# CUTTING-EDGE APPROACHES TO EMPHYSEMATOUS PYELONEPHRITIS: DIAGNOSIS, MANAGEMENT, AND FUTURE DIRECTIONS


**Abstract :-**

**Introduction**: Emphysematous Pyelonephritis (EPN) is a life-threatening infection characterized by gas formation within renal tissues, often associated with diabetes and immunocompromised states. Mortality rates were previously high, but advances in imaging, diagnosis, and treatment have improved outcomes.

**Aim**: This study aims to review recent advancements in EPN management, from early diagnosis to current therapeutic approaches, while identifying areas for future research and innovation.

**Results**: EPN is predominantly diagnosed in diabetic patients and those with urinary obstruction. Key pathogens include Escherichia coli and Klebsiella pneumoniae. Imaging, especially CT scans, plays a critical role in classifying and managing EPN, with minimally invasive techniques such as percutaneous drainage emerging as effective interventions. Medical management, including strict glycaemic control and targeted antibiotics, has reduced the need for nephrectomy in lower-grade EPN cases.

**Conclusion**: Advances in EPN management—diagnostic imaging, minimally invasive interventions, and improved medical therapy—have decreased mortality and morbidity. Future directions include predictive analytics for early diagnosis and novel antibiotics for resistant pathogens.


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**Commented [B3]:** CT scan (Computed Tomography)

**Keywords:** Emphysematous Pyelonephritis, diabetes, CT imaging, percutaneous drainage, nephrectomy,

**Introduction** : Emphysematous Pyelonephritis (EPN) is a severe, life-threatening infection of the kidney characterized by gas formation within the renal parenchyma, collecting system, and perinephric tissues [1]. Initially described as a highly fatal disease with mortality rates as high as 80%, EPN was considered a medical emergency requiring immediate intervention [2]. Over the past two decades, advancements in imaging techniques, better understanding of the pathophysiology, and improved medical and surgical management have revolutionized the treatment approach, significantly reducing mortality and morbidity [3].

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The term "EPN" was coined by Schultz and Klorfein in 1962 when they described the characteristic radiographic findings of gas formation in a diabetic patient. Previously, terms such as "pneumonephrosis" and "pneumopyonephrosis" were used to describe the gas-producing infections of the kidneys [4]. EPN occurs predominantly in individuals with uncontrolled diabetes mellitus, compromised immune function, or urinary tract obstruction. Early detection, aggressive medical treatment, and minimally invasive surgical interventions have drastically improved outcomes for patients suffering from this once-dreaded condition.

**Epidemiology and Risk Factors**: EPN is most commonly seen in individuals with diabetes, accounting for 85-95% of cases [5]. It has been postulated that hyperglycemia and ketoacidosis in diabetic patients provide an optimal environment for the growth of gas-forming organisms. The presence of necrotizing infections in EPN can also be linked to poor tissue perfusion, which is often observed in these patients. Other risk factors include urinary tract obstruction (e.g., urolithiasis), chronic kidney disease (CKD), and immunosuppressive states (e.g., transplant recipients, patients on corticosteroids).

The typical pathogens isolated from EPN patients include gram-negative organisms such as Escherichia coli (70-80% of cases) and Klebsiella pneumoniae [6]. These organisms are capable of fermenting glucose and producing gas, which accumulates within the kidney and surrounding tissues. In recent years, there has been an increase in reports of fungal and polymicrobial infections, particularly in patients who are immunocompromised. Prompt recognition of these atypical organisms and early antifungal therapy is critical in improving outcomes.

**Diagnostic Modalities**: Accurate and timely diagnosis of EPN is essential for effective management. The evolution of imaging techniques has played a pivotal role in reducing the need for invasive procedures and improving survival rates. The shift from traditional radiographs to advanced cross-sectional imaging has allowed for more precise visualization of the extent of infection and gas accumulation.

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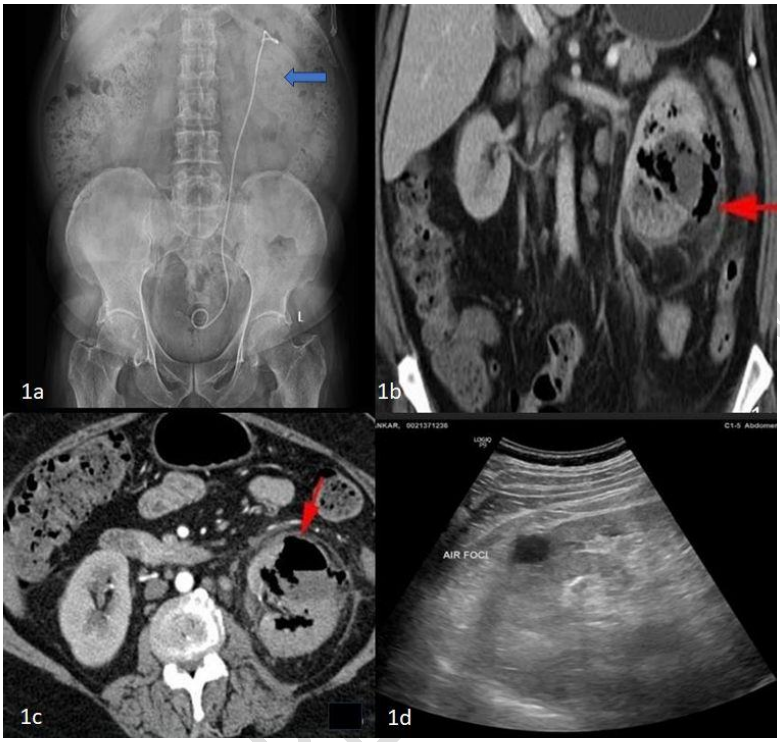


Fig 1. Imaging showing gas in renal parenchyma. 1a. X-ray KUB showing multiple gas shadows- EPN in Right Kidney. 1b and 1c. Coronal and axial CT imaging showing gas in left renal parenchyma. 1d. ultrasound showing hyperechogenic foci in the left kidney. Historically, plain radiography was one of the earliest diagnostic tools used to detect gas formation in EPN. The presence of gas in the renal parenchyma or surrounding tissues could be visualized on X-ray films. However, X-rays have significant limitations in sensitivity and specificity, and their role in modern-day EPN diagnosis is minimal, primarily reserved for initial evaluations or when advanced imaging is unavailable.

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Ultrasound imaging, particularly in resource-limited settings, provides a non-invasive and relatively accessible method to detect gas and fluid collections in the kidneys. Gas appears as hyperechoic areas with "dirty shadows" on ultrasound, and abscess formation can also be visualized. While ultrasound is useful for detecting EPN, it is less sensitive than other imaging modalities, particularly in the early stages of infection or in cases where gas production is minimal. CT scan (Computed Tomography) is the gold standard for diagnosing EPN is a contrast-enhanced CT scan. CT provides detailed anatomical images, allowing for accurate assessment of the extent of renal and perirenal gas, abscess formation, and involvement of surrounding tissues. CT scans also enable the classification based on the extent of gas and the severity of renal destruction.

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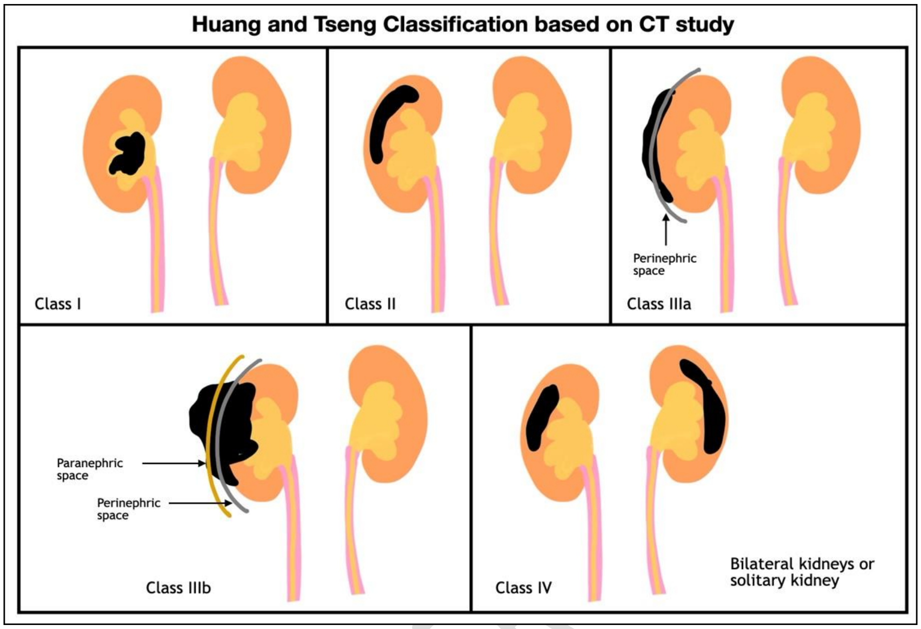
The following classification system, based on CT findings, is widely used (Huang and Tseng) [7]:




- Class 1: Gas confined to the collecting system (emphysematous pyelitis).
- Class 2: Gas within the renal parenchyma without extension to the perirenal space.
- Class 3A: Gas or abscess extension into the perinephric space.
- Class 3B: Extension of gas beyond the Gerota's fascia.
- Class 4: Bilateral EPN or solitary kidney involvement.

A CT scan not only helps in diagnosis but also aids in deciding the management approach. Patients with Class 1 or 2 disease often respond to conservative management, while those with Class 3 and 4 EPN may require drainage or nephrectomy.

MRI (Magnetic Resonance Imaging): MRI is not routinely used in the evaluation of EPN due to its limited ability to detect gas formation compared to CT. However, in specific clinical scenarios where CT is contraindicated, such as in patients with contrast allergies or poor renal function, MRI may be considered. MRI is also useful in assessing soft tissue involvement and can provide additional information on abscess formation and vascular involvement.

Renal Scintigraphy: Renal scans, using technetium-99m (Tc-99m) mercaptoacetyltriglycine (MAG3), can be useful to evaluate the functional status of the kidney. In cases where the viability of the renal tissue is in question, renal scintigraphy can help guide the decision to proceed with nephrectomy. It provides an objective assessment of renal perfusion and function, particularly in cases where there is significant destruction of the renal parenchyma.

**Management Strategies**

The management of EPN has evolved significantly, with a shift from radical surgical interventions to a more conservative and minimally invasive approach.

**MEDICAL MANAGEMENT**

Antibiotic Therapy: The mainstay of EPN treatment is broad-spectrum antibiotic therapy targeting the gram-negative organisms most commonly associated with the disease. Newer generations of cephalosporins (e.g., cefepime, ceftriaxone) and carbapenems (e.g., meropenem, imipenem) have shown efficacy in treating severe infections. Piperacillin-tazobactam is another potent combination with broad coverage against gram-negative organisms, including Pseudomonas aeruginosa. Antibiotic

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Glycemic Control: As uncontrolled diabetes is one of the most significant risk factors for EPN, strict glycemic control is essential in managing these patients. Continuous glucose monitoring (CGM) devices allow for real-time tracking of blood sugar levels, enabling better control and reducing the risk of complications. Advances in diabetes medications, such as SGLT2 inhibitors and GLP-1 receptor agonists, have also improved long-term glucose control and may contribute to better outcomes in diabetic patients with EPN [9].

**INTERVENTIONAL TECHNIQUES**

***Percutaneous Drainage (PCD)***: In patients with gas or fluid collections, percutaneous drainage (PCD) is an effective, minimally invasive technique that can help drain abscesses and relieve pressure. Under image guidance (CT or ultrasound), catheters are placed to allow continuous drainage of infected material. PCD has reduced the need for nephrectomy in many patients with EPN, especially those with Class 1 or 2 disease [10].

Fig 2. Percutaneous drainage of the left renal gas, with a Malecot drainage tube in place.

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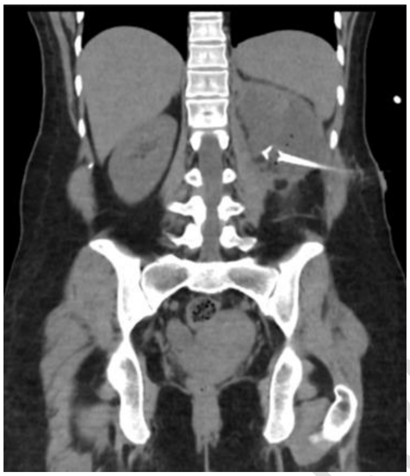

***Double-J (DJ) Stenting***: For patients with concomitant urinary obstruction, placement of a DJ stent can help restore urinary flow and prevent further complications. DJ stents are inserted into the ureter to bypass the obstruction and facilitate the drainage of urine from the kidney to the bladder [11].

***Nephrectomy***: Despite advances in conservative management, nephrectomy remains necessary for patients with extensive renal destruction or failure to respond to medical and minimally invasive interventions. Indications for nephrectomy include non-resolving sepsis, extensive abscess formation, or functional loss of the kidney as confirmed by imaging or renal scans [12].

**Prognostic Factors and Risk Stratification**

The prognosis of EPN depends on several factors, including the extent of infection, the presence of co-morbidities such as diabetes and CKD, and the timing of intervention. Early diagnosis and prompt treatment are associated with better outcomes. Various scoring systems have been developed to help stratify patients based on the severity of the disease and guide treatment decisions.

***NEWS 2 scoring System***: Developed to triage EPN patients, this system takes into account factors such as renal function, extent of gas formation, and the presence of multi-organ dysfunction. Patients with higher scores are more likely to require nephrectomy or have a higher risk of mortality [13].

***Laboratory Markers***: Elevated levels of C-Reactive Protein (CRP) and Erythrocyte Sedimentation Rate (ESR) are commonly seen in EPN and can help monitor disease severity and response to treatment. Persistent elevation of these markers may indicate inadequate control of infection and the need for further intervention [14].

**Future Directions**

The management of EPN has significantly evolved with the advent of better imaging techniques, antibiotic therapies, and minimally invasive interventions. Looking ahead, the integration of machine learning and artificial intelligence into diagnostic radiology may further enhance early detection and prognostication of EPN. Additionally, the development of novel antibiotics targeting multi-drug-resistant organisms, as well as advancements in diabetic management, will continue to improve outcomes for patients with EPN.

The future of EPN management may also involve the use of prognostic algorithms based on large-scale data from electronic medical records (EMR) and predictive analytics. With increased awareness and continued research, the goal of achieving zero nephrectomy rates and near-complete renal salvage in EPN patients seems within reach.

Recent advancements in diagnosing Emphysematous Pyelonephritis (EPN) have emphasized precision and early detection, allowing for timely and targeted interventions. Here are some of the key recent diagnostic developments:

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## I. ADVANCED IMAGING TECHNIQUES

*Dual-Energy CT (DECT)*: DECT enables more detailed visualization of gas and other soft tissue structures, potentially differentiating gas pockets from fluid collections or renal parenchyma. This technique can enhance sensitivity and specificity in identifying the spread of infection.

*Functional MRI (Diffusion-Weighted Imaging - DWI)*: MRI with DWI can provide insight into tissue perfusion and cellular activity, which may help distinguish EPN from other types of renal infections. This is particularly useful in patients for whom radiation exposure from CT may be a concern.

*3D Imaging and Reconstruction*: Newer software can reconstruct high-resolution 3D images from CT scans, helping clinicians visualize the extent and severity of gas formation within the renal and perinephric areas. This allows better planning for drainage or surgical interventions.

## II. POINT-OF-CARE ULTRASOUND (POCUS)

*Contrast-Enhanced Ultrasound (CEUS)*: CEUS is gaining traction as a quick, bedside tool that can provide real-time images of kidney perfusion and areas of gas formation. It’s especially valuable for patients who are critically ill and cannot be transported for a CT scan.

*Elastography*: This ultrasound technique assesses tissue stiffness, which can help in differentiating EPN (often associated with gas and necrosis) from other less severe renal infections.

## III. BIOMARKERS AND MOLECULAR DIAGNOSTICS

Procalcitonin and C-Reactive Protein (CRP): Elevated levels of procalcitonin and CRP have shown promise in assessing infection severity. While not specific to EPN, they can provide a quantitative measure of inflammation that supports imaging findings and helps in risk stratification.

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*Novel Molecular Markers*: Research into specific biomarkers, such as urinary cytokines and proteins, is ongoing. Markers that indicate renal tissue necrosis or gas-producing organisms could potentially serve as early indicators of EPN severity or prognosis.

## IV. ARTIFICIAL INTELLIGENCE (AI) AND MACHINE LEARNING MODELS

AI-Assisted Imaging Analysis: Machine learning algorithms trained on CT and MRI data are being developed to detect gas pockets and necrotic tissue patterns indicative of EPN. These tools can aid radiologists in identifying EPN with greater accuracy, especially in early stages.

*Predictive Models for Risk Stratification*: AI-based predictive models can analyze a range of data (e.g., demographic, clinical, and lab data) to assess a patient's risk for developing EPN or experiencing severe outcomes. This supports early diagnosis and proactive management, especially in high-risk groups.

## V. MULTIPARAMETRIC APPROACHES

Combining imaging with laboratory and molecular data allows for a multiparametric approach, where diagnostic algorithms integrate multiple inputs to assess the likelihood of EPN versus other types of renal infections. This approach is especially useful for challenging cases where EPN may not present with classic imaging features.

These advances collectively contribute to faster, more accurate diagnosis of EPN, enabling clinicians to start appropriate interventions sooner and potentially reducing the need for invasive procedures in many cases.

**Conclusions**:

While EPN remains a serious and potentially life-threatening condition, the advances in medical, radiological, and surgical techniques have transformed the prognosis for patients with this disease. Early diagnosis, aggressive management of infection and diabetes, and minimally invasive interventions have drastically reduced the mortality associated with EPN, offering hope for continued improvement in the future.

**References**

1. Adli OE, El Ammari JE, Elfassi MJ, Farih MH. Extensive emphysematous pyelonephritis leading to renal destruction. African Journal of Urology. 2012 Dec 16;18(2):87-9.

Commented [B15]: 89

2. Kone K, Mallikarjun NT, Rams MK. Mortality in emphysematous pyelonephritis: Can we reduce it further by using a protocol-based treatment? The results of a prospective study. Urology Annals. 2022 Jan 1;14(1):73-80.

3. Malolan PA, Shivaswamy BS, Babu GR, Santhosh CS. Emphysematous pyelonephritis masquerading as hollow viscus perforation. African Journal of Emergency Medicine. 2014 Dec 1; 4(4):e9-11.

4. Welch NM, Prather GC. Pneumonephrosis a Complication of Necrotizing Pyelonephritis. J Urol. 1949;61(4):712-718. doi:10.1016/S0022-5347(17)69130-4

5. Banerjee S, editor. Infections in Diabetes-ECAB. Elsevier Health Sciences; 2012 Jul 5.

6. Aleyo R. Characterization and antimicrobial activity of Serratia Marcescens endosymbionts of Rhabditis nematodes against selected bacterial and fungal pathogen (Doctoral dissertation, University of Nairobi).

7. Wang JM, Lim HK, Pang KK. Emphysematous pyelonephritis: Twelve years' experience at a medical center. Scandinavian journal of urology and nephrology. 2007 Jan 1;41(3):223-9.

8. Huang JJ, Tseng CC. Emphysematous pyelonephritis: clinicoradiological classification, management, prognosis, and pathogenesis. Archives of internal medicine. 2000 Mar 27;160(6):797-805.

9. González-Pérez RA, Cisneros-García DL, Hernández-Muñoz EA, González-González CA, Beas-Ruíz-Velasco C, Sierra-Díaz E. Empirical management of


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emphysematous pyelonephritis: comparison between two antimicrobial schemes Tratamiento empirico de la pielonefritis enfisematosa: carbapenémicos contra antibióticos alternativos. Bol Col Mex Urol. 2023;38(2):55-9.

10. Anson M, Zhao SS, Austin P, Ibarburu GH, Malik RA, Alam U. SGLT2i and GLP-1 RA therapy in type 1 diabetes and reno-vascular outcomes: a real-world study. Diabetologia. 2023 Oct;66(10):1869-81.

11. Fukunaga S, Naito Y, Hoshino Y, Oba M, Kawanishi M, Yoshikane K, Egawa M, Ito T, Tanabe K. Indications for Percutaneous Drainage in Patients with Huang Class 3B Emphysematous Pyelonephritis: A Case Report and Literature Review. Internal Medicine. 2023 Oct 1;62(19):2871-6.

12. Joshi HK, Shah VR, Parikh MD. Clinical profile and outcome of emphysematous pyelonephritis presenting to a tertiary care hospital. African Journal of Urology. 2023 Oct 10;29(1):51.

13. Aggarwal D, Mandal S, Parmar K, Manoharan V, Singh S, Yadav AK, Kumar S, Sharma AP, Singh SK. Predictors of mortality and nephrectomy in emphysematous pyelonephritis: a tertiary care centre study. The Annals of The Royal College of Surgeons of England. 2023 Apr 26;105(4):323-30.

14. Bibi M, Chaker K, Ouanes Y, Baccouch R, Madani MA, Mediouni H, Mosbahi B, Mourad Dali K, Rahoui M, Nouira Y. Comparison of prognosis of five scoring systems in emphysematous pyelonephritis patients requiring intensive care. International Urology and Nephrology. 2023 Dec;55(12):3045-50.

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**Commented [B22]:** percutaneous drainage in patients with

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15. Shaikh KJ, Osio VA, Leeflang MM, Shaikh N. Procalcitonin, C-reactive protein, and erythrocyte sedimentation rate for the diagnosis of acute pyelonephritis in children. Cochrane Database of Systematic Reviews. 2020(9).

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**Commented [B28]:** DOI: 10.1002/14651858.CD009185.pub3.