistant to multiple drugs (MDR) [13]. *K. pneumoniae* is categorized as an ESKAPE pathogen, which refers to a collection of opportunistic bacteria that are predominantly accountable for causing healthcare-associated infections (HAI) that are resistant to several drugs and have clinical significance [14]. *K. pneumoniae* has been revealed to possess over 100 distinct antibiotic-resistance genes [15], It is currently acknowledged as a major contributor to antimicrobial resistance through the production of extended-spectrum beta-lactamases (ESBLs) and carbapenemases. The World Health Organization (WHO) has classified it as one of the most pressing diseases worldwide, necessitating the development of advanced antibiotics and innovative control techniques [16]. The treatment of *Enterobacteriaceae* infections commonly relies on β-lactam medicines, which are the most frequently used antibiotics. However, this approach has inadvertently accelerated the development of bacterial resistance [17]. Beta-lactamase production is a particularly prominent approach to beta-lactam antibiotic resistance. The prevalence of resistance due to Extended-Spectrum Beta-Lactamases (ESBLs) has increased in medical practice [18]. ESBLs are a group of β-lactamase enzymes that break down and render ineffective a broad spectrum of β-lactam antibiotics, such as first-, second-, and third-generation cephalosporins and monobactams [19]. Plasmid-expressed enzymes catalyze the hydrolysis of β-lactam bonds present in antibiotics such as penicillin, cephalosporins, and aztreonam. Clavulanic acid inhibits their action. The presence of many altering enzymes on a single plasmid allows for the emergence of resistance to different classes of antibiotics, including fluoroquinolones, aminoglycosides, tetracyclines, and trimethoprim-sulfamethoxazole [18]. The WHO regards carbapenem-resistant Enterobacterales as highly significant pathogens. Carbapenem-resistant *K. pneumoniae* (CRKP) is the bacterial species that is most commonly found among carbapenem-resistant Enterobacterales [20]. Carbapenem-resistance coding genes typically occur on mobile genetic components such as plasmids or transposons, which facilitate the dissemination of strains resistant to drugs [21]. Carbapenemase-generating enzymes are the primary mechanisms that lead to the development of CRKP resistance [22]. Given the growing occurrence of multidrug resistance, it is imperative to devise novel approaches for managing and averting MDR *K. pneumoniae* infection in both humans and animals. Immunization is an efficacious supplementary approach to avoid communicable diseases. At present, there are no available vaccines for *K. pneumoniae* infection. As a result, the creation of vaccinations for *K. pneumoniae* has become a high-ranking concern in many countries [23]. The global health community faces a significant threat due to the emergence of antimicrobial resistance, particularly the production of *K. pneumoniae* carbapenemases (KPC) and cefotaxime (CTX-M) enzymes, as well as the rapid dissemination of *K. pneumoniae* ESBL producers. Regardless of the implementation of local and national guidelines and advancements in innovative therapeutic approaches, this threat persists [24].

2. Materials and Methods

2.1. Bacterial isolate

The bacteria used in our study was *K. pneumoniae* isolated from the sputum of mortal infected women with COVID-19. *K. pneumoniae* was able to produce extended-spectrum β-lactamase (ESBL). The bacteria isolated were obtained from nutrient agar slant which was preserved for further investigational studies, after obtaining the isolates were rejuvenated and proliferated in nutrient broth and then incubated for 24 hours at 37˚C. The next day, yielded bacteria were adjusted with 0.5 McFarland to dilute to 1.2 log8 to 2.4 log8 CFU/ml as infectivity dose**.**

2.2. Animal model

A total of thirty-two female albino red-eyed rats, aged between 6-8 months and weighing approximately 150-200g, were acquired from the animal house at Cihan University. The rats were maintained in a controlled environment with a consistent dark/light cycle and a temperature range of 20-25˚C. All animals underwent a 24-hour fasting period prior to the trial.

2.3. Induction of *Pneumonia* in animal models

The albino rats were randomly randomized to four groups: the control group (n=8), which received only normal saline and was kept in a safe environment; the urinary tract infection group (n=8), which had *K. pneumoniae* mixed with their water; the gastrointestinal group (n=8), which had *K. pneumoniae* mixed with their food; and the inhalation group (n=8), which was exposed to *K. pneumoniae* through swab. The optimal infectious dose was standardized according to previous studies [25-27]. The operations in this study were conducted under the aseptic principle. The dose of bacteria for infection ranged from 0.8 log8 to 2.4 log8 CFU/ml for respiratory tract infection. After the upper airway of the swab inhalation rat group was exposed, the nasal cavities of the rats were inoculated and smeared with 0.2 ml of the isolate. The food and water infectious groups were treated with 1/10 of the bacterial suspension and the dose was increased gradually. The process continued for an entire week before dissection.

2.4. Confirming the infection

The presence of infection in rats was verified using physiological, fecal, and urine analysis.

2.4.1. Clinical signs

The rat's infection was verified within 24 hours based on clinical signs such as debility, inflammation, respiratory distress, and narrowed eyes.

2.4.2. Fecal and urine examination

MacConkey agar was prepared and utilized. Fecal and urine samples were harvested from rats of GIT and UTI groups. The urine specimens were directly cultivated on the MacConkey agar plates while the fecal specimens were homogenized first and diluted 10 folds with distilled water, then cultured on the media to confirm the infection.

2.4.3. Nasopharyngeal swab examination

The specimens were obtained by employing swabs to swipe the nasal/oral canals of rats in the inhalation group. These specimens were then placed on MacConkey agar plates for cultivation. Following the collection of the

samples and their cultivation in a sterile environment, they were placed in an incubator at a temperature of 37˚C for 24 hours.

2.4.4. Blood examination

After 6 days of infection, blood samples were collected through cardiac puncture. The blood was drawn to perform CBC test, and another sample was centrifuged to obtain serum for the following tests: Lipid profile, Kidney function, Liver function, and CRP level.

2.5. Statistical analysis

Significant variations in the morbidity and fatality rates associated with ESBL *K. pneumoniae* infections among the different delivery route groups were shown by statistical analysis using ANOVA. Compared to 10% in the oral group and 0% in the control group ($p<0.05$), the inhalation group saw a 30% mortality rate and a considerably greater incidence of severe clinical symptoms ($p<0.01$). Additionally, the inhalation group's liver enzyme levels were significantly greater than those of the other groups ($p<0.01$), indicating a significant impact on organ function. These results highlight how important the exposure route is in determining the course of an infection.

3. Results

3.1. Clinical diagnosis

Depending on clinical signs, the infection was first detected in the inhalation rat group where the signs of infection generally appeared after 1-2 days of the infection, while the food group was the second group to show infection signs, with less extent appearance of signs on water mixed bacteria group.

3.2. Culturing and gram staining diagnosis

After culturing swabs, fecal, and urine samples on MacConkey agar, the result revealed mucoid viscous pink colonies indicating *Klebsiella spp.* characteristics (Fig. 1). After that, Gram staining was conducted to confirm *Klebsiella's* presence (Fig. 2).

3.3. Blood examination

3.3.1. CBC analysis

The CBC results indicate that the inhalation group of rats was the most affected depending on the elevated WBC level, especially lymphocytes while rats in the food group came in second place compared to the water-drinking group (Table 1). The changes in the RBC level and its component as well as Platelet with its related component are shown in Fig. 3 and 4, respectively.

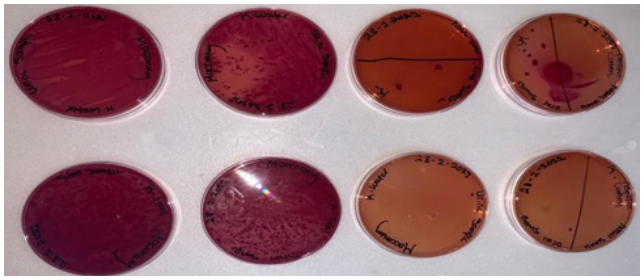

Fig. 1. Sample cultures of *K. pneumoniae* from different rat groups, showing the formation of mucoid, viscous pink colonies on MacConkey agar plates.

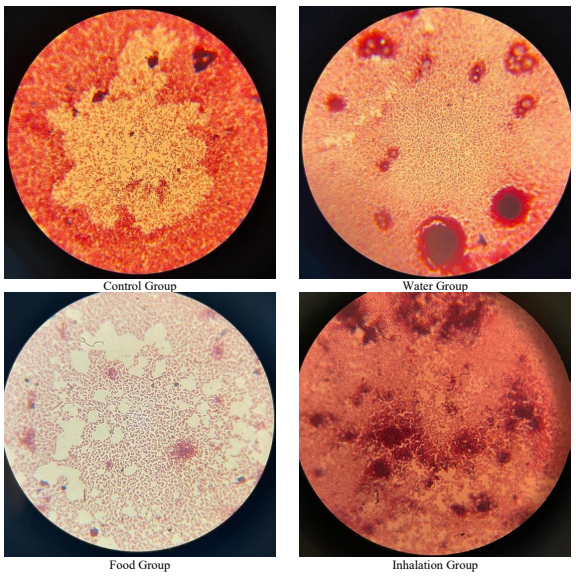

Fig. 2. Demonstrates Gram staining of *K. pneumoniae* samples of different rat groups, the presence of a capsule around the rod-shaped bacilli confirms that the sample was *K. pneumoniae*.

Table 1. The inhalation group exhibited the most noteworthy increase in lymphocyte levels, followed by the food group and ultimately the water-drinking group. Elevated RBC, MHCH, and platelet counts were observed in all groups. Nevertheless, there was a substantial decrease in the MCV, MCH, RDW, and MPV levels.

Mean of Groups	RBC (×1012/L)	HGB (g/dl)	HCT (%)	MCV (Fl)	MCH (pg)	MCHC (g/dL)	RDW (%)	RDWa (FL)
Control 1	H 6.67	13.7	36.2	L 54.1	L 20.5	37.9	12.9	L 26.5
Control 2	H 5.96	12.4	L 32.3	L 54.2	L 20.9	H 38.6	14.4	39.2
Control 3	H 6.71	13.6	35.4	L 52.8	L 20.2	H 38.3	14.2	L 27.0
W1	H 6.74	14.2	36.9	L 54.7	L 21.1	H 38.6	11.9	L 25.1
W2	H 6.16	13	L 34.0	L 55.2	L 21.1	H 38.3	12.1	L 25.9
W3	H 5.85	12.5	L 33.8	L 57.8	L 21.4	37	14.6	31.3
S1	H 6.38	13.1	L 33.6	L 52.6	L 20.5	H 38.9	14.6	L 27.4
S2	H 6.08	13.1	35.2	L 57.9	L 21.6	37.7	13.7	30.8
S3	H 6.43	14.1	38.5	L 59.9	L 21.9	36.5	12.2	L 29.1
F1	H 6.71	13.6	35.8	L 53.4	L 20.3	38	12.4	L 25.2
F2	H 5.88	12	L 31.4	L 53.3	L 20.4	H 38.2	11.5	L 23.7
F3	H 7.4	14.6	37.7	L 50.4	L 19.5	H 38.8	12.8	L 23.3

Continuation of Table 1. The inhalation group exhibited the most noteworthy increase in lymphocyte levels, followed by the food group and ultimately the water-drinking group. Elevated RBC, MHCH, and platelet counts were observed in all groups. Nevertheless, there was a substantial decrease in the MCV, MCH, RDW, and MPV levels.

Mean of Groups	WBC (×109/L)	LYM (%)	LYM (×109/L)	MID (%)	MID (×109/L)	GRA (%)	GRAN (×109/L)	PLT (×109/L)	MPV (FL)	PDW (FL)	PCT (%)	P-LCR (%)
Control 1	6.6	42.5	2.8	8.2	0.5	49.3	3.3	H 577	L 5.6	8	0.32	2.3
Control 2	8.8	45.6	4.1	9.7	0.8	44.7	3.9	H 557	L 5.7	8.1	0.32	2.2
Control 3	8.8	H 62.3	H 5.5	7.6	0.7	L 30.1	2.6	H 639	L 6.0	8.3	0.38	2.7
W1	8.2	37.8	3.1	7.4	0.6	54.8	4.5	H 667	L 6.2	8.5	0.41	4.4
W2	7.1	47.9	3.4	7.2	0.6	44.9	3.1	H 499	L 5.8	8.1	0.29	2.6
W3	5.6	H 68.8	3.8	5.4	0.4	L 25.8	1.4	H 444	L 5.5	7.9	0.24	2.4
S1	H 14.5	38	H 5.5	7.7	1.1	54.3	7.9	H 689	L 6.2	8.5	0.42	4.1
S2	8.8	H 50.5	4.4	6.5	0.6	43	3.8	H 544	L 6.0	8.3	0.32	3.6
S3	H 11.4	H 66.8	H 7.6	H 21.7	H 2.5	L 11.5	1.3	314	L 6.3	8.7	0.2	5.5
F1	6.9	H 59.2	4.1	6.4	0.4	L 34.4	2.4	H 460	L 6.2	8.5	0.28	5.1
F2	6.2	H 62.4	3.9	6.3	0.4	L 1.3	1.9	H 464	L 5.4	7.7	0.25	1.9
F3	7.2	H 52.6	3.8	H 26.6	H 1.9	L 20.8	1.5	H 535	L 6.2	8.5	0.33	4

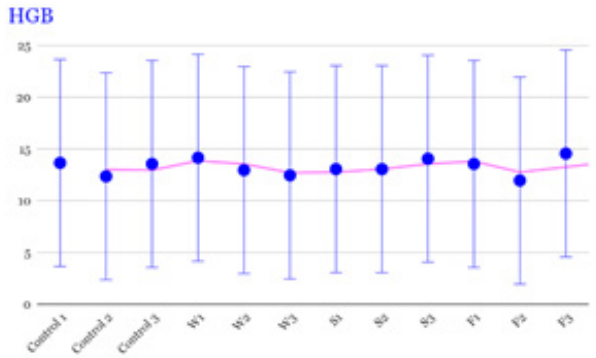

Fig. 3. Demonstrates that there wasn't a notable variation in hemoglobin levels among the groups.

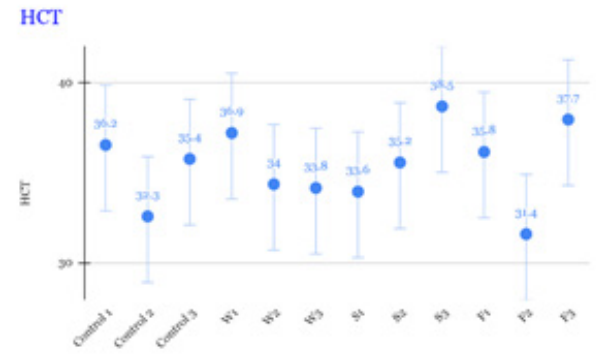

Fig. 4. Shows that the hematocrit level was comparatively lower in the water group compared to the other groups.

As shown in Fig. 5, there is a notable reduction in the levels of MCH and MCH, particularly in the food group, along with an elevation of MCHC levels in both the food and water groups.

Figure 6 demonstrates a substantial elevation in RBC levels among all groups, highlighting the impact of the treatment on red blood cell counts.

3.3.2. C-reactive protein

The level of C-reactive protein was assessed in blood specimens to monitor the progression of bacteremia. As shown in Fig. 7, the level of CRP is increased especially in the inhalation group.

3.3.3. Kidney function and liver function tests

To observe the influence of *K. pneumoniae* on kidney function, creatinine and urea levels were estimated. The kidney function tests demonstrated slightly high creatinine with a very high urea level (Fig. 8 and 9). The impact of *K. pneumonia's* infection on the liver was evidenced using liver function testing, which revealed a significant alteration in liver enzymes as a consequence of the infection (Table 2).

3.3.4. Lipid profile test

Determining levels of lipid profile in different rat

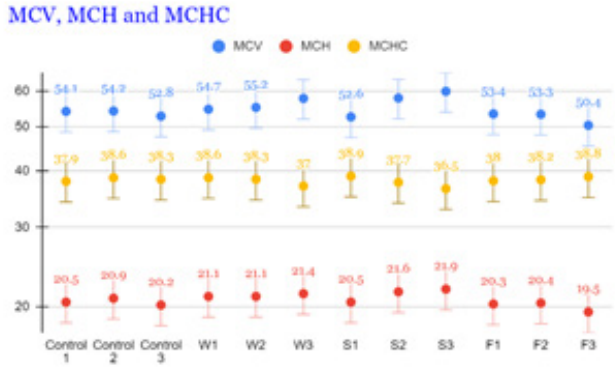

Fig. 5. Illustrates a notable reduction in the levels of MCH and MCH, particularly in the food group. Furthermore, MCHC level elevation in both food and water groups.

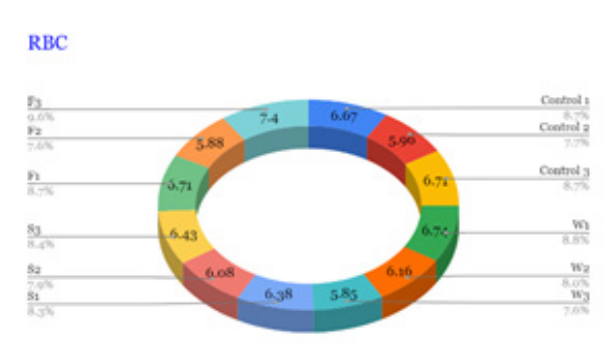

Fig. 6. Demonstrates a substantial elevation in the RBC levels among all groups.

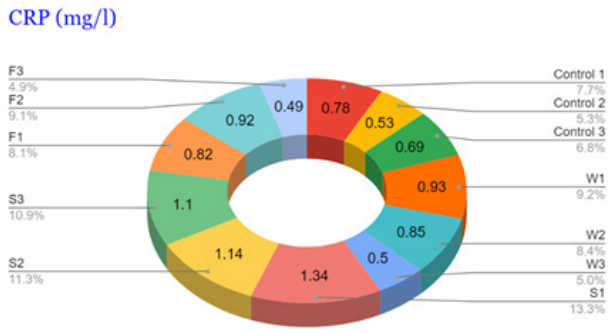

Fig. 7. Shows the C-reactive protein level from blood samples of different rat groups, the inhalation group demonstrated the most significant increase in C-reactive protein level, followed by the water group and, ultimately, the food group.

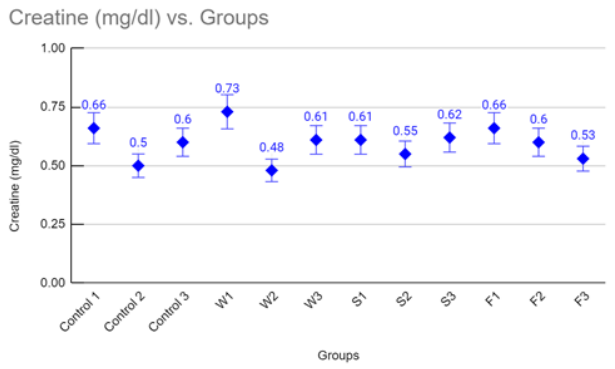

Fig. 8. Shows the Creatine levels from blood samples of different rat groups, demonstrating only a minor variation in creatinine levels between the groups.

groups infected with *K. pneumoniae,* showed that infection caused by *Klebsiella* didn't have a noticeable effect on the lipid profile except for the food group in which hypertriglyceridemia was present (Table 3).

3.3.5. Histological results

Histological examinations of different rat groups were performed to determine *K. pneumonia's* effect on the tissues, which demonstrated the presence of inflammatory cells infiltrating the tissues, along with alveolar congestion and pulmonary alveolar edema (Fig.10).

4. Discussion

K. pneumoniae causes a variety of illnesses depending on the colonization site, including gastrointestinal infec-

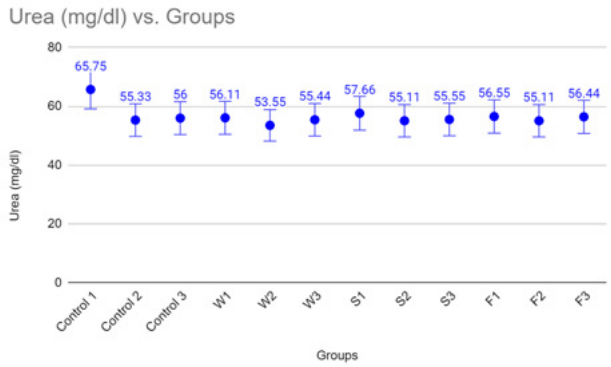

Fig. 9. Shows the Urea levels from blood samples of different rat groups, revealing highly elevated urea levels among the groups.

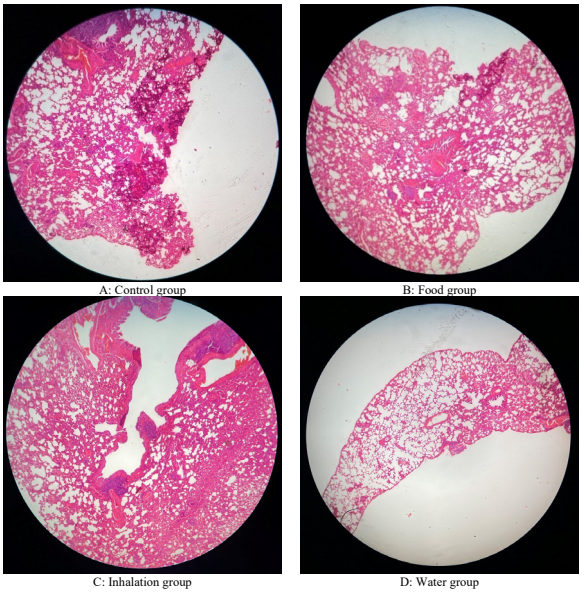

Fig. 10. Shows the histological examinations of the different rat groups. In comparison to the control group, both the inhalation and water-drinking groups exhibited moderate inflammatory cell infiltration which included lymphocytes, plasma cells and neutrophils. Additionally, there was mild alveolar damage associated with haemorrhage, vascular congestion and pulmonary alveolar edema. While the food group exhibited only a mild inflammatory cell infiltration.

Table 2. Shows the Liver Function Test of different rat groups. The liver enzyme levels were most significantly elevated in the inhalation group, followed by the food group, and ultimately the water group, as a consequence of an infection.

Groups	ALP (IU/L)	GPT (IU/L)	GOT (IU/L)	TSB (mg/dl)
Control 1	374.47	103.5	123.95	0.1
Control 2	267.37	77.35	103.7.3	0.04
Control 3	283.96	83.36	122.54	1.91
W1	387.87	63.13	144.37	0.31
W2	180.55	42.8	132.68	0.39
W3	254.67	53.21	150.34	0.59
S1	290.24	46.55	105.11	0.66
S2	262.68	61.21	88.85	2.29
S3	250.2	89.79	156.01	1.02
F1	228.29	57.76	138.25	1.78
F2	211.91	48.11	115.96	0.63
F3	199.36	201.87	413.18	0.76

Table 3. Shows the Lipid Profile Test of different rat groups. An elevation in the triglyceride level was observed only in the food group among all other groups.

Groups	VLDL (mg/dl)	LDL (mg/dl)	HDL (mg/dl)	Chol (mg/dl)	TG (mg/dl)
Control 1	14.13	12.82	67.8	69.11	70.65
Control 2	5.65	7.42	80.77	79.13	28.27
Control 3	13.98	15	75.11	74.01	69.9
W1	1.95	3.45	39.6	45.05	9.78
W2	5.46	9.64	39.9	55.09	27.3
W3	10.77	13	50.9	48.02	53.86
S1	6.88	29.52	17.6	54.01	34.42
S2	11.39	27.41	17.2	56.99	12.84
S3	3.94	28.4	17.5	65	19.7
F1	16.62	27.58	19.8	64	83.08
F2	27.62	1.58	12.8	42.08	138.4
F3	32.81	20.5	14.7	35.05	164.24

tions, pneumonia, and UTI among others Mailafia et al. [28] mentioned in their study that the extensive prevalence of *Klebsiella spp.* should be regarded as a public health concern due to its association with rats as a reservoir and its significant contribution to infections in the urinary tract, respiratory infections, septicemias, and soft tissue infections. Also, Wang et al. [29] revealed from their study that *K. pneumoniae* was the leading cause of pneumonia, after which came urinary tract and bloodstream infections. As it was shown from the results the first group to be infected and showing the most signs and symptoms of illness was the inhalation group and that's because they were infected with the bacterial isolate directly by the swab and also due to the *K. pneumonias* affinity to lung tissue as Alsadawi et al. [30] mentioned that in the current investigation, there was a significant correlation between the four infection routes (intranasal, left lung, oral, and intra-dermal), and *K. pneumoniae* induces acute inflammation in the rats' lungs when it infects them through the intranasal and left lung routes. While in contrast to a study implemented by Abubakar et al. [31] which mentioned that the most prevalent illnesses were bacteremia and urinary tract infection.

In order to ensure that the infectious organism is *K. pneumoniae*, the samples were cultivated on MacConkey agar owing to being selective for gram-negative bacteria and from its characteristics, as it appeared to be mucoid lactose fermenter, forming mucoid pink colonies on the MacConkey agar it was proven. As Qaisar et al. [32] suggested in their work following inoculation on MacConkey Agar, *K. pneumoniae*, which was isolated from the samples, produced mucoid pink colonies. Wu et al. [33] outlined in their work that the MacConkey medium is a regularly utilized selective medium in therapeutic settings. The presence of bile salts in it serves to hinder the proliferation of gram-positive bacteria. Additionally, lactose and acid-base markers distinct lactose-fermenting bacteria (pink colonies) from non-lactose fermenters (colorless and translucent colonies). *K. pneumoniae* exhibits the capacity to flourish on MacConkey media, giving rise to substantial, moist, raised pink colonies. The microscopic features *of K. pneumoniae* were ascertained through the process of gram staining. As Safika et al. [34] also mentioned the Gram stain of *K. pneumoniae* bacterium is rod-shaped and pink, as is characteristic of Gram-negative bacteria.

Several tests were performed for the identification of *K. pneumonia's* effect, as the CBC test demonstrated that all groups, notably the inhalation group, had an increased RBC level. Also, high lymphocyte, platelet, and low MPV indicated and approved the infection and inflammation in agreement with Li et al. [35] who also stated in their study that most patients demonstrated elevated levels of white blood cell counts, neutrophil percentages, C-reactive protein, procalcitonin, and fibrinogen, which are recognized as indicators of infection. Both studies undertaken by Albarracin et al. [27] and Dentice Maidana et al. [36] suggested that the infection increased blood neutrophils, lymphocytes, and leukocytes. Iqbal et al. [37] also showed from their work that WBC levels were measured in the blood of non-cancer patients, and they were (56%) elevated. According to Elemary et al. [38] Neutrophils were counted as CD45+ and CD11b+. During infection, neutrophil numbers improved. This indicates that neutrophils are crucial to the elimination of *K. pneumoniae*. Badakali et al. [39] mentioned in their study that they noticed 19 (21.8%) cases of severe thrombocytopenia were present. As opposed to a study carried out by Ma et al. [40] which stated that in comparison to the non-*K. pneumoniae* group, the platelet, procalcitonin, and CRP levels in the *K. pneumoniae* group elevated considerably.

A C-reactive protein test was also carried out in order to establish bacteremia and according to the high CRP level, the rats were suffering from systemic inflammation. Tang et al. [41] revealed that elevated CRP and liver dysfunction were the main two abnormalities of KLA in the laboratory. Additionally, it was shown in this analysis that diabetic-KLA patients had higher CRP levels, which indicated an increasingly serious infection. An inadequately handled host response to an infection results in sepsis and severe organ failure that can be fatal. Also, Al-Faifi and Ibrahim [42] mentioned that TLC and CRP levels were higher than expected during the first blood check, whereas platelet counts were lower.

Slightly high creatinine with a very high urea level was demonstrated from the kidney function tests as Battula et al. [43] revealed from their study that the majority of infections in CKD patients were brought on by *K. pneumoniae*. Herraiz et al. [44] also carried out a study that revealed that Electro-disinfection tests were conducted on urine samples containing *K. pneumoniae, S. aureus, and P. aeruginosa*. The results indicated that the organic compound with the maximum concentration, urea, had the lowest elimination percentage (2.66%), in comparison to creatinine (2.37%) and uric acid (78.57%). Hammadi [45] also demonstrated that an elevation in the renal function

assays, specifically B. urea and S. creatinine, was observed in the vaccinated category, indicating a substantial elevation. As well as levels of the AST, ALT, and ALP enzymes being considerably elevated. Our findings agreed with the study of Hammadi [45] revealed notable changes in the liver enzyme levels, which were all elevated, indicating liver damage and diseases. *K. pneumoniae* is recognized as the causative agent of pyogenic liver abscess, a fluid-filled pocket within the liver that is full of pus as Sohrabi et al. [46] also interpreted that *K. pneumoniae* was detected in 37% of pyogenic liver abscesses, surpassing the prevalence of *E. coli* (30%), which is the prevailing pathogen discovered in pyogenic liver abscesses. The *K. pneumoniae* isolates responsible for PLAs exhibit a higher abundance of virulence factors compared to other *K. pneumoniae* isolates.

Infection with *K. pneumoniae* didn't show any remarkable changes in the lipid profile, only in the food group hypertriglyceridemia was presented. However, Elwakil et al. [47] revealed from their work that Cholesterol and glucose levels were found to be considerably elevated in the rats infected with *K. pneumoniae* and *P. aeruginosa*, respectively, when various biochemical parameters were examined. Jia et al. [48] also mentioned that in AP patients suffering from *K. pneumoniae* infection, the main cause of infection with Carbapenem-Resistant Enterobacteriaceae (CRE) in AP patients was hyperlipidemia, which has recently been identified as the most common underlying factor, according to latest research. However, the findings in a study executed by Liu et al. [49] suggested that in comparison to less severe cases, people with a higher ratio of neutrophils to lymphocytes, low levels of triglycerides, and a low level of proteins are at an elevated risk of developing severe community-acquired pneumonia.

5. Conclusion

K. pneumonia caused infection in different groups of albino rats within 6 days. The inhalation group was the most susceptible to the infection due to its affinity to lung cells, that's so it was the first to exhibit the signs and symptoms of the infection. Several tests were performed to assess the morbidity effect of *K. pneumoniae* in albino rats, which demonstrated that it significantly influences liver enzyme levels and the CBC and causes impaired renal function. *Klebsiella* infection was also associated with an increase in CRP levels, but it had no or only a minor impact on the lipid profile.

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