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A Prospective Study of Role of Minimally Invasive Approaches for Renal Salvageability in Management of Emphysematous Pyelonephritis

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HIGHLIGHTS

- Minimally invasive renal salvage
- Renal dysfunction predicts failure
- Shock and thrombocytopenia indicate severity
- CT severity predicts poor outcomes
- *E. coli* predominates in infections

Key Words:

Emphysematous pyelonephritis
Renal salvage
Minimally invasive management
Percutaneous catheter drainage
Nephrectomy

ABSTRACT

Introduction: Emphysematous pyelonephritis (EPN) is a severe, potentially life-threatening necrotizing renal infection characterized by gas formation within the renal parenchyma and surrounding tissues. Although nephrectomy was traditionally considered the definitive treatment, minimally invasive approaches have increasingly been used to achieve renal preservation. **Aim & Objective:** This study evaluated renal salvageability with minimally invasive management and identified factors associated with treatment failure and the need for invasive intervention. **Material & Methods:** The 40 patients with EPN were evaluated clinically, biochemically, microbiologically, and radiologically using CT-based Huang classification. Initial management included antibiotics, DJ stenting and/or percutaneous catheter drainage (PCD). Patients requiring open drainage or nephrectomy following failure of minimally invasive treatment were considered to have poor outcomes. Statistical analysis was performed using unpaired t-test and Fisher's exact test, with $p < 0.05$ considered significant. **Results:** The mean age was 56.2 ± 7.76 years, with females comprising 74% of patients. Diabetes was present in 87.5%. Minimally invasive management achieved renal salvage in 90% (36/40) of patients, while 10% required invasive intervention. Elevated serum creatinine (3.63 vs. 1.48 mg/dL, $p = 0.0019$), blood urea (99.5 vs. 41.42 mg/dL, $p = 0.0004$), thrombocytopenia ($p = 0.0001$), leukocytosis ($p = 0.011$), shock ($p = 0.0027$), altered mental status ($p = 0.004$), positive blood cultures ($p = 0.0001$), urinary obstruction ($p = 0.017$), and advanced CT severity ($p = 0.00001$) were significantly associated with poor outcomes. *E. coli* was the predominant urinary pathogen (72.5%). **Conclusion:** Minimally invasive treatment provides a high rate of renal salvage in EPN and should be considered as the initial management strategy. Early identification of renal dysfunction, thrombocytopenia, shock, altered sensorium, bacteremia, obstruction, and advanced CT disease can help predict treatment failure and guide timely escalation to invasive procedures.



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INTRODUCTION

Emphysematous pyelonephritis (EPN) is a severe, necrotizing infection characterized by the presence of gas within the renal parenchyma, collecting system, or surrounding perinephric tissues. The condition was first described by Kelly and Mac Callum in 1898 and was subsequently termed “emphysematous pyelonephritis” by Schultz and Klorfein, a terminology that has since become widely accepted [1,2]. Other historical terms include renal emphysema, pneumonephritis, pyelonephritis emphysematosa, and pneumonephrogram. EPN is now recognized as a distinct and potentially life-threatening form of complicated urinary tract infection [3,4].

EPN most commonly results from infection with gas-producing microorganisms, particularly *Escherichia coli* and *Klebsiella pneumoniae*. These organisms utilize glucose and other substrates within infected tissues to produce gas, particularly in patients with diabetes mellitus. Urinary tract obstruction, impaired tissue perfusion, and defective host immune responses further facilitate bacterial proliferation and gas formation. Clinically, patients may present with fever, chills, flank or loin pain, vomiting, dysuria, hypotension, and altered mental status. The disease may rapidly progress to systemic inflammatory response, septic shock, multiorgan dysfunction, and death, making EPN an important urological emergency [5-7].

Although EPN was historically regarded as a rare condition, its reported incidence and recognition have increased with the widespread availability of ultrasonography and computed tomography (CT). These imaging modalities, particularly CT, have substantially improved the detection of intrarenal and extrarenal gas and enabled accurate assessment of the extent of infection. Huang JJ & Tseng CC. 2000, emphasized that EPN may be underdiagnosed rather than truly rare and highlighted the importance of early imaging in patients with severe or complicated urinary tract infections. CT also provides valuable

prognostic information by demonstrated the distribution of gas, renal parenchymal destruction, perinephric extension, and involvement of adjacent structures, thereby assisting clinicians in selecting an appropriate treatment strategy [8].

Historically, the standard treatment for EPN consisted of aggressive fluid resuscitation, intravenous antibiotics, and early nephrectomy, particularly in patients with extensive renal destruction or clinical deterioration. Open surgical drainage was also employed in selected cases. However, nephrectomy results in permanent loss of renal function and may be particularly hazardous in patients with diabetes, chronic kidney disease, a solitary functioning kidney, or bilateral renal involvement. The introduction of fluoroscopically guided percutaneous drainage by Hudson et al. represented an important change in the management of EPN and established the basis for minimally invasive renal-preserving treatment [6,7,9].

Contemporary management increasingly follows a stepwise approach involving broad-spectrum intravenous antibiotics, aggressive fluid and hemodynamic support, strict glycemic control, correction of electrolyte abnormalities, and prompt relief of urinary obstruction. Image-guided percutaneous catheter drainage (PCD) allows evacuation of infected material and gas while preserving functioning renal tissue. Endoscopic procedures, including double-J ureteral stenting or nephrostomy, may be required when obstruction is present. These interventions can be combined according to disease severity and clinical response. Renal preservation is particularly important because diabetes may affect the contralateral kidney through long-term microvascular and metabolic complications, while bilateral disease occurs in approximately 10% of cases [10].

The reported mortality of EPN varies considerably, ranging from approximately 7% to 75%, depending on disease severity, comorbidities, extent of infection, and treatment strategy. Prognostic factors associated with poor outcomes include

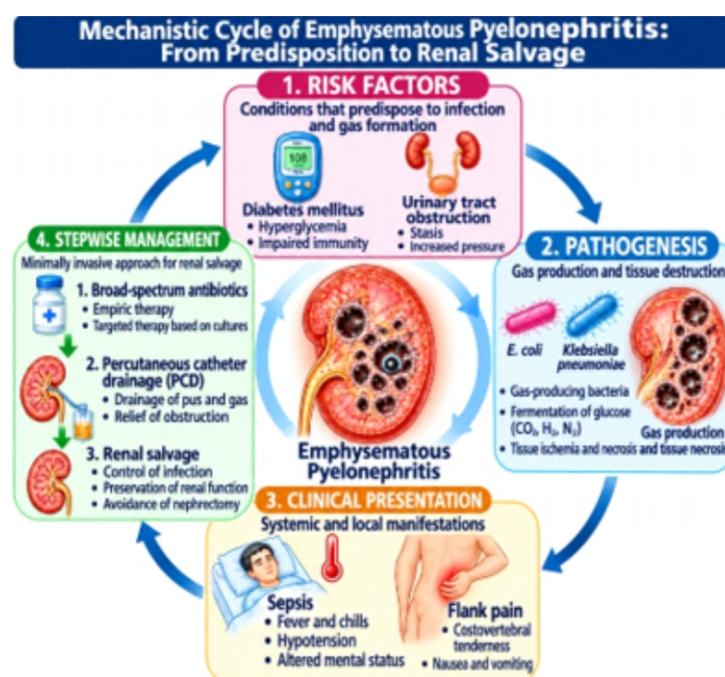


Figure 1: Mechanistic Cycle of Emphysematous Pyelonephritis: From Predisposing Risk Factors to Renal Salvage.

thrombocytopenia, acute kidney injury, elevated serum creatinine, altered consciousness, shock, and extensive disease on CT. Consequently, early identification of high-risk patients is essential for timely escalation of therapy. Current evidence supports individualized treatment, with minimally invasive drainage and appropriate antimicrobial therapy serving as effective renal-preserving strategies in many patients, while nephrectomy remains an option for those with extensive non-functioning renal tissue or failure of conservative and minimally invasive management [8-10].

Schematic representation of the pathophysiology of emphysematous pyelonephritis, highlighting predisposing factors such as diabetes mellitus and urinary tract obstruction, gas production by organisms including *Escherichia coli* & *Klebsiella pneumoniae*, clinical manifestations of sepsis and flank pain, and stepwise management involving broad-spectrum antibiotics, percutaneous catheter drainage, and renal-preserving strategies to control infection and preserve renal function (**Figure 1**).

The study aims to assess the possibility of renal salvageability using minimally invasive approaches in patients with emphysematous pyelonephritis and to identify and analyse the factors associated with the need for invasive interventions, particularly those contributing to the failure of minimally invasive approaches in the management of emphysematous pyelonephritis.

MATERIAL & METHODS

This prospective clinical study was conducted at the Department of Urology, Andhra Medical College King George Hospital, Visakhapatnam, Andhra Pradesh from May 2023 to April 2025. Ethical approval has been obtained from the Ethical Approval Committee of Andhra Medical College King George Hospital, Visakhapatnam, Andhra Pradesh.

Study Population

The study included 40 patients with acute pyelonephritis and gas within the renal parenchyma, perinephric, or paranephric tissues, presenting with fever, chills, loin pain, altered sensorium, or vomiting. Patients admitted through the emergency department and subsequently diagnosed with emphysematous pyelonephritis were included. Patients without renal gas, those with recent endoscopic or open urinary tract interventions, and those with recent urinary catheterization were excluded from the study.

Data Analysis

Data were analysed using descriptive statistics, with appropriate tests applied for comparison between groups. Continuous variables were assessed using the unpaired t-test, while categorical variables were analysed using Fisher's exact test. Statistical significance was determined at a p-value of <0.05. All analyses were performed systematically to evaluate differences between study groups and identify statistically significant associations, ensuring appropriate interpretation of the collected clinical and demographic data.

RESULTS

The mean age of the patients was 56.2 ± 7.76 years, and age was not significantly associated with outcome ($p=0.4847$). Females constituted the majority of cases (74%), while males accounted for 26%, with no significant association between sex and outcome ($p=0.999$). The left kidney was involved in 52.5% of cases, the right kidney in 40%, and bilateral involvement in 7.5%, without significant association with outcome ($p=0.2057$). Diabetes mellitus was present in 87.5% of patients, including 8.5% newly diagnosed cases, whereas 12.5% were non-diabetic; diabetic status was not significantly related to outcome ($p=0.9999$). Among diabetic patients, 65% received regular treatment, while 25% had unavailable treatment information and 5% received treatment irregularly, with no significant association with outcome ($p=0.6446$). Regarding treatment modality, 65% of treated patients received oral hypoglycemic agents and 5% received insulin; this variable was also not significantly associated with outcome ($p=0.6415$).

Fever with loin pain was the most common presentation (65%), while loin pain alone occurred in 30% of cases; seizures, altered sensorium, and vomiting accounted for the remaining 5%.

The duration of complaints was shorter among patients with poor outcomes compared with those having good outcomes, with a mean duration of 6.25 ± 3.75 days in the poor-outcome group versus 11.52 ± 3.45 days in the good-outcome group. On clinical examination, loin tenderness was the most common finding, observed in 75% of patients, while 20% presented with an abdominal mass and 5% had abdominal distension. These findings indicate that loin tenderness was the predominant clinical presentation, whereas a shorter duration of symptoms was observed among patients with poor outcomes (**Table 1**).

Raised serum creatinine was observed in 50% of patients and was significantly associated with poor outcomes ($p=0.0019$). Mean serum creatinine was lower in patients with good outcomes (1.48 U/L) than in those with poor outcomes (3.63 U/L), indicating that elevated baseline creatinine was strongly associated with an increased risk of poor outcomes (**Table 2**).

Baseline blood urea levels were markedly higher in patients with poor outcomes compared with those with good outcomes, with mean values of 99.5 ± 9.04 mg/dL and 41.42 ± 8.65 mg/dL, respectively. This difference was statistically significant ($p=0.000435$), with a mean difference of 58.08 mg/dL, indicating a strong association between elevated blood urea and poor outcomes. Shock was present in 25% of patients and was significantly associated with poor outcomes ($p=0.0027$), suggesting that hemodynamic instability adversely affected prognosis. Regarding mental status, 92.5% of patients were normal at presentation, whereas 7.5% had altered mental status; all patients with altered mental status belonged to the poor-outcome group, demonstrating a statistically significant association with outcome ($p=0.004$). Overall, elevated blood urea, shock, and altered mental status at presentation were important predictors of poor outcomes in patients with emphysematous pyelonephritis (**Table 3**). Mean blood sugar at presentation was

significantly higher in patients with poor outcomes (375.50 ± 40.55) than in those with good outcomes (206.44 ± 39.15), showing a statistically significant association with outcome ($p=0.001981$) (**Table 4**). DKA was present in 7.5% of patients at presentation, with no statistically significant association between DKA and clinical outcome ($p=0.2773$). In contrast, baseline platelet count showed a strong and statistically significant association with outcome ($p=0.0001$). Among patients with platelet counts below 120,000/cu.mm, 4 of 5 had poor outcomes, whereas all 35 patients with platelet counts above 120,000/cu.mm had good outcomes, indicating thrombocytopenia as an important adverse prognostic factor. Similarly, baseline total leukocyte count was significantly associated with outcome ($p=0.011$). All patients with counts below 10,000/cu.mm had good outcomes, while 3 of 10 patients with counts above 10,000/cu.mm had poor outcomes. Overall, thrombocytopenia and leukocytosis at presentation were significantly associated with poor outcomes, whereas DKA did not demonstrate a significant relationship with prognosis (**Table 5**). The mean haemoglobin level was 10.75 ± 0.43 g/dL, with higher values in the good-outcome group (10.75 ± 0.43 g/dL) compared with the poor-outcome group (8.15 ± 1.29 g/dL); however, this difference was not statistically significant ($p=0.294$) (**Figure 2**). CT classification showed that 5% of patients had Class 1 disease, 45% Class 2, 30% Class 3A, 10% Class 3B, and 10% Class 4 disease.

CT classification was significantly associated with outcome ($p=0.00001$), with advanced Class 4 disease being strongly associated with poor outcomes. Urine culture most commonly isolated *E. coli* (72.5%), followed by *Klebsiella* and *Proteus* (22.5%); however, urine culture findings were not significantly associated with outcome ($p=0.102$). Blood cultures were positive in 15% of patients, of whom five had poor outcomes, demonstrating a significant association between blood culture positivity and poor outcome ($p=0.0001$). Urinary tract obstruction was present in 47.5% of patients and was significantly associated with outcome ($p=0.017$), with timely relief of obstruction potentially contributing to renal preservation. Regarding treatment, 10% received antibiotics alone, 65% underwent DJ stenting, 5% underwent PCD alone, and 15% received combined PCD and DJ stenting. Open drainage and nephrectomy were required in 5% each following failure of minimally invasive treatment. Overall, renal conservation was achieved in 90% of patients (36/40), while 10% (4/40) had poor outcomes, including two requiring open drainage and two undergoing nephrectomy. Among patients with good outcomes, 100% were managed with continued minimally invasive treatment, whereas open drainage and nephrectomy were required only in patients with poor outcomes (50% each). The association between treatment modality and outcome was statistically significant (Fisher's exact test, $p=0.0001$), indicating that escalation to invasive treatment was associated with poor outcomes (**Table 6**).

Table 1: Duration of diabetes treatment

Diabetes Duration of Treatment (in years)	Good Outcome	%	Poor Outcome	%
No Treatment	10	27.78	0	0.00
1 to 5	5	13.89	0	0.00
6 to 10	11	30.56	2	50.00
11 to 15	8	22.22	0	0.00
>15	2	5.56	2	50.00
Total	36	100	4	100.00
Diabetes-Duration of Treatment (in years)		Good outcome	Poor Outcome	
N		36	4	
Mean		7.083333	14	
SD		5.827889	4.898979	
p-value of Unpaired t-test			0.05836	

Table 2: Baseline serum creatinine

Baseline Serum Creatinine	Good Outcome	%	Poor Outcome	%
≤1.5 U/L	20	55.56	0	0.00
1.6-2.5 U/L	15	41.67	0	0.00
2.6-3.5 U/L	0	0.00	2	50.00
3.6-4.5 U/L	1	2.78	2	50.00
Total	36	100	4	100.00

Baseline Serum Creatinine	Good Outcome	Poor Outcome
N	36	4
Mean	1.447222	3.625
SD	0.585777	0.485627
p-value of Unpaired t-test	0.001092*	

Table 3: Baseline Blood Urea

Baseline Blood Urea	Good Outcome	%	Poor Outcome	%
≤40 mg/dl	16	44.44	0	0.00
41 -60 mg/dl	20	55.56	0	0.00
61 -80 mg/dl	0	0.00	0	00.00
>80 mg/dl	0	0.00	4	100.00
Total	36	100	4	100.00
Baseline Blood Urea	Good Outcome	Poor Outcome		
N	36	4		
Mean	41.41667	99.5		
SD	8.649938	9.036961		
p-value of Unpaired t -test			0.000435 *	

Table 4: Mean Blood Sugar

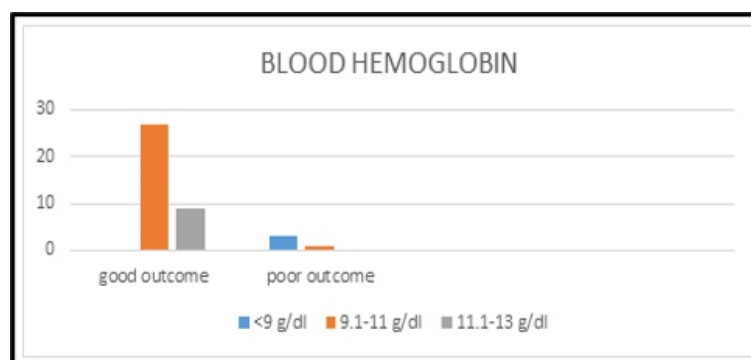
Blood sugar	Good outcome	Poor outcome
N	37	3
MEAN	206.444	375.5
SD	39.15	40.55

Table 5: DKA and Outcome

Diabetic Ketoacidosis	Good Outcome	%	Poor Outcome	%
DKA-	34	94.44	3	75.00
DKA+	2	5.56	1	25.00
Total	36	100	4	100.00
p-value of Fisher's Exact test				0.2773

Table 6: Treatment and Outcome

Further Treatment	Good Outcome	%	Poor Outcome	%
Continued	36	100.00	0	0.00
Open Drainage	0	0.00	2	50.00
Nephrectomy	0	0.00	2	50.00
Total	36	100	4	100.00
p-value				0.0001*
Fisher's Exact Test				

**Figure 2: Blood Haemoglobin**

DISCUSSION

The present prospective study evaluated the role of minimally invasive approaches in achieving renal salvage in 40 patients with emphysematous pyelonephritis (EPN) and assessed factors associated with failure of conservative and minimally invasive treatment. The mean age of the study population was 56.2±7.76 years, with a marked female predominance (74%). This demographic pattern is comparable with previous reports, including Huang JJ & Tseng CC. 2000, who described EPN predominantly in middle-aged and elderly patients, and studies reporting a female predominance. EPN is strongly associated with diabetes mellitus and urinary tract obstruction, which are

important predisposing factors for gas-forming renal infection. The present study similarly demonstrated a high prevalence of diabetes mellitus (87.5%), although diabetic status itself was not significantly associated with treatment outcome. This finding suggested that the severity of systemic illness and renal involvement may be more important determinants of outcome than the mere presence of diabetes. Huang JJ & Tseng CC. 2000, also reported diabetes in 96% of their patients, supported its established association with EPN [11,8].

Renal dysfunction emerged as one of the strongest predictors of poor outcome in the present study. Mean serum creatinine was substantially higher in patients with poor outcomes than in those

with good outcomes (3.63 vs. 1.48 mg/dL; $p=0.0019$), while blood urea was also significantly elevated (99.5 vs. 41.42 mg/dL; $p=0.0004$). Huang JJ, et. al; 1991, identified acute renal function impairment as an important predictor of failure of conservative management. Renal dysfunction may reflect extensive renal parenchymal destruction, sepsis-associated hypoperfusion and impaired renal reserve. Thus, early assessment of renal function is important when deciding whether minimally invasive renal-preserving treatment is likely to succeed [12,8].

Hemodynamic and neurological instability were also significantly associated with poor outcomes. Shock was present in 25% of patients and showed a significant association with treatment failure ($p=0.0027$), while altered mental status was observed in 7.5% and was significantly associated with poor outcome ($p=0.004$). These findings closely correspond with the prognostic model proposed by Huang JJ & Tseng CC. 2000, in which shock, altered consciousness, thrombocytopenia and renal impairment were important predictors of failure of percutaneous management in extensive EPN [13,8].

Hematological abnormalities further supported the relationship between systemic severity and treatment outcome. Thrombocytopenia with platelet counts below 1.2 lakh/cu.mm was significantly associated with poor outcome ($p=0.0001$), while leukocytosis above 10,000/cu.mm was also significant ($p=0.011$). Wan YL, et. al; 1998, identified thrombocytopenia as an important prognostic factor in EPN, supporting the findings of the present study. These abnormalities may represent severe systemic inflammatory response, sepsis and consumption associated with advanced infection [7,14].

Microbiologically, *Escherichia coli* was the predominant urinary pathogen (72.5%), followed by *Klebsiella* and *Proteus*. This is consistent with the established microbiological profile of EPN, in which *E. coli* and *Klebsiella pneumoniae* are the predominant organisms. Positive blood cultures, although present in only 15% of the cohort, were strongly associated with poor outcome ($p=0.0001$), indicating that bacteremia may serve as a marker of systemic dissemination and severe infection [15].

CT-based classification demonstrated a strong relationship with prognosis. Patients with Class 1 and 2 disease had uniformly favourable outcomes, whereas Classes 3B and 4 were associated with a 75% poor-outcome rate. This finding is in agreement with Huang et al., whose CT classification demonstrated increasing treatment failure with increasing disease extent. CT therefore remains essential not only for diagnosis but also for treatment planning and early identification of high-risk patients [16].

The most important finding of the study was the 90% renal salvage rate achieved using minimally invasive treatment, including antibiotics, DJ stenting and PCD. Only 10% required escalation to open drainage or nephrectomy. This supported the shift from routine early nephrectomy toward a stepwise renal-preserving strategy. Earlier studies also demonstrated favourable outcomes with PCD combined with antibiotics, particularly in less extensive disease. Jain A, et. al; 2019, concluded that percutaneous drainage was associated with lower mortality than medical treatment or emergency nephrectomy [13,17].

Urinary obstruction was present in 47.5% of patients and was significantly associated with outcome ($p=0.017$). Prompt relief of obstruction through DJ stenting or drainage may therefore contribute to renal preservation. Wu SY, et. al; 2022, identified obstruction as an important pathogenic and prognostic factor in EPN. Overall, the findings supported minimally invasive treatment as the initial renal-preserving strategy, while emphasizing that patients with renal dysfunction, shock, altered consciousness, thrombocytopenia, bacteremia and advanced CT disease require close monitoring and early consideration of invasive intervention [18,13].

CONCLUSION

In our prospective study of 40 patients with emphysematous pyelonephritis, renal salvage was achieved in 90% using minimally invasive management, including DJ stenting, percutaneous catheter drainage, and antibiotics. Poor outcomes were significantly associated with elevated creatinine and urea, thrombocytopenia, leukocytosis, altered sensorium, shock, CT Class 4 disease, and positive blood cultures. CT classification strongly predicted prognosis, while promptly relieved urinary obstruction favored salvage. Although diabetes was prevalent, it did not independently predict poor outcomes. Overall, early recognition of high-risk features and stepwise minimally invasive treatment can improve outcomes, preserve renal function, and reduce nephrectomy.

LIMITATIONS & FUTURE PERSPECTIVES

The study's limitations include a single-centre setting, a relatively small sample size, and a short study duration, which may limit the broader applicability of the results. Future studies should incorporate multicentre designs with larger populations to enhance validity, assess long-term outcomes, and investigate advanced diagnostic & management approaches. Such efforts will improve overall patient care & help minimize complications.

CLINICAL SIGNIFICANCE

The clinical significance of this study lies in its potential to bridge the gap between research findings and practical health-care, diagnosis, and treatment outcomes. By highlighting real-care applications. It emphasizes the importance of translating scientific observations into meaningful improvements in patient world relevance, the study contributes to evidence based medical practice and supports informed clinical decision making. Ultimately, the findings aim to enhance patient quality of life, optimize therapeutic strategies, and promote better disease management in clinical settings.

ABBREVIATIONS

EPN: Emphysematous Pyelonephritis

CT: Computed Tomography

DJ stent: Double-J stent

PCD: Percutaneous Catheter Drainage

E. coli: *Escherichia coli*

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AUTHOR CONTRIBUTIONS

All authors significantly contributed to the study conception and design, data acquisition, or data analysis and interpretation. They participated in drafting the manuscript or critically revising it for important intellectual content, consented to its submission to the current journal, provided final approval for the version to be published, and accepted responsibility for all aspects of the work. Additionally, all authors meet the authorship criteria outlined by the International Committee of Medical Journal Editors (ICMJE) guidelines

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CONFLICT OF INTEREST

Authors declared that there is no conflict of interest.

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ETHICAL APPROVAL & CONSENT TO PARTICIPATE

All necessary consent & approval was obtained by authors.

CONSENT FOR PUBLICATION

All necessary consent for publication was obtained by authors.

DATA AVAILABILITY

All data generated and analyzed are included within this research article. The datasets utilized and/or analyzed in this study can be obtained from the corresponding author upon a reasonable request.

USE OF ARTIFICIAL INTELLIGENCE (AI) & LARGE LANGUAGE MODEL (LLM)

The authors confirm that no AI & LLM tools were used in the writing or editing of the manuscript, and no images were altered or manipulated using AI & LLM.

AUTHOR'S NOTE

This article serves as an important educational tool for the scientific community, offering insights that may inspire future

research directions. However, they should not be relied upon independently when making treatment decisions or developing public health policies.

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