Original Article

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Outcome of Different Surgical Interventions in Management of Emphysematous Pyelonephritis: A Retrospective Cohort Study from Dharwad, India

Urology Section

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ABSTRACT

Introduction: Emphysematous Pyelonephritis (EPN) is a rare, life-threatening infection of the renal parenchyma characterised by gas formation within the kidney and surrounding tissues. When not promptly diagnosed and treated, this condition presents with a mortality rate ranging from 20% to 80%.

Aim: This study aimed to evaluate the outcomes of different surgical interventions in managing EPN, focusing on minimally invasive interventions {Double J Stent (DJS), Percutaneous Nephrostomy (PCN), Percutaneous Drainage (PCD)} and nephrectomy.

Materials and Methods: A retrospective cohort study was conducted at SDM College of Medical Sciences and Hospital, Dharwad, Karnataka, India, examining 80 cases of EPN over a 54-month period from January 2017 to June 2023. Data were collected from hospital records, including clinical notes, laboratory results, imaging studies, and surgical reports. The study assessed demographics, clinical presentation, laboratory investigations, imaging studies, treatment details, and patient outcomes. Descriptive statistics were used for demographic and clinical characteristics and Chi-square test was applied for categorical variables. A p-value of <0.05 was considered statistically significant.

Results: The study included 80 patients with a gender distribution of 48.8% female and 51.2% male, with a mean age of 57.9±12.2 years. Flank pain (91.3%), fever (86.3%), and dysuria (36.3%) were the predominant clinical manifestations. Laboratory evaluation revealed significant findings, including anaemia (52.5%), renal dysfunction (56.3%), and sepsis (61.3%). *Escherichia coli* were the primary causative organism, identified in 34 patients (42.5%). Class 2 EPN was the most prevalent classification, occurring in 25 patients (31.3%). Hypotension (p-value=0.015), elevated Glycated haemoglobin (HbA1c) levels (p-value=0.018), and the need for dialysis (p-value=0.008) were significantly associated with mortality. Minimally invasive interventions were predominantly successful, with various drainage procedures employed: unilateral DJS (48.8%), bilateral DJS (27.5%), PCN (3.8%), and PCD (18.8%). Nephrectomy was required in only 5% of cases.

Conclusion: This study supports the efficacy of minimally invasive intervention approaches for EPN, thereby reducing the necessity for nephrectomy. Prognostic indicators, including hypotension, elevated HbA1c, and the requirement for dialysis, warrant careful monitoring. Minimally invasive interventions, coupled with targeted antibiotic therapy, are validated as a preferred treatment for EPN.

Keywords: Diabetes mellitus, Double J stent, Nephrectomy, Percutaneous nephrostomy, Urinary tract infection

INTRODUCTION

The EPN is a rare, life-threatening infection of the renal parenchyma characterised by gas formation within the kidney and surrounding tissues. The condition predominantly affects individuals with diabetes mellitus and presents significant challenges in clinical management due to its rapid progression. The mortality rates range from 20% to 80% when not promptly diagnosed and treated [1,2].

Historically, nephrectomy was the primary treatment for EPN, especially in severe cases, due to its association with reduced mortality compared to medical management alone [3]. However, advancements in imaging techniques, antibiotic therapies, and minimally invasive procedures have shifted treatment paradigms towards more conservative approaches. Recent studies have highlighted the efficacy of PCD and ureteral stenting as first-line treatments for EPN, particularly in patients with less severe disease (Classes 1 and 2 according to Huang and Tseng's classification) [4-6]. These interventions not only help preserve renal function but also reduce the risk of complications associated with surgical nephrectomy. Recent evidence from Desai R and Batura D, reported a mortality rate of 9.7% with medical management alone and further suggested minimally invasive treatment as the initial management strategy for EPN, as these approaches carry lower mortality risks [7].

This shift underscores the importance of early diagnosis and intervention, facilitated by Computed Tomography (CT) imaging, which remains the gold standard for EPN diagnosis and severity assessment. Despite these advancements, nephrectomy remains a critical option for patients who do not respond to conservative treatment or present with severe disease (Classes 3 and 4). The decision to proceed with nephrectomy is often influenced by several prognostic factors, including advanced age, altered mental status, thrombocytopenia, acute renal failure, and shock [8]. These factors are associated with poorer outcomes and necessitate aggressive surgical intervention when conservative measures fail. The evolving understanding of EPN's pathophysiology has also led to a more nuanced approach to its management. Studies have shown that EPN is commonly caused by gas-forming pathogens such as *Escherichia coli* and *Klebsiella pneumoniae*, with diabetes being a major predisposing factor [9,10].

Effective management thus involves not only addressing the infection through antibiotics and drainage but also optimising glycaemic control in diabetic patients. The shift towards conservative management is supported by evidence demonstrating that minimally invasive procedures can achieve outcomes comparable to surgical nephrectomy in selected patients. For instance, PCD has been shown to preserve renal function in approximately 70% of cases

[11]. While nephrectomy was historically the mainstay treatment, emerging evidence suggests that minimally invasive interventions can effectively manage EPN while preserving renal function [11]. However, there is limited data from tertiary care centres in India [4] comparing the outcomes of minimally invasive versus invasive surgical management, highlighting the need for this study to provide real-world insights into optimal treatment strategies. Thus, the study aims to evaluate the outcomes of different surgical interventions, specifically minimally invasive treatments and nephrectomy, in managing EPN.

MATERIALS AND METHODS

A retrospective cohort study was conducted at SDM College of Medical Sciences and Hospital (SDMCMSH), Dharwad, Karnataka, India, planned for February 2024. Institutional ethical approval was obtained on 26 April 2024 from the same institute (SDMIEC/2024/688). After reviewing the medical records from January 2017 to June 2023, a total of 80 cases were selected that matched our inclusion and exclusion criteria through total sampling.

Inclusion criteria: The study included all patients diagnosed with EPN who underwent surgical intervention from the Department of Urology at SDMCMSH and presented as follows:

- Patients admitted with a diagnosis of EPN.
- Patients who underwent surgical management, including minimally invasive treatments such as DJS, PCN, or both, as well as PCD and those who required nephrectomy.

Exclusion criteria:

- Patients managed without surgical intervention.
- Recent urinary interventions unrelated to EPN.
- Cases involving trauma, urinary fistulae, or pregnancy.

Data Collection

From the records of the 80 patients, a structured proforma was used to extract the data. The study collected comprehensive patient information starting with basic demographics, including name, age, sex, and Unique Hospital Identification Number (UHID). Clinical presentations were documented through key symptoms such as flank pain, fever, dysuria, and haematuria, along with any additional symptoms noted. Comorbid conditions were recorded with particular attention to vital signs, including tachycardia (heart rate >90 bpm) [3] and hypotension (defined as systolic blood pressure <90 mmHg) [2,3]. Physical examination findings focused on flank tenderness and the presence of abdominal masses.

Laboratory investigations formed a crucial component, encompassing complete blood count parameters with specific attention to anaemia (Hb% <11 g/dL) [2] and sepsis markers (defined as WBC count below 3,000 or above 11,000/mL) [12]. Platelet counts were monitored for thrombocytopenia (defined as counts below 150,000/mL) [3]. Renal function was assessed through serum creatinine levels, with values above 2 mg/dL indicating renal dysfunction [12]. Additional metabolic parameters, including sodium levels for hyponatraemia (serum sodium levels below 135 mEq/L) [2], albumin for hypoalbuminaemia (serum albumin level below 3 g/dL) [2,3], and HbA1c (more than 7% defined as poor glycaemic control) [3], were documented.

The diagnostic workup included imaging to determine EPN laterality (right, left, or bilateral) and grading according to the Huang-Tseng classification system [Table/Fig-1] [9]. Urine culture results were recorded, and the presence of obstructive or non obstructive stone disease was noted. Treatment modalities were thoroughly documented, including antibiotic choice and grouping, the necessity for dialysis, minimally invasive management approaches (including DJS, PCN, and PCD placement), and whether nephrectomy was performed. Patient outcomes were assessed based on survival or death at six months post interventions.

- Class 1: Gas in the collecting system only.
- Class 2: Gas in the renal parenchyma without extension beyond the kidney.
- Class 3A: Extension of gas or abscess to the perinephric space.
- Class 3B: Extension to the pararenal space.
- Class 4: Bilateral EPN or solitary kidney involvement.

[Table/Fig-1]: EPN grades as per Huang and Tseng's classification [9].

STATISTICAL ANALYSIS

Data analysis was performed using coGuide v2.0 [13]. Descriptive statistics, such as mean, frequency, and percentages, were used to summarise demographic and clinical characteristics. Graphical representations were employed for visual interpretation of data distributions. For inferential statistics, the Chi-square test was applied to examine associations between categorical variables, such as treatment type (minimally invasive interventions vs nephrectomy) and outcomes (survival vs death). A p-value of <0.05 was considered statistically significant.

RESULTS

The study analysed 80 cases of EPN, with a gender distribution of 39 females (48.8%) and 41 males (51.2%), and a mean age of 57.9±12.2 years. The predominant clinical manifestations included flank pain in 73 patients (91.3%), fever in 69 (86.3%), and dysuria in 29 (36.3%), with left-sided flank tenderness being the most common, occurring in 41 patients (51.3%). Laboratory evaluations revealed significant findings, including anaemia in 42 patients (52.5%), renal dysfunction in 45 (56.3%), and sepsis in 49 (61.3%), while the mean HbA1c of 9.9±2.6 indicated poor glycaemic control [Table/Fig-2]. Of the study population, there were 68 survivors (85%) and 12 deaths (15%).

Parameters	n (%)
Age (years) (n=80) (Mean±SD)	57.9±12.2
Sex	
Female	39 (48.8%)
Male	41 (51.2%)
Clinical presentation	
Symptoms	
Flank pain	73 (91.3%)
Fever	69 (86.3%)
Dysuria	29 (36.3%)
Haematuria	2 (2.5%)
Signs	
Tachycardia	27 (33.8%)
Hypotension	12 (15.0%)
Abdominal mass	2 (2.5%)
Flank tenderness	
-Bilateral	18 (22.5%)
-Right	21 (26.3%)
-Left	41 (51.3%)
Lab parameters	
S.creatinine (mg/dL), (n=80)	2.7±1.8
HbA1c (%), (n=50)	9.9±2.6
Platelets (10^5/µL), (n=80)	2.3±1.4

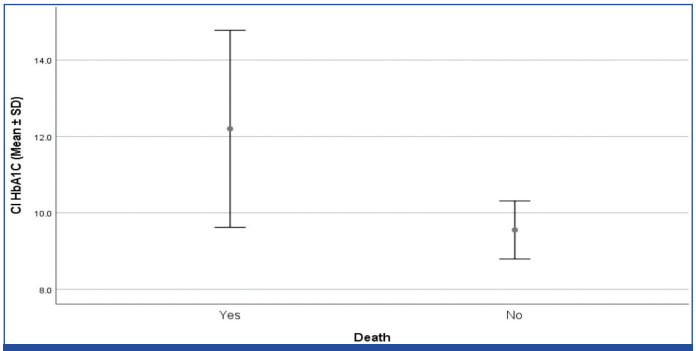
[Table/Fig-2]: Frequency distribution of clinical presentation in the study population (N=80).

Escherichia coli emerged as the primary causative organism in 42.5% of cases, and imaging revealed Class 2 EPN to be the most prevalent classification, occurring in 31.3% of cases [Table/Fig-3]. Several prognostic factors were significantly associated with mortality, including hypotension (p-value=0.015), elevated HbA1c

levels (12.2±2.5 vs. 9.5±2.5; p-value=0.018), and the need for dialysis (p-value=0.008) [Table/Fig-4,5]. No significant association was found between the presence of any comorbidity and death [Table/Fig-6].

Laboratory parameters	n (%)
Anaemia	42 (52.5%)
Sepsis	49 (61.3%)
Thrombocytopenia	25 (28.7%)
Renal dysfunction	45 (56.3%)
Hyponatraemia	55 (68.8%)
Hypoalbuminaemia	47 (58.8%)
Urine culture	
Escherichia coli	34 (42.5%)
No growth	15 (18.8%)
Enterococcus species	6 (7.5%)
Klebsiella pneumoniae	5 (6.3%)
Citrobacter freundii	3 (3.8%)
Candida	2 (2.5%)
Staphylococcus aureus	2 (2.5%)
NA* (Not available)	13 (16.3%)
Imaging- EPN class (Huang Sang)	
Class 1	20 (25.0%)
Class 2	25 (31.3%)
Class 3	17 (21.3%)
Class 4	18 (22.5%)

[Table/Fig-3]: Frequency distribution of laboratory and imaging parameters in the study population (N=80).



[Table/Fig-4]: Error bar graph of the comparison of HbA1c with the outcome (survival vs death) in EPN (N=80).

Parameters	Death		p-value
	Yes (n=12)	No (n=68)	
Hypotension			
Yes {12 (15.0%)}	5 (41.7%)	7 (10.3%)	0.015
No {68 (85%)}	7 (58.3%)	61 (89.7%)	
HbA1c	12.2±2.5	9.5±2.5	0.018
Dialysis			
Yes {15 (18.8%)}	6 (50%)	9 (13.2%)	0.008
No {65 (81.2%)}	6 (50%)	59 (86.8%)	

[Table/Fig-5]: Comparison of outcome (survival vs death) with hypotension, HbA1C, and dialysis in EPN (N=80).

The study demonstrated successful outcomes with predominantly minimally invasive surgical management, utilising various drainage procedures, including unilateral DJS in 39 patients (48.8%), bilateral DJS in 22 (27.5%), and PCD in 15 (18.8%), while nephrectomy was required in only 5% of cases [Table/Fig-7]. There was no statistically significant difference in deaths according to the parameters in the study population (p-value >0.05) [Table/Fig-7]. The patient who died following nephrectomy had previously undergone PCD (a minimally invasive intervention). Only one patient underwent nephrectomy directly without prior minimally invasive intervention and survived. The other two patients who underwent nephrectomy also had minimally invasive interventions beforehand and survived.

Parameters {N (%)}	Death		p-value
	Yes	No	
HTN			
Yes, 43 (53.8%)	7 (16.3%)	36 (83.7%)	0.730
No, 37 (46.2%)	5 (13.5%)	32 (86.5%)	
T2DM			
Yes, 71 (88.8%)	11 (15.5%)	60 (84.5%)	1.000
No, 9 (11.2%)	1 (11.1%)	8 (88.9%)	
IHD			
Yes, 6 (7.5%)	1 (16.7%)	5 (83.3%)	1.000
No, 74 (92.5%)	11 (14.9%)	63 (85.1%)	
BPH			
Yes, 1 (1.3%)	1 (100%)	0 (0%)	1.000
No, 79 (98.7%)	11 (13.9%)	68 (86.1%)	
CKD			
Yes, 2 (2.5%)	0 (0%)	2 (100.0%)	1.000
No, 78 (97.5%)	12 (15.4%)	66 (84.6%)	
Nil			
Yes, 4 (5.0%)	0 (0%)	4 (100%)	1.000
No, 76 (95.0%)	12 (15.8%)	64 (84.2%)	

[Table/Fig-6]: Comparison of comorbidity with outcome (survival vs death) in EPN (N=80).
HTN: Hypertension; T2DM: Type 2 diabetes mellitus; IHD: Ischaemic heart disease; BPH: Benign prostate hyperplasia; CKD: Chronic kidney disease

Parameters	Death		p-value
	Yes (n=12)	No (n=68)	
Minimally invasive interventions			
Unilateral DJS {39 (48.8%)}	4 (33.3%)	35 (51.5%)	0.713
Bilateral DJS {22 (27.5%)}	4 (33.3%)	18 (26.5%)	
PCN {3 (3.8%)}	1 (8.3%)	2 (2.9%)	
PCD {15 (18.8%)}	3 (25%)	12 (17.6%)	
None {1 (1.3%)}	0 (0%)	1 (1.5%)	
Nephrectomy intervention* {4 (5.0%)}	**Yes (n=1)**	**No (n=3)**	**p-value**
	1 (8.3%)	3 (4.4%)	0.485

[Table/Fig-7]: Comparison of minimally invasive interventions vs nephrectomy interventions with outcome (survival vs death) in EPN (N=80).
*The patient who died following nephrectomy had earlier undergone PCD (min. invasive intervention); Only one patient underwent nephrectomy directly without minimally invasive intervention and survived. Other two patients who underwent nephrectomy also had minimally invasive interventions before and survived; DJS: Double J stenting; PCN: Percutaneous nephrostomy; PCD: Percutaneous drainage

When analysing interventional outcomes for EPN, mortality counts were 1/20 (5.0%) for Class 1, 4/25 (16.0%) for Class 2, 3/17 (17.6%) for Class 3, and 4/18 (22.2%) for Class 4. Minimally invasive interventions were predominantly utilised, with unilateral DJS being common in Classes 1 (20/20, 100%) and 2 (19/25, 76%). PCD was frequently used in Class 3 (14/17, 82.4%), while bilateral DJS was common in Class 4 (16/18, 88.9%). Nephrectomy was performed selectively across all classes, with 1/25 (4.0%) in Class 2, 2/17 (11.8%) in Class 3, and 1/18 (5.6%) in Class 4 [Table/Fig-8].

EPN Class (N=80)	Interventions	Death
Minimally invasive interventions based on EPN class (Survival vs Death)		
Class 1 (n=20)	Unilateral DJS (20)	Yes (1)
		No (19)
Class 2 (n=25)	Unilateral DJS (19)	Yes (3)
		No (16)

	Bilateral DJS (4)	Yes (1)
		No (3)
	PCN (1)	No (1)
	None (1)	No (1)
Class 3 (n=17)	Bilateral DJS (2)	No (2)
	PCD (14)	Yes (2)
		No (12)
	PCN (1)	Yes (1)
Class 4 (n=18)	Bilateral DJS (16)	Yes (3)
		No (13)
	PCN (1)	No (1)
	PCD (1)	Yes (1)
Nephrectomy intervention based on EPN class (Survival vs Death)		
Class 1 (n=20)	No (20)	Yes (1)
		No (19)
Class 2 (n=25)	Yes (1)	No (1)
	No (24)	Yes (4)
		No (20)
Class 3 (n=17)	Yes (2)	No (2)
	No (15)	Yes (3)
		No (12)
Class 4 (n=18)	Yes (1)	Yes (1)
	No (17)	Yes (3)
		No (14)

[Table/Fig-8]: Outcomes (Survival vs Death) of minimally invasive interventions and nephrectomy intervention based on EPN class (N=80).

DISCUSSION

The EPN is an acute necrotising infection of the renal parenchyma or urinary system caused by gas-forming organisms such as *E. coli* and *Klebsiella* [14]. Kelly and MacCullem reported the first case of EPN in 1898; the term "EPN" was coined by Schultz and Klorfein in 1962 [15]. The mortality rate observed in the present study was 15% (12 deaths), which is consistent with the lower end of the reported range (11-42%) [16-18] and below the overall mortality of 19% [19] documented in an international meta-analysis.

The study's mean age of 57.9±12.2 years and gender distribution (48.8% female, 51.2% male) are consistent with findings in some studies but deviate from others. Desai R and Batura D's meta-analysis reported a higher female predominance (68.9%) [7], attributed to the predisposition of females to Urinary Tract Infections (UTIs). This divergence highlights that gender distribution in EPN may vary by demographic factors and population characteristics. The high prevalence of diabetes mellitus in the study cohort (88.8%) reinforces its role as the most critical predisposing factor for EPN. Huang JJ and Tseng CC also found diabetes in 96% of their cases, attributing this to hyperglycaemia-induced immunosuppression and a glucose-rich environment that facilitates gas-forming infections [9]. Other studies, such as those by Eswarappa M et al., and Wu SY et al., further corroborate that poor glycaemic control is a universal finding in EPN patients [2,20].

Flank pain (91.3%) and fever (86.3%) emerged as hallmark symptoms in the study cohort, consistent with findings by Eswarappa M et al., and Khandelwal AK who reported these symptoms as predominant in EPN patients [2,21]. In addition to these classic presentations, we documented dysuria in 36.3% of cases and left-sided flank tenderness in 51.3%, highlighting the potential for lateralised clinical manifestations. This specificity may aid in distinguishing EPN from other renal or urological conditions during differential diagnosis. Other atypical symptoms such as nausea, abdominal discomfort, and dysuria have been previously noted by Storey B et al., and Wu SY et al., as secondary indicators, further emphasising the importance of clinical suspicion in diabetic patients with non specific presentations [3,20].

Microbiologically, *Escherichia coli* was the predominant pathogen isolated in 42.5% of the study cases, aligning with findings from Desai R and Batura D who reported a 58% prevalence [7]. Klebsiella and Pseudomonas were also frequently identified pathogens, as highlighted by Das D and Pal DK, and Wu SY et al., [15,20]. The predominance of E. coli in EPN cases is attributed to its ability to ferment glucose and produce gas, a hallmark of this necrotising infection.

Radiological findings remain central to the diagnosis and classification of EPN. In the study, Class 2 EPN (31.3%) was the most common classification, reflecting moderate disease severity. This aligns with findings from Storey B et al., and Somani BK et al., who observed a similar predominance of moderate disease (Classes 2 and 3) in their cohorts [3,22]. The Huang and Tseng classification system, which stratifies EPN severity based on gas distribution, continues to serve as a vital tool in guiding management decisions [9]. Wu SY et al., emphasise that higher classes (e.g., Class 3B or Class 4) are associated with poor prognosis and increased mortality rates, further underscoring the clinical importance of early imaging [20].

The study identified key prognostic factors for mortality, including hypotension (p-value=0.015), elevated HbA1c levels (mean 12.2 vs. 9.5; p-value=0.018), and the need for dialysis (p-value=0.008). These findings are consistent with Desai R and Batura D conclusions that shock, hyperglycaemia, and renal dysfunction are critical predictors of poor outcomes [7]. Hypotension, in particular, reflects systemic involvement and sepsis, which significantly worsens prognosis, as corroborated by Storey B et al., and Khandelwal AK [3,21].

The overall mortality rate in the study cohort was 15%, with 14.47% (11 out of 76 patients) in the minimally invasive group and 25% (1 out of 4 patients) in the delayed nephrectomy group; this is slightly higher than the 13.5% reported by Somani BK et al., for cases with minimally invasive interventions [22]. This disparity may reflect the higher prevalence of severe cases in the study. Storey B et al., noted that patients with advanced disease (e.g., Class 3B or Class 4) had mortality rates exceeding 50%, underscoring the need for early intervention and close monitoring in such cases [3]. The mortality rate with emergency nephrectomy was 33.3%, as per Aboumarzouk OM et al., [19].

The emphasis on minimally invasive interventions in the study reflects a significant paradigm shift in EPN management. Nearly half (48.75%) of the study patients underwent unilateral DJS, while 27.5% required bilateral stenting. This approach resulted in a remarkably low nephrectomy rate of 5%, significantly lower than historical rates of 40-50% reported in earlier studies [3]. The success of these interventions aligns with findings by Das D and Pal DK, who achieved 100% survival using DJS and PCN as primary treatments [15]. Similarly, Storey B et al., highlighted that minimally invasive approaches not only reduce nephrectomy rates but also improve overall survival outcomes, particularly in patients with moderate disease severity [3].

Minimally invasive techniques, such as PCN, have shown particular efficacy in managing severe cases (e.g., Class 3B and 4). Das D and Pal DK demonstrated that timely drainage significantly reduces systemic complications and facilitates renal preservation [15]. However, advanced cases with extensive perirenal involvement or poor initial response to conservative management often necessitate nephrectomy. Khandelwal AK and Wu SY et al., both advocate reserving nephrectomy as a last resort, emphasising the need for patient-specific management strategies [20,21].

The study findings further underscore the survival benefits of early and individualised management. Even in higher EPN classes, timely use of broad-spectrum antibiotics combined with minimally invasive drainage yielded favourable outcomes. These results align with

Eswarappa M et al., who reported significant reductions in mortality and morbidity with similar approaches [2].

The global trend towards minimally invasive intervention management of EPN is well-supported by recent studies. Das D and Pal DK, and Wu SY et al., emphasise that early drainage, combined with antibiotic therapy, has dramatically improved survival rates while minimising the need for nephrectomy [15,20]. The study findings align with this growing consensus, contributing to the evolving understanding of EPN management.

However, as highlighted by Storey B et al., and Khandelwal AK the success of conservative approaches depends on early recognition and appropriate risk stratification [3,21]. Poor prognostic indicators, such as shock, thrombocytopenia, and hypoalbuminaemia, necessitate aggressive intervention and close monitoring. Storey B et al., further noted that delayed or inadequate management in severe cases can lead to rapid clinical deterioration, emphasising the critical importance of early imaging and tailored treatment strategies [3].

Limitation(s)

The limitation of the study is that it's a retrospective cohort study, which may introduce selection bias and limit the ability to establish causal relationships. Additionally, the follow-up period was restricted to 24 weeks, potentially reducing the ability to assess long-term outcomes. Furthermore, some data were unavailable, such as a few missing urine culture reports and the subdivision of Class 3 into 3A and 3B on CT imaging, which may affect the completeness of the analysis.

CONCLUSION(S)

The findings in the study reinforce the growing consensus favouring minimally invasive interventional management, offering significant survival benefits and reduced nephrectomy rates. Delayed nephrectomy is advisable and should be reserved for those who do not respond to initial treatments or in cases of non functioning kidneys. Hypotension, poorly controlled diabetes, and the need for dialysis were key prognostic factors and should guide the early identification of high-risk patients to manage outcomes. It is imperative to adopt individualised, patient-centred care strategies in the management of this life-threatening condition.

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