

Decoding acute pyelonephritis: imaging signatures and patterns of renal involvement across modalities

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ABSTRACT

Aims: Acute pyelonephritis (APN) and acute focal bacterial nephritis (AFBN) are severe forms of urinary tract infection with overlapping clinical features. Differentiating these entities and assessing disease extent by imaging are critical for guiding management and preventing complications. Each modality has unique strengths and limitations. This study aimed to evaluate imaging-based differences between APN and AFBN and to assess the diagnostic performance of commonly used modalities.

Methods: This retrospective study included 87 adult patients with renal parenchymal infection evaluated between 2018 and 2024. Imaging modalities comprised computed tomography (CT, n=87; 20 non-contrast, 67 contrast-enhanced), magnetic resonance imaging (MRI, n=20), and ultrasound (USG, n=53). Imaging features were compared between APN and AFBN. The diagnostic performance of non-contrast CT (NCCT), USG, and MRI was assessed using contrast-enhanced CT (CECT) as the reference standard. Agreement between CECT and contrast-enhanced MRI (CE-MRI) was analyzed using Cramer's V.

Results: APN was diagnosed in 40 patients (46%) and AFBN in 47 (54%). Complication rates, causative microorganisms, and associated findings did not differ significantly between groups. CECT was the most reliable modality, whereas USG (sensitivity 26.4%) often failed to detect the infection, and NCCT frequently failed to delineate the extent of disease. CE-MRI showed excellent agreement with CECT (Cramer's V=0.93, p<0.001) but offered no additional diagnostic value. DWI was more sensitive in defining infection extent, revealing additional foci in AFBN or more localized disease in APN. All lesions visible on CE-T1WI were also detected on T2WI, and the combined use of DWI and T2WI improved diagnostic confidence, with T2WI contributing additional specificity.

Conclusion: While APN and AFBN share similar clinical and microbiological characteristics, radiological patterns suggest differences in inflammatory pathogenesis. CECT remains the reference standard, but USG and NCCT have limited diagnostic value. MRI—particularly diffusion-weighted imaging (DWI) combined with T2-weighted image (T2WI)—demonstrated superior sensitivity and may serve as a promising contrast-free alternative, especially in children, pregnant patients, and those with impaired renal function.

Keywords: Acute pyelonephritis, acute focal bacterial nephritis, magnetic resonance imaging, diffusion-weighted imaging, contrast-enhanced CT

INTRODUCTION

Acute pyelonephritis (APN) represents the severe end of the urinary tract infection (UTI) spectrum, extending from simple cystitis to renal parenchymal involvement. Delayed diagnosis or inadequate treatment may cause severe complications, even in healthy individuals, such as renal/perirenal abscess, emphysematous pyelonephritis (PN), sepsis, renal failure, multiorgan dysfunction, shock, and death.¹ Although APN is most prevalent in young women, hospitalization rates are slightly higher in men and young children.² Risk factors for severe disease include diabetes mellitus (DM), immunosuppression, urinary tract anomalies,

nephrolithiasis, prior instrumentation, and advanced age.³ *Escherichia coli* is the most common pathogen, though the microbial spectrum may vary depending on host factors.⁴

Acute focal bacterial nephritis (AFBN) is a localized but severe form of renal parenchymal infection involving one or more lobules. It typically appears as single or multiple mass-forming, non-liquefactive foci of bacterial inflammation and is considered a precursor to renal abscess, analogous to early cerebritis or phlegmon.⁵ Historically regarded as a pediatric entity,⁶⁻⁸ AFBN is increasingly recognized in adults with the widespread use of cross-sectional imaging.⁹⁻¹¹

The clinical presentation of APN is highly variable, ranging from lower urinary tract symptoms (e.g., dysuria, urgency, suprapubic pain) to renal colic-like manifestations (e.g., flank pain, costovertebral angle tenderness, nausea, vomiting) or systemic inflammatory signs (e.g., fever, chills, sepsis). Laboratory findings such as pyuria, bacteriuria, leukocytosis, and elevated acute-phase reactants support the diagnosis, but the wide variability in presentation makes it difficult to establish standardized diagnostic criteria.^{1,12}

Imaging plays a pivotal role in the prompt and accurate diagnosis of APN, particularly given its diverse clinical presentations and substantial risk of complications. In APN cases presenting with acute obstructive uropathy symptoms, imaging is crucial for detecting parenchymal infection that accompanies calculi or structural anomalies.¹³ Underestimating disease severity—for example, mistaking APN for simple cystitis in patients with mild symptoms—may lead to recurrence, progression, or sequelae such as renal scarring. Likewise, in patients presenting with systemic inflammatory signs, where the differential diagnosis is broad, imaging becomes indispensable for ensuring timely and precise evaluation.

This study aimed to assess the extent of renal involvement in adult APN based on imaging characteristics and to relate these findings to underlying etiology, associated complications, and potential sequelae. Furthermore, we sought to compare the diagnostic performance of commonly used imaging modalities in delineating and extending the characterization of disease patterns. Although both computed tomography (CT) and magnetic resonance imaging (MRI) have been studied in APN, most prior reports have evaluated these modalities in isolation, and comparative analyses remain limited. Moreover, few studies have systematically correlated imaging patterns with etiology, complications, and sequelae in adult populations. Our study addresses these gaps by comparatively evaluating CT, MRI, and ultrasound (USG) in adult cases of both APN and AFBN.

METHODS

This study has been approved by the Non-interventional Clinical Researches Ethics Committee of İstanbul Medipol University (Date: 03.07.2025, Decision No. 819). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki. Written informed consent was obtained from all patients prior to imaging, permitting the use of their anonymized imaging data for scientific research. Owing to the retrospective design, no additional consent was required.

Cross-sectional imaging performed between 2018 and 2024 in patients with suspected renal colic, UTI, abdominal pain, or fever of unknown origin was retrospectively reviewed. Patients younger than 18 years and those evaluated solely with radiography or USG were excluded. Of 225 cases initially identified, 87 were diagnosed with PN, categorized as APN, (diffuse involvement) or AFBN (localized involvement). Patients with isolated pyelitis, ureteritis, cystitis, or obstructive uropathy were excluded from the analysis. The patient selection process is illustrated in the flow diagram (Figure 1).

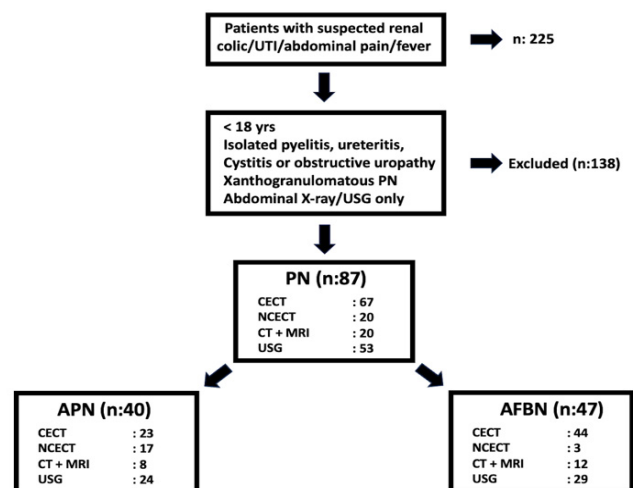


Figure 1. Flow diagram of patient selection and exclusion

PN: Pyelonephritis, APN: Acute pyelonephritis, AFBN: Acute focal bacterial nephritis, CECT: Contrast-enhanced CT, NCCT: Non-contrast CT, USG: Ultrasonography, MRI: Magnetic resonance imaging

CT and MRI scans were evaluated for extent of infection. In patients with both modalities, findings were compared. USG reports were reviewed when available to assess diagnostic contribution.

Two abdominal radiologists (3- and 9-years' experience) independently assessed images, with consensus on discrepancies. Features analyzed included: number of foci, laterality, parenchymal pattern (focal/segmental/diffuse), mass-forming lesions, cortical edema, renal enlargement, hydronephrosis, perirenal effusion, fat stranding, Gerota's fascia thickening, demarcation of foci, and loss/blurring of corticomedullary differentiation. Mass-forming lesions were defined by their morphologic appearance rather than by a strict size threshold, and were characterized by parenchymal mass effect with expansion, mass-like contour and space-occupying features, and localized undulation or lobulation of the renal outer contour.

For contrast-enhanced CT (CECT) and contrast-enhanced MRI (CE-MRI), the phase in which infection-related abnormalities were most clearly visualized (corticomedullary, nephrographic, or excretory) was recorded, and disease extent was compared across modalities. Among non-contrast MRI (NC-MRI) sequences, the most effective sequence for detecting abnormalities was identified. Diffusion-weighted imaging (DWI) was evaluated for the number and distribution of infectious foci and compared with CT findings. Finally, a comparative analysis was performed across non-contrast CT (NCCT), CECT, and MRI.

Predisposing factors, complications, and follow-up imaging were documented. Demographic, clinical, laboratory, and microbiological data (including culture results and treatment regimens) were collected.

Statistical Analysis

The data analyses were performed with Stata version 18.0 (StataCorp LLC, College Station, TX, USA). Descriptive statistics summarized all variables. Imaging features and laboratory parameters were compared between APN and AFBN. Complications were analyzed in relation to imaging.

Chi-square and Levene's tests were used for categorical data; Student's t-test for continuous. Diagnostic performance of NCCT, MRI, and USG was assessed with CECT as reference. Sensitivity and PPV were calculated. Correlation between CECT and CE-MRI was assessed with Cramer's V. Interobserver agreement was measured with Cohen's κ , interpreted as poor (<0.20), fair ($0.21-0.40$), moderate ($0.41-0.60$), good ($0.61-0.80$), or excellent (>0.80).

All patients underwent abdominal CT and MRI examinations using the same institutional protocols and identical acquisition parameters. MR imaging was performed on a 1.5-T system (Ingenia; Philips Healthcare). Routine institutional abdomen imaging sequences were acquired, including; Axial T2W TSE (TR/TE: 1250/80; slice thickness: 4 mm, gap: 0.6; matrix: 288×212). Axial DWI (b=800) (TR/TE: 1028/64; slice thickness: 6 mm; matrix: 132×116). Pre- and post-contrast axial 3D-T1W Dixon (TR/TE1/TE2: 5.9/1.8/1.4; slice thickness: 2 mm; matrix: 200×200).

CT imaging was performed on a 64-detector scanner (SOMATOM go. All; Siemens Healthineers). The protocol included NCCT and, when indicated, CECT urography with corticomedullary, nephrographic, and excretory (pyelographic) phases. Scan parameters were: tube voltage 120 kV, tube current 110 mAs, and pitch 0.80. Data acquisition was performed in spiral mode with a detector configuration of 32×0.7 mm, and images were reconstructed at 1.5-mm slice thickness.

RESULTS

Imaging findings of 87 patients with PN (21 males, 66 females; mean age, 47 years; range, 18–81) were retrospectively reviewed. Age did not differ significantly between sexes (46 vs. 48 years; $p=0.298$). All patients underwent CT (20 NCCT, 67 CECT); 20 also had MRI (mean interval, 3 ± 2 days), and 53 (61%) underwent USG before cross-sectional imaging. APN was diagnosed in 40 patients (46%) and AFBN in 47 (54%), with AFBN more frequent in females (59% vs. 38% in males; $p=0.093$). AFBN cases tended to be older than APN cases among males, whereas the opposite trend was observed in females, though neither difference was statistically significant ($p=0.749$).

High fever was the most common presenting symptom (47%), followed by abdominal pain including flank or suprapubic pain (24%), bladder symptoms (11%), chills (7%) and nausea/vomiting (3%). Imaging was performed for non-UTI indications in 39% of patients ($n=34$), most commonly for suspected renal colic ($n=18$), followed by acute appendicitis ($n=5$), colitis/enteritis ($n=6$), and fever of unknown origin ($n=5$). Laboratory analysis revealed leukocytosis in 65% of patients and leukopenia in 5%. Pyuria and hematuria were detected in 54% and 41%, respectively. The mean CRP level was 149.3 mg/L (95% CI, 123–175), and the mean admission temperature was 38.3°C (95% CI, 38.1–38.6). No significant differences in CRP or body temperature were observed between APN and AFBN; six patients (7%) were afebrile at presentation. Urine cultures were positive in 62 patients (71%), of whom 11 also had concurrent positive blood cultures, all yielding the same pathogen. The rate of blood culture

positivity was significantly higher in APN than in AFBN ($p=0.023$).

Predisposing factors were identified in 48 patients (55%), most commonly immunosuppression (29%) and renal or urothelial calculi (20%). Additional factors included catheterization, recent lithotripsy, urinary tract abnormalities, DM, recurrent UTI, and BPH. Associated findings included ureteritis±cystitis (42%), hydronephrosis (18%), perirenal fat stranding or Gerota's fascia thickening (52%), and perirenal effusion (32%). Pre-existing parenchymal sequelae of unknown cause were present in 23 patients (26%) at the time of imaging. Complications occurred in 16%, predominantly renal abscess (71% of complicated cases). Although the overall complication rate did not differ significantly between APN and AFBN ($p=0.610$), abscesses were more often associated with single, mass-forming lesions ($p=0.001$). ESB+ *E. coli*, *Klebsiella* spp., and Gram-positive cocci were more common in complicated cases, but pathogen distribution did not differ significantly between complicated and uncomplicated infections ($p=0.384$).

Figure 2 shows examples of PN cases with complications. Post-infectious sequelae or scarring were observed in 49 patients (56%) at follow-up and were significantly more frequent in APN cases ($p=0.025$). **Table 1** provides a comprehensive summary of patient demographics, predisposing factors, associated findings, while pathogen distribution and antibiotic treatment are detailed in **Table 2**.

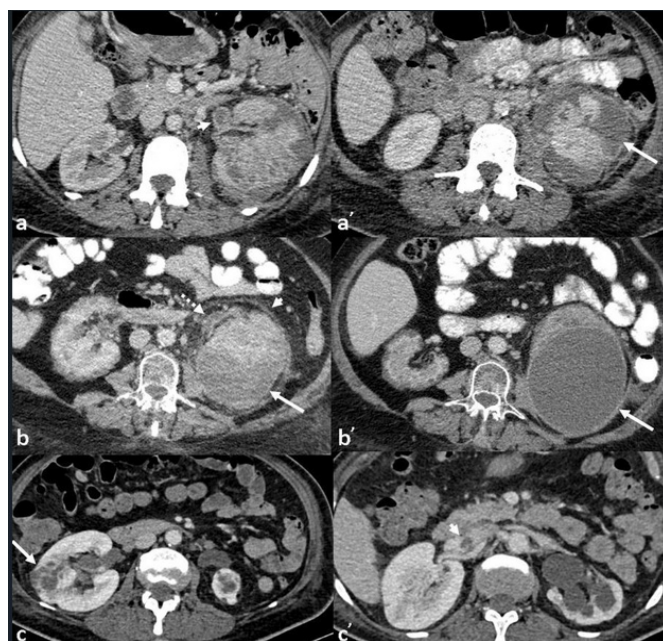


Figure 2. CECT images of pyelonephritis cases with complications. (a, a') APN case: 53-year-old female with DM, admitted with fever and chills. (a) Enlarged left kidney with cortical edema, loss of corticomedullary differentiation, multiple minute hypodense foci consistent with small abscesses, and proximal ureteral wall thickening with enhancement (arrow). (a') Follow-up CT after 4 days shows a subcapsular abscess (arrow). *Klebsiella* spp. isolated from urine and blood cultures. (b, b') AFBN case: 67-year-old female with endometrial carcinoma and DM, presenting with flank pain and fever. (b) Mass-forming lesion in the left kidney (arrow) with thickened Gerota's fascia and ureteritis (short and dotted arrows). Chronic parenchymal changes in the contralateral kidney. (b') Follow-up CT after 10 days demonstrates a large left renal abscess, which was drained. *E. coli* isolated from urine culture. (c, c') AFBN case: 65-year-old female with abdominal pain. (c) Localized right renal lobular enlargement with millimetric abscesses; atrophic left kidney due to chronic obstructive uropathy. (c') CT at renal vein level shows focal right renal vein thrombus (arrow). *Candida glabrata* isolated from urine culture.

CECT: Contrast-enhanced CT, APN: Acute pyelonephritis, DM: Diabetes mellitus, AFBN: Acute focal bacterial nephritis

Table 1. Summary of patient demographics, predisposing factors and associated findings

Patients	Sum	Acute pyelonephritis (APN)	Acute focal bacterial nephritis (AFBN)	p
n	87	40/87	47/87	
Sex (f/m), n	21/66	27/13	8/39	0.093
Age (f/m), yrs	46 (19-81)	48/47	45/50	0.749
Presenting symptoms, % (n)				
-High fever	41 (47%)	23	18	0.402
-Abdominal pain	21 (24%)	6	15	
-Fever + flank pain	5 (6%)	2	3	
-Bladder symptoms	10 (11%)	4	6	
-Chills	6 (7%)	3	3	
-Nausea/vomiting	3 (3%)	2	1	
-Hematuria	1 (1%)	0	1	
Fever °C [95% CI]	38.3 [38.1–38.6]	38.2 [37.9–38.6]	38.5 [38.2–38.9]	0.114
CRP (mg/L) [95% CI]	149.3 [123–175]	150.3 [107–193]	148.4 [115 – 181]	0.471
Laboratory analysis				
-Leukocytosis	56 (65%)	25	31	0.433
-Leukopenia	4 (5%)	3	1	
-Pyuria	47 (54%)	26	21	0.058
-Hematuria	36 (41%)	19	17	0.285
Preliminary diagnosis, n (%)	Other than UTI (34%)			
-Renal colic	18			
-Acute appendicitis	5			
-Colitis/enteritis	6			
-Fever of unknown origin	5			
Urine culture, n (%)	62 / 87 (71%)	32	30	0.112
Blood culture	11/41 (26%)	9	2	0.023*
Predisposing factors, n (%)	48 (55%)			
Immunosuppression	14 (29%)			
-Primary malignancy (CTx±RT)	8			
-Acute Myeloid Leukemia	2			
-Post-transplant	4			
Calculi	10 (20%)			
Recurrent UTI history	4			
Catheterization	4			
Recent history of lithotripsy	4			
DM	4	5	5	0.786
Urinary tract anomaly	3			
BPH	3			
Others	2			
Pre-existing parenchymal sequelae	23 (26%)	8	15	0.209

CTx: Chemotherapy, RT: Radiotherapy, DM: Diabetes mellitus, BPH: Benign prostatic hyperplasia, UTI: Urinary tract infection. p<0.05 considered statistically significant

Among APN cases (n=40), 12 (30%) showed segmental involvement, 18 (45%) diffuse renal involvement without normal parenchyma, and 10 (25%) multiple small foci scattered throughout the kidney. A striated nephrogram pattern on CT was observed only in APN with extensive parenchymal involvement. Of 20 patients who underwent NCCT, 17 were diagnosed with APN and 3 with AFBN. In 12 of the 17 APN cases, NCCT suggested diffuse involvement; however, in 4 cases subsequently evaluated with MRI, 3 (75%) demonstrated discordant findings, with DWI revealing more localized rather than diffuse disease. **Figure 3** illustrates representative imaging findings in APN cases.

Among AFBN cases (n=47), 18 (38%) presented with a single focus, 22 (47%) with a few foci, and 7 (15%) with multiple foci. Of 44 AFBN patients evaluated with CECT, 10 (23%) also underwent MRI; in 9 of these (90%), DWI revealed a greater number of foci than CECT. Among AFBN cases initially assessed with NCCT (n=3), 2 underwent MRI, and in 1 of them (50%), DWI demonstrated more generalized involvement. Despite these differences, comparison of disease extent on CECT and CE-MRI showed excellent correlation

(Cramer's V=0.93, p<0.001). **Figure 4** illustrates representative imaging findings in AFBN cases.

Among patients who underwent USG before cross-sectional imaging (n=53), 39 (74%) were reported as normal and 14 (26%) as abnormal. Reported abnormalities included increased parenchymal echogenicity (n=7, with renal enlargement in 2), uroepithelial thickening (n=2), and perirenal effusion (n=5). The overall sensitivity of USG for detecting abnormal renal findings was 26.4%. When all abnormalities were considered positive, the PPV was 100%; however, restricting positivity to increased parenchymal echogenicity as a more specific marker reduced the PPV to 50%.

Comparative CT analysis showed that cortical edema and renal enlargement were significantly more frequent in APN than in AFBN (cortical edema: 95% vs. 72%, p=0.005; renal enlargement: 75% vs. 8.5%, p<0.001). In APN, 65% of cases appeared hypodense relative to normal parenchyma, whereas 57% of AFBN cases demonstrated heterogeneous attenuation (p<0.001). No significant differences were observed between APN and AFBN in terms of loss of corticomedullary differentiation, hydronephrosis, ascending infection

Table 2. Pathogen distribution and antibiotic treatment				
Causative micro-organisms	Sum	Acute pyelonephritis (APN)	Acute focal bacterial nephritis (AFBN)	P
	n (%)			
Gram-negative bacilli	49 (79%)	10	19	0.053
- <i>Escherichia coli</i>	29	6	4	
- <i>Klebsiella</i> spp.	10	1	0	
- <i>Actinobacteria</i>	1	0	2	
- <i>Pseudomonas aeruginosa</i>	2	5	2	
-Not specified	7			
Gram-positive cocci	8 (13%)	1	1	
- <i>Staphylococcus saprophyticus</i>	2	2	0	
-Coagulase- <i>Staphylococcus</i>	2	3	1	
-Not specified	4			
Gram-positive bacilli	3 (5%)	2	1	
-Not specified	2 (3%)			
Fungi	1	1	0	
- <i>Candida albicans</i>	1	0	1	
- <i>Candida glabrata</i>				
Treatment				
Fosfomisin	2			
Karbapenem	2			
Kolistin (kolistimetat sodyum)	2			
Meropenem	4			
Piperasilin tazobaktam	19			
Sefpodoksım proksetil	4			
Seftriakson	27			
Sefuroksım	2			
Siprofloksasin	6			
Trimetoprim+sulfametoksazol	8			
APN: Acute pyelonephritis, AFBN: Acute focal bacterial nephritis				



Figure 3. Imaging examples from APN cases. (a, a') 25-year-old male with abdominal pain. Extensive segmental involvement of both kidneys is shown, with hypodense areas, cortical edema, and enlargement (arrows). (b) 30-year-old female with fever and flank pain. Pyelogram phase images show bilateral involvement: hypodense and slightly enlarged cortices, with more generalized involvement in the right kidney and a striated nephrogram in the left kidney. (c, c') 44-year-old female with fever. The right kidney is enlarged with multiple small infectious foci scattered throughout, appearing as heterogeneous areas with blurred corticomedullary differentiation in the nephrogram phase. (c') Corresponding NCCT at the same level demonstrates only renal enlargement, without additional detectable abnormalities. (d, d', d'') 70-year-old female with dysuria. (d) NCCT demonstrates only subtle enlargement and decreased density of the left kidney. On the same day, MRI shows clearer abnormalities: (d') axial T2WI reveals heterogeneous cortical hyperintensity; (d'') DWI and ADC maps demonstrate more localized parenchymal infection rather than diffuse involvement. Note the small right kidney, a common finding in elderly patients, highlighting that NCCT evidence of unilateral enlargement may be misleading in this group.

APN: Acute pyelonephritis, NCCT: Non-contrast CT, MRI: Magnetic resonance imaging, T2WI: T2-weighted image, DWI: Diffusion-weighted imaging

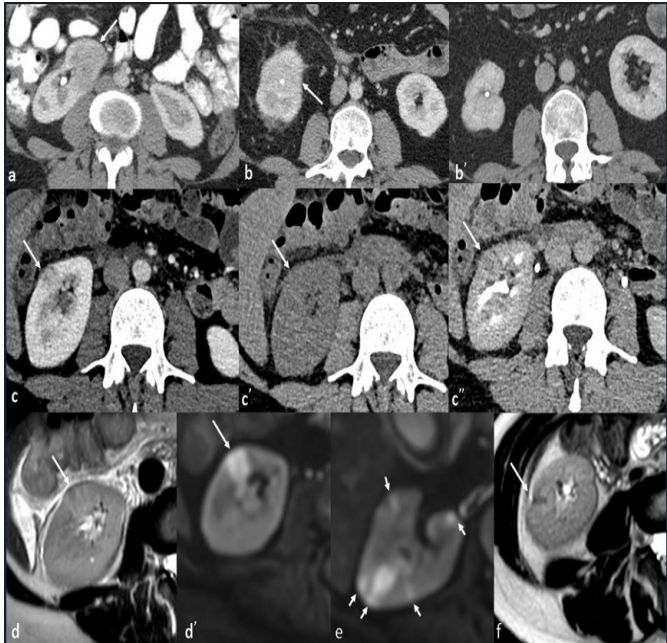


Figure 4. Imaging examples from AFBN cases. (a) CECT of 45-year-old female admitted with flank pain, slightly hypodense mass forming lesion is seen on right kidney (arrow). ESBL+ *E. coli* was isolated from urine cultures. (b, b') CECT of 53-year-old female with flank pain, mass forming lesion with heterogeneous density is displayed (arrow), at the center of infected parenchyma caliceal calculi is seen. Note the peri-renal fat stranding and thickening of Gerato's fascia. (b') CECT taken 9-months after the infection, parenchymal thinning with contour lobulation is shown as slight sequelae. (c-f) 43-year-old female with fever. (c) CECT nephrogram demonstrates a focal small cortical lesion with heterogeneous density and slight expansion (arrow). (c') Corresponding NCCT fails to show the lesion, and (c'') CECT pyelogram makes it less conspicuous due to density similarity with normal parenchyma. (d, d') MRI obtained the following day shows clearer findings: (d) axial T2WI demonstrates a hyperintense expansile lesion (arrow); (d') DWI highlights the infectious focus (arrow). (e) Axial DWI from inferior sections reveals additional small infectious foci not visualized on CECT (short arrows). *Staphylococcus saprophyticus* isolated from urine culture. (f) Follow-up T2WI at 3 months shows focal parenchymal scarring (arrow).

AFBN: Acute focal bacterial nephritis, CECT: Contrast-enhanced CT, NCCT: Non-contrast CT, MRI: Magnetic resonance imaging, T2WI: T2-weighted image, DWI: Diffusion-weighted imaging

(ureteritis), calculi, perirenal effusion, perirenal fat stranding, Gerota's fascia thickening, or complication rates.

A mass-forming pattern was observed in 49% of AFBN cases, compared with 20% of APN cases with segmental involvement ($p=0.006$). Both APN and AFBN were most distinctly visualized in the nephrographic phase on CT (62% vs. 77%, $p=0.291$). Among patients who underwent MRI ($n=20$), DWI demonstrated a greater number of foci than CT in 50% (10/20). On MRI, T2W signal characteristics differed significantly between APN and AFBN: 83% of APN cases showed hypointense signal, whereas 67% of AFBN cases displayed heterogeneous parenchymal intensity ($p=0.017$) **Table 3** summarizes the imaging findings, complications, and associated features of APN and AFBN, with comparisons across different modalities.

Interobserver agreement between the two radiologists for APN vs. AFBN classification was low ($\kappa=0.18$; 95% CI, $-0.13-0.49$; $p=0.003$), indicating only slight-to-fair concordance. Although the overall agreement rate was high (90.8%; 95% CI, 82.9–95.3), κ was substantially reduced by prevalence imbalance, with much higher positive agreement for renal parenchymal infection (95.1%; 95% CI, 90.7–97.5) than negative agreement (20.0%; 95% CI, 5.7–51.0). This discrepancy reflects a well-recognized limitation of Cohen's κ ,

Table 3. Imaging findings of APN and AFBN across different modalities

	n (%)	APN	AFBN	p
Disease extent				
Diffuse		18 (45%)		
Segmental		12 (30%)		
Multiple small foci		10 (25%)		
Single focus			18 (38%)	
A few foci			22 (47%)	
Multiple foci			7 (15%)	
Laterality				
-Right	44 (51%)	14	15	
-Left	29 (33%)	19	25	
-Bilateral	14 (16%)	7	7	
CECT	67 (77%)	23	44	
CECT+MRI	14 (16%)	4	10	
NCECT	20 (23%)	17	3	
NCECT+MRI	6 (6%)	4	2	
CT findings				
Ureteritis	32 (37%)	15	17	0.898
Cortical edema	72 (83%)	38 (95%)	34 (72%)	0.005*
Renal enlargement	34 (39%)	30 (75%)	4 (8.5%)	<0.001*
Mass forming	31 (36%)	8 (20%)	23(49%)	0.006*
CT-density				
-Hypodense		26 (65%)	14 (35%)	<0.001*
-Heterogenous		20 (43%)	27 (57%)	
T2WI				
-Hypointense		5 (83%)	1(16%)	0.017*
-Heterogenous		4 (33%)	8 (67%)	
Hydronephrosis	16 (18%)	10	6	0.142
Perirenal effusion	28 (32%)	16	12	0.150
Perirenal stranding or Gerota's fascia thickening	45 (52%)	24	21	0.154
Complications rate				
-Renal abscess	14 (16%)	6	8	0.610
-Abscess + RVT	8	1	7	
-Perirenal abscess	2	2	0	
-Sepsis	3	2	1	
	2	1	1	
Post-infectious sequelae or scarring				
-Present	49 (56%)	27	22	0.025*
-Absent	28 (32%)	7	21	
-Unknown	10 (12%)	6	4	
USG				
-Positive	53 (61%)	24	29	
-Negative	14 (26%)	11	3	
	39(74%)	13	26	
Diagnosis	Initial CT type	n (CT)	n (DWI)	DWI vs. CT result
APN	Non-contrast CT	17	4	3/4 (75%) showed more localized involvement
AFBN	Non-contrast CT	3	2	1/2 (50%) showed more generalized involvement
AFBN	Contrast-enhanced CT	44	10	9/10 (90%) showed more infectious foci
RVT: Renal vein thrombosis, APN: Acute pyelonephritis, AFBN: Acute focal bacterial nephritis, CT: Computed tomography, CECT: Contrast-enhanced computed tomography, NCECT: Non-contrast-enhanced computed tomography; MR: Magnetic resonance, T2WI: T2-weighted imaging, DWI: Diffusion-weighted imaging. p<0.05 considered statistically significant.				

RVT: Renal vein thrombosis, APN: Acute pyelonephritis, AFBN: Acute focal bacterial nephritis, CT: Computed tomography, CECT: Contrast-enhanced computed tomography, CECT: Non-contrast-enhanced computed tomography; MR: Magnetic resonance, T2WI: T2-weighted imaging, DWI: Diffusion-weighted imaging. p<0.05 considered statistically significant.

whereby skewed distributions between positive and negative cases disproportionately deflate the coefficient despite high raw agreement. After adjusting for prevalence and bias, the prevalence-adjusted bias-adjusted κ (PABAK) increased to 0.82, reflecting substantial agreement and supporting the reproducibility of the imaging classification in this context.

DISCUSSION

UTI is a broad term encompassing a spectrum of infectious diseases, ranging from simple forms such as cystitis and urethritis to more advanced conditions like pyelitis and PN.^{13,14} In our cohort, CT showed ureteritis±cystitis in 42% of patients, with similar rates in APN and AFBN, supporting an ascending pathway from simple UTI to renal parenchymal infection.^{15,16} Underscoring the potential for disease progression, Jansåker et al.¹⁷ reported a 0.99% incidence of PN within 30 days among patients initially diagnosed with cystitis.

Once infection extends into the renal parenchyma, it may progress to serious complications such as pyonephrosis, renal or perirenal abscess, and emphysematous PN. AFBN, in particular, has been associated with abscess formation and is considered a potential precursor of this complication.^{6,7,18,19} In our cohort, renal abscess was the most frequent complication; however, the overall complication rates did not differ significantly between APN and AFBN ($p=0.610$). Similarly, causative microorganisms and associated clinical findings were comparable across the two groups. Taken together, these parallels suggest that the observed radiological differences are more likely related to variations in inflammatory pathogenesis than to clinical or microbiological factors.

A substantial proportion of patients present with vague symptoms that may be mistaken for lower UTIs or other infectious diseases.^{4,9} While high fever is the most common presentation, afebrile cases are also documented;^{1,4,20} 7% were afebrile, and 18% underwent imaging with a preliminary diagnosis of acute appendicitis, enterocolitis, or fever of unknown origin. Flank pain, the second most common symptom, can also be misleading;^{3,9,15} in 20% of cases, imaging was requested with a preliminary diagnosis of urothelial calculi. These overlapping and nonspecific presentations underscore the indispensable role of imaging in ensuring rapid diagnosis and accurately excluding competing differentials. However, indications and optimal timing for imaging in PN vary widely across institutions and remain debated.^{3,21,22}

In our cohort, imaging confirmation of renal involvement frequently guided clinical management, particularly in cases where hospitalization and initiation of intravenous antibiotics were warranted until fever resolution. Imaging was also critical in complicated cases, such as those requiring percutaneous abscess drainage, and in patients who underwent close follow-up with repeat imaging to monitor disease course. Previous reports suggest that antimicrobial therapy in AFBN should be prolonged;^{8,9} however, due to the retrospective nature of our study, we could not determine whether our findings influenced treatment duration.

The role of USG in diagnosing PN is inherently limited.^{12,23} USG sensitivity for abnormal renal findings was 26.4%: low, yet approaching the higher range reported previously.^{3,24} This higher figure likely stems from classifying any abnormality as positive; yet USG can still overlook subtle changes (e.g., loss of corticomedullary differentiation, mild swelling) because of operator dependence and limited sensitivity.²⁵ Decreased parenchymal echogenicity has been reported as a sonographic indicator of infection, whereas increased echogenicity has been linked to hemorrhage or later evolutionary stages.^{14,24,26} In our cohort, increased parenchymal echogenicity, whether focal or diffuse, was identified in a small proportion of USG-positive cases (13%); notably, no case demonstrated decreased echogenicity. Uroepithelial thickening (n=2) may support the diagnosis of upper UTI but does not indicate renal parenchymal involvement. Other abnormalities, such as hydronephrosis and perirenal effusion, are more indicative of obstructive uropathy and may mislead clinicians. Overall, these findings highlight the poor reliability of USG in specific diagnosing of renal parenchymal infections, whether APN or AFBN. Nonetheless, USG remains reasonable in pregnancy and pediatrics. In adults—especially those with comorbidities or advanced age—it often adds cost without meaningful incremental yield before CT.

Discriminating AFBN from APN is critical to avoid inadequate treatment and prevent persistent renal inflammation that may progress to chronic kidney disease.⁸ CECT remains the reference standard for diagnosing PN, reliably distinguishing APN from AFBN and proving especially valuable in complicated cases.^{12,13,24} In our cohort, we compared CT findings between APN and AFBN and evaluated MRI to explore its potential additive value as an alternative modality. As the terminology implies, the key imaging distinction is focal versus diffuse parenchymal infection. However, in our AFBN cases, a substantial proportion of patients demonstrated multiple foci, with bilateral involvement occurring at rates comparable to APN. Similarly, some APN patients showed segmental involvement or multiple small, scattered foci throughout the affected kidney. In such cases, CECT frequently revealed a striated nephrogram pattern, a well-described but nonspecific finding in PN.^{14,25,26} Although not specific to either subtype, this feature was more often linked to the extensive parenchymal involvement typical of APN than to the focal/mass-forming pattern of AFBN. Although the AFBN–APN distinction has been discussed previously, most studies prioritized clinical/laboratory criteria over systematic imaging-based comparisons.^{8,22}

Blurring of corticomedullary differentiation was observed at similar rates in both groups, whereas renal enlargement and cortical edema were more common in APN, and a mass-forming pattern was more characteristic of AFBN. In line with the literature, parenchymal abnormalities were most conspicuous in the nephrogram phase, regardless of imaging modality or disease subtype.^{12,14} However, our results showed slight differences compared with previous reports: APN lesions more often appeared hypodense, whereas AFBN lesions typically demonstrated heterogeneous attenuation.^{14,27,28} A similar trend was observed on MRI, with

APN lesions more frequently showing hypointense T2WIs, while AFBN lesions displayed heterogeneous parenchymal signal intensity. The different CT and MRI imaging findings between APN and AFBN may be attributed to variations in inflammatory pathogenesis, although the exact mechanisms remain unclear.

No false-negative findings were observed in patients who underwent additional MRI, supporting previous reports on the validity of MRI in diagnosing PN.^{29,30} Given the excellent agreement between CE-MRI and CECT findings (Cramer's $V=0.93$, $p<0.001$), our results suggest that CE-MRI offers no incremental diagnostic value over CECT. However, DWI is highly sensitive for detecting renal parenchymal inflammation.^{24,31-33} Faletti et al.³⁴ reported higher visibility scores with DWI compared to CE-MRI. Similarly, in our cohort, DWI was more accurate than CT in delineating the extent of disease. In AFBN cases, DWI revealed more infectious foci than CECT, likely reflecting its higher sensitivity for detecting inflammatory changes before they become apparent on CT. In APN cases initially diagnosed with NCCT, DWI depicted more localized involvement. This aligns with reports of NCCT's limited ability to delineate extent or parenchymal change and underscores DWI's advantage.³⁵ Pinto et al.³² emphasized the added value of combining T2WI with DWI in improving the specificity of PN diagnosis. All areas seen on CE-T1WI were readily detectable on T2WI in our study, supporting T2WI as an acceptable alternative. Accordingly, pairing T2WI with DWI offers a rapid, contrast-sparing approach for suspected PN—especially in pediatrics, pregnancy, and patients with reduced renal function.

Our findings align with recent international guidelines. The 2024 EAU guidelines recommend imaging in pregnant patients with complicating factors, in febrile patients who fail to improve after 72 hours of antibiotic therapy, and in differentiating obstructive PN.¹³ Similarly, the 2022 ACR Appropriateness Criteria® emphasize imaging in high-risk patients, including those with diabetes, urinary tract anomalies, renal obstruction, urolithiasis, prior renal surgery, treatment-resistant or nosocomial infections, advanced age, pregnancy, renal transplantation, and immunosuppression. In such groups, imaging is essential to aid diagnosis, identify precipitating factors, and distinguish lower UTI from renal parenchymal involvement. Consistent with these recommendations, CECT remains the reference standard for diagnosis and disease characterization, while MRI is generally reserved for patients in whom radiation exposure or iodinated contrast is a concern.¹² These guidelines further reinforce the clinical relevance of our comparative evaluation.

Building on this framework, to the best of our knowledge, no prior study has systematically evaluated and compared radiological findings between APN and AFBN in the adult population, particularly with regard to the extent and patterns of disease involvement. The strength of our work lies in providing a comprehensive comparative analysis of CT, MRI, and USG, moving beyond descriptive reports of single modalities. By focusing on disease extent and distribution, as well as correlating imaging features with underlying etiology, complications, and sequelae, our study offers new insights

into the practical value of imaging modalities in adult PN and contributes to an area of the literature that remains underexplored.

Limitations

This study has several limitations. First, its retrospective design may have introduced selection bias and limited the standardization of imaging protocols. Second, only a subset of patients underwent MRI (n=20). The relatively small MRI subgroup not only reduced the statistical power but also restricts the generalizability of our conclusions regarding MRI performance. Although MRI appeared to provide comparable diagnostic value to CT, the limited sample size precludes firm conclusions about its potential superiority, and this observation should be interpreted with caution until validated in larger, prospective cohorts. Third, the number of cases across different imaging modalities was heterogeneous, which may have influenced comparative analyses. Finally, MRI interpretation was performed with knowledge of CT findings; therefore, prospective studies with blinded MRI evaluation are warranted to more accurately determine its diagnostic performance.

CONCLUSION

In this comparative study, complication rates, causative microorganisms, and associated findings did not differ significantly between APN and AFBN. CECT remained the most reliable modality for diagnosis and disease characterization, while USG and NCCT provided limited diagnostic value. Although CE-MRI showed excellent agreement with CECT, it offered no additional diagnostic benefit. By contrast, DWI proved more sensitive in assessing disease extent, and the combined use of DWI and T2WI represents a promising contrast-free strategy for rapid evaluation. This approach may be particularly advantageous in children, pregnant patients, and those with impaired renal function. Our findings highlight the potential of MRI—particularly DWI and T2WI—to assume a greater role in PN imaging, especially when radiation exposure or iodinated contrast is a concern. However, given the retrospective design and small MRI subgroup, our MRI findings should be interpreted as preliminary and require validation in larger, prospective studies.

ETHICAL DECLARATIONS

Ethics Committee Approval

This study has been approved by the Non-interventional Clinical Researches Ethics Committee of İstanbul Medipol University (Date: 03.07.2025, Decision No. 819).

Informed Consent

Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

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Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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