J Ped Nephrol
Journal of Pediatric Nephrology
Spring 2022. Volume 10. Number 2

Original Article

Diagnostic Performance of Procalcitonin and C-Reactive Protein in Pediatric Acute Pyelonephritis: A Hospital-based Study

Ishrat Jahan[1*], Tahmina Jesmin[1], Sudipta Saha[1], Sufia Khatun[1], Rezwana Ashraf[1], Azizur Rahman[1], Shorna Rahman[1], Abdullah Al Mamun[1], Golam Muin Uddin[1]

1. Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh.

Use your device to scan and read the article online

Citation Jahan A, Jesmin T, Saha S, Khatun S, Ashraf R, Rahman A, et al. Diagnostic Performance of Procalcitonin and C-Reactive Protein in Pediatric Acute-Pyelonephritis: A Hospital-based Study. Journal of Pediatric Nephrology. 2022; 10(2):83-90. https://doi.org/10.22037/jpn.v10i2.35634

https://doi.org/10.22037/jpn.v10i2.35634

Article info:
Received: 23 Aug 2021
Accepted: 26 Nov 2021
Publish: 01 Apr 2022

Corresponding Author:
Ishrat Jahan
Address: Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh.
E-mail: ishratjahan853@gmail.com

ABSTRACT

Background and Aim: Urinary Tract Infection (UTI) is a common bacterial infection in children causing permanent renal damage. Differentiation between Acute Pyelonephritis (APN) and lower UTI is vital due to the involvement of renal parenchyma in APN.

This study aimed to assess the efficiency of Procalcitonin (PCT) with C-Reactive Protein (CRP) to predict APN in children with UTI in a tertiary care hospital.

Methods: This analytical cross-sectional study was conducted in a tertiary care hospital between March 2013 and July 2014. Children aged 1 month to 16 years with febrile UTI were included in the study. Routine and microscopic examination and urine culture and sensitivity, serum PCT, CRP, and White Blood Cell count (WBC) were measured. All the patients underwent 99mTc-Dimercaptosuccinic Acid (DMSA) scan. Their findings were categorized as APN and lower UTI according to the decreased uptake without evidence of cortical loss in the 99mTc-Dimercaptosuccinic Acid (DMSA) scan. Sensitivity, specificity, positive predictive value, negative predictive value, and receiver operating characteristic (ROC) curve were used to assess quantitative variables for diagnosing APN.

Results: The Mean±SD age values in the APN group were 73.11±52.29 months, while it was 76.25±47.23 months in the lower UTI group. The median (min-max) of PCT was 1596 (103-2158) pg/mL and 109 (43-426) pg/mL in APN and lower UTI groups, respectively. The median (min-max) of CRP was 22.0 (5.0-57.0) mg/L and 5.0 (3.14-24.0) mg/L in APN and lower UTI groups, respectively. The Area Under the Curve (AUC) for fever, White Blood Cell (WBC), CRP, and PCT of the respondent showed that CRP was at the cut-off point of 5.0 mg/L, resulting in a sensitivity of 82.4% and a specificity of 80.0%, respectively. PCT was at the cut-off point of 1300 pg/mL, resulting in a sensitivity of 76.5% and a specificity of 100.0%, respectively. By comparing the Receiver Operating Characteristic (ROC) curve, PCT had a significantly higher Area Under the Curve (AUC) than CRP for differentiating APN and lower UTI.

Conclusion: Serum CRP and PCT are good markers for diagnosing APN in febrile UTI in children. However, the study showed that PCT is a better marker to differentiate APN and lower UTI compare to CRP.

Keywords: Urinary tract infection, Procalcitonin, C-reactive protein

J Ped Nephrol
Journal of Pediatric Nephrology

Introduction

Urinary Tract Infection (UTI) is a common bacterial infection in children with a prevalence of 3%-5% in the pediatric emergency department [1]. Approximately 30%-60% of pediatric cases result in renal scarring after an episode of Acute Pyelonephritis (APN) [2].

The non-specific symptoms and signs in febrile children make clinical differentiation between APN and-lower UTI difficult. Furthermore, delayed diagnosis and treatment of APN in children expose them to the risk of permanent kidney damage and long-term sequelae of hypertension, proteinuria, and end-stage renal disease [3]. However, the distinction between upper and lower UTIs in children is associated with some ambiguities [4]. Because clinical manifestations and laboratory indices are insufficient for APN and lower UTI differentiation [5]. Clinical presentations such as fever and flank pain, as well as commonly used inflammatory markers including C-Reactive Protein (CRP), Erythrocyte Sedimentation Rate (ESR), and White Blood Cell (WBC) count do not accurately localize the site of the UTI [6]. Therefore, it is essential to find out an easy and practical technical method to differentiate between upper and lower UTI [5].

Recently serum Procalcitonin (PCT) has been used to predict the level of infection in children with UTIs. PCT, a 116-amino acid peptide and a precursor of calcitonin [7], is produced in the medullary C-cells of the thyroid gland in healthy humans. In normal individuals, the PCT level is very low (<0.5 µg/L). Test results can be available within 2.5 to 3.0 hours [8]. PCT can serve as an early diagnosis index of serious bacterial infections and septicemia; though, it is almost undetectable in physiological conditions or viral infections. It is a satisfactory predictor of renal parenchymal involvement in acute and late renal scars [5].

To predict APN, the sensitivity and specificity of PCT were 94.1% and 89.7%, respectively, while CRP had a sensitivity of 100% and a specificity of 18.5%.8 An accepted gold standard method to detect APN and assess the extent and progression of renal damage is the 99mTc-Dimercaptosuccinic Acid (DMSA) renal scan [9]. It is problematic and challenging to assess renal parenchymal involvement in children with UTI. It is highly essential to find out an accurate, rapid, and readily available diagnostic test to detect APN in children with febrile UTI. The present study was conducted to determine the diagnostic value of serum PCT compared to CRP in predicting APN in children with UTI.

Materials and Methods

Study population

This analytical cross-sectional study was conducted in the Department of Pediatric Nephrology, Bangabandhu Sheikh Mujib Medical University (BSMMU), Dhaka between March 2013 and July 2014. A total number of 37 patients (1 month to 16 years) with the criteria of fever (axillary temperature ≥38°C), other symptoms and signs of UTI, leucocyturia (≥5 WBC/[High-Pass Filter] HPF), and positive urine culture were included in the study. Patients with a history of previous UTI, other bacterial infections, renal dysplasia, renal scarring on DMSA scan, kidney and bladder disease, and known urinary tract malformations were excluded from the study.

Study procedure

After obtaining ethical clearance from Institutional Review Board (IRB), Bangabandhu Sheikh Mujib Medical University (BSMMU), a brief interview was conducted regarding the patient's particulars, symptoms, and any risk factors for UTI using a structured questionnaire. Clean-catch midstream urine was collected from children who could follow the instruction. In the case of 5 infants, who could not follow the instructions, urine was collected by temporary transurethral catheterization in 3 cases and suprapubic puncture in 2 cases. Before giving an antibiotic, urine and blood samples were sent. Two urine samples were collected from each patient: One for routine and microscopic examination and another for culture and sensitivity. Urine samples were examined within 1 hour of collection. A colony count of more than 10^5 CFU/mL organisms of a single species was considered significant. Approximately 5 mL of blood was drawn for WBC count, CRP, PCT, and blood culture. PCT values were determined using Enzyme-Linked Immunosorbent Assay (ELISA) and assay time was less than 20 minutes.

An ultrasonogram of the KUB region with Post-Void Residual (PVR) was performed within 3 days to exclude any renal anomaly. The DMSA scan was performed within 7 days of patient enrollment to verify the presence of renal parenchymal lesions reflecting an ongoing inflammatory process in the kidneys. A normal scan was defined as normal radioactive tracer uptake in the kidneys.

Treatment of the patients was started empirically with oral cefixime or cefuroxime in the case of less

toxic patients and with intravenous ceftazidime and amikacin in cases of toxicity and/or inability to feed the child. These drugs were later adjusted according to the culture and sensitivity report. The total duration of antibiotic therapy was 7-14 days.

Statistical analysis

Statistical analysis was done using SPSS software version 20. If necessary, the Chi-square test, independent t-test, and Mann-Whitney U test were used. ROC curve analysis was performed to assess quantitative variables for diagnosing APN. The diagnostic values of each cut-off point, such as sensitivity, specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV), and accuracy were calculated.

Operational definition

UTI: UTI is defined as the growth of a single microorganism $\geq 10^5$ CFU/mL in case of clean-catch midstream urine and $\geq 10^4$ CFU/mL in urine collected from transurethral catheterization.

APN: APN is defined as an infection in the renal pelvis confirmed by the presence of focal or diffuse areas of decreased uptake without evidence of cortical loss or a split renal uptake of < 45% on a DMSA scan.

Lower UTI: Lower UTI is defined as an infection of the bladder and urethra.

Values: PCT values ≥500 pg/mL and CRP values ≥6 mg/L were considered abnormal.

Results

A total of 37 children (17 boys and 20 girls) aged 1 month to 16 years with a confirmed diagnosis of first febrile UTI were included in the study. Among them, 78.3% of UTI were caused by Escherichia coli. Table 1 presents the clinical and laboratory data of the patients. Based on DMSA scan results, 17 subjects (45.9%, 10 boys and 7 girls) were diagnosed as APN. The rest of the children, 20 children (54.1%, 7 boys and 13 girls) with normal DMSA scan results were diagnosed with lower UTIs. No significant differences were observed between the groups.

The median values of PCT, CRP, and temperature were significantly higher in children with APN than in those with lower UTI (P=0.001). No significant difference was observed in age and WBC values between the two groups (Figure 1).

For differentiating APN from lower UTI, ROC curves were plotted by the sensitivity versus 1-specificity for different cut-off values of fever, WBC count, CRP, and PCT (Figure 2). The AUC was higher in PCT followed by CRP, fever, and WBC count.

The optimum cut-off value of PCT to differentiate APN from lower UTI was 1300 pg/mL, with a sensitivity of 76.5% and a specificity of 100.0%. For CRP, the optimum cut-off value was 5 mg/L (sensitivity 82.4% and specificity 80.0%). The specificity of PCT is higher than CRP and WBC count. PPV and accuracy were also better for PCT (Tables 2, 3, 4, 5, 6).

Discussion

UTI is a common bacterial infection in children and approximately 30-60% of pediatric cases result in renal scarring after an episode of APN [2]. In this study, the age of most patients in the APN and lower UTI group was more than 60 months. The Mean±SD age values in the APN group were 73.11±52.29 months and in the lower UTI groups, it was 76.25±47.23 months. Pecile et al. showed the relationship between age and the occurrence of acute pyelonephritis and renal scars where 59% of the children had renal involvement in the acute phase of infection [10]. The frequency of kidney involvement in infants less than 1 year (49%) was significantly lower than in children aged 1-4 years (73%) and older than 5 years (81%).

In the present study, the male to female ratios was 1 to 0.7 and 1 to 1.86 in APN and UTI groups, respectively, while no significant difference was observed in gender between the two groups (P>0.05). In another study conducted by Chen et al., the percentage of female was higher in both APN and lower UTI groups; though, the difference was also insignificant [11].

In this study, the preponderance of growth of *E.coli* was found in APN (70.6%) and lower UTI (85.0%) groups; however, the difference between them was not significant. A similar result (*E.coli* was 85.3%) was observed by Chen et al. [11].

The Mean±SD value of WBC counts was 16352±6518 /cmm^3, and it was 11405±3537/cmm^3 in APN and lower UTI groups, respectively, and the difference between the groups was significant (P<0.05). The median (min-max) of PCT of patients was 1596 (103-

J Ped Nephrol
Journal of Pediatric Nephrology

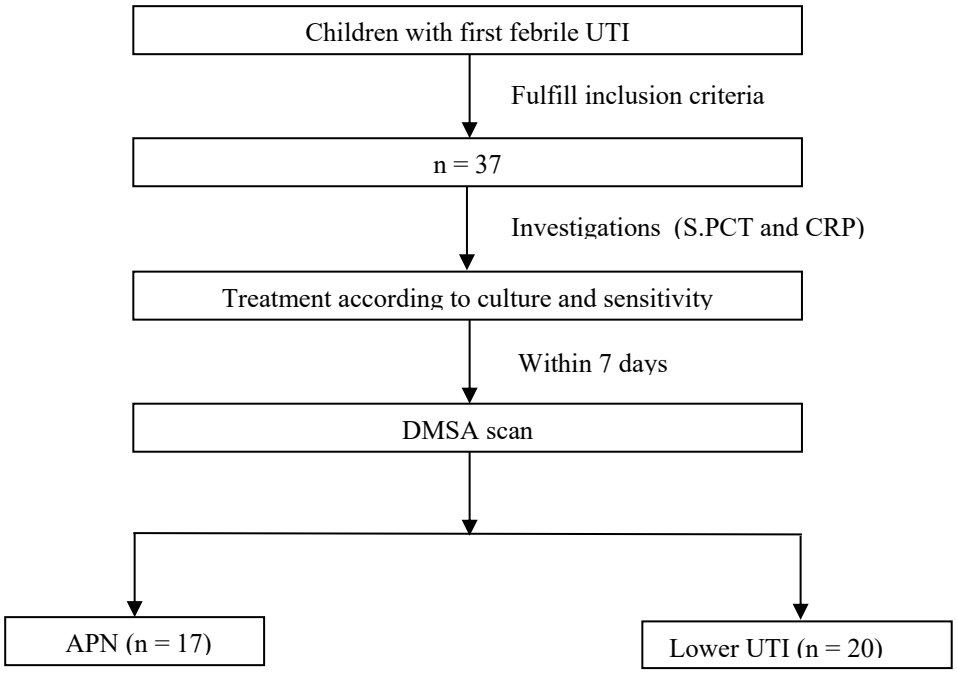

Figure 1. Flowch art of study group

2158) pg/mL and 109 (43-426) pg/mL in APN and lower UTI groups, respectively, which the difference was significant (P=0.001). Median (min-max) of CRP of patients was 22.0 (5.0-57.0) mg/L and 5.0 (3.14-24.0) mg/L in APN and lower UTI groups, respectively. A significant difference existed in CRP between the groups (P=0.001). Benador et al. reported that in lower UTI, the Mean±SD value of PCT was 0.38±0.19 mg/L compared to pyelonephritis with the value of 5.37±1.9 mg/L. Among these groups, the Mean±SD values of leukocyte counts were 10939±834/mm^3 and 17429±994/mm^3 and it was 30.3±7.6 mg/L and 120.8±8.9 mg/L in CRP levels. When inflammatory markers were correlated to the severity of the renal lesion as ranked by DMSA scan and found a highly significant correlation with plasma levels of PCT but borderline significance with CRP and none with leukocyte counts [12]. Xu et al. in their study showed

Table 1. Clinical characteristics and laboratory data for the whole population and children with APN and lower UTI

Variables	Whole Population	APN (n=17)	Lower UTI (n=20)	P
Age (mon), Mean±SD	74.81±48.94	73.11±52.29	76.25±47.23	0.841*
Gender, No. (male/female)	17/20	10/7	7/13	0.147***
E.Coli, No. (%)	29(78.30)	12(70.60)	17(85.0)	0.492***
Fever (°C), Mean±SD	39.31±0.47	39.60±0.40	39.07±0.38	0.001*
PCT (pg/mL), median (min-max)	328 (43-2158)	1596 (103-2158)	109 (43-426)	0.001**
CRP (mg/L), median (min-max)	6.0 (3.14-57.60)	22.0 (5.0-57.0)	5.0 (3.14-24.0)	0.001**
WBC (/mm^3), Mean±SD	13678±5633	16352±6518	11405±3537	0.006*

* Independent t test. ** Mann-Whitney U test. *** Chi square test.

APN: Acute Pyelonephritis; UTI: Urinary Tract Infection; *E.Coli*; *Escherichia coli*; PCT: Procalcitonin; CRP: C-Reactive Protein; WBC: White Blood Cell.

Table 1 presents clinical characteristics and laboratory findings of the whole population and of children with APN and lower UTI group where P values for fever, PCT, and CRP were 0.001 and it was 0.006 for WBC, which were significant. However, P values for age, gender, and E. coli were 0.841, 0.147, and 0.492 respectively, and hence insignificant.

Table 2. Procalcitonin of patients in APN and lower UTI

PCT	DMSA Scan, No. (%)		Total, No. (%)
	APN	Lower UTI	
1300 pg/mL	13(76.5)	0(0)	13(35.1)
≤1300 pg/mL	4(23.5)	20(100)	24(64.9)
Total	17(100)	20(100)	37(100)

APN: Acute Pyelonephritis; UTI: Urinary Tract Infection; PCT: Procalcitonin; DMSA: 99mTc-Dimercaptosuccinic Acid

Table 2 presents the PCT value of patients categorized into APN and lower UTI groups according to the DMSA scan report. Among 37 patients, 35.1% had PCT level > 1300 pg/mL and 64.9% had ≤1300 pg/mL. Among 17 patients of APN group, 76.5% had PCT level >1300 pg/mL and 23.5% had ≤1300 pg/mL. In the lower UTI group, all patients had PCT ≤1300 pg/mL.

Table 3. Validity test of procalcitonin

Validity Test	Value (%)	95% CI	
Sensitivity	76.5	59.1	76.5
Specificity	100	85.3	100.0
PPV	100	77.3	100.0
NPV	83.3	48.4	83.3
Accuracy	89.2	73.3	89.2

PPV: Positive Predictive Value; NPV: Negative Predictive Value.

Table 3 presents the sensitivity, specificity, PPV, NPV and accuracy of PCT, which were 76.5%, 100%, 100%, 83.3% and 89.2%, respectively.

that the Mean±SD values of PCT and CRP in children with APN were significantly higher than children with lower UTI (3.90±3.51 ng/mL and 68.17±39.42 mg/L vs 0.48±0.39 ng/mL and 21.39±14.92 mg/L). They also reported that PCT values were correlated with the degree of renal involvement, whereas the CRP values failed to show such a significant correlation [5]. Simon et al. evaluated the accuracy of determining PCT and CRP levels for the diagnosis of bacterial infection and concluded that the diagnostic accuracy of PCT markers was higher than CRP markers among patients hospitalized for suspected bacterial infections [13].

In the present study, the Area Under the Curve (AUC) of fever, WBC, CRP, and PCT of the respondent showed that fever at the cut-off point of 39.0°C resulted

Table 4. CRP value in APN and lower UTI

CRP	DMSA Scan, No. (%)		Total, No. (%)
	APN	Lower UTI	
5.0 mg/L	15(88.2)	4(20.0)	19(51.4)
≤5.0 mg/L	2(11.8)	16(80.0)	18(48.6)
Total	17(100)	20(100)	37(100)

APN: Acute Pyelonephritis; UTI: Urinary Tract Infection; CRP: C-Reactive Protein; DMSA: 99mTc-Dimercaptosuccinic Acid

Table 4 presents the CRP value of patients in the APN and lower UTI group. APN and lower UTI are categorized according to the DMSA scan report. Among the 37 patients, 51.4% had CRP >5.0 mg/L and 48.6% had CRP ≤5.0 mg/L. Among the 17 patients in the APN group, 88.2% had CRP >5 mg/L and 11.8% had ≤5.0mg/L. Among the 20 patients in the lower UTI group 20.0% had CRP >5.0 mg/L and 80.0% had ≤5.0 mg/L.

J Ped Nephrol
Journal of Pediatric Nephrology

Table 5. Validity test of CRP

Validity Test	Value (%)	95% CI	
Sensitivity	88.2	68.8	97.7
Specificity	80.0	63.5	88.1
PPV	78.9	61.6	87.4
NPV	88.9	70.6	97.8
Accuracy	83.8	65.9	92.5

PPV: Positive Predictive Value; NPV: Negative Predictive Value.

Table 5 lists the sensitivity, specificity, PPV, NPV and accuracy of CRP, which were 88.2%, 80.0%, 78.9%, 88.9% and 83.8%, respectively.

Table 6. AUC of fever, WBC, CRP, and PCT

Variables	AUC (95% CI)	P	Cut-off Point	%				
				Sensitivity	Specificity	PPV	NPV	Accuracy
Fever	0.840 (0.707-0.972)	0.001	39.0°C	88.2	45.0	57.7	81.8	64.9
WBC	0.751 (0.586-0.917)	0.009	14000/mm^3	58.8	80.0	71.4	69.6	70.3
CRP	0.881 (0.767-0.995)	0.001	5.0 mg/L	82.4	80.0	78.9	88.9	83.8
PCT	0.968 (0.904-1.032)	0.001	1300 pg/mL	76.5	100.0	100.0	83.3	89.2

PCT: Procalcitonin; CRP: C-Reactive Protein; WBC: White Blood Cell; PPV: Positive Predictive Value; NPV: Negative Predictive Value; AUC: Area Under the Curve.

Table 6 lists the AUC of fever, WBC, CRP, and PCT of the patients. Fever was at cut-off points of 39.0°C, resulting in a sensitivity of 88.2%, a specificity of 45.0%, a PPV of 57.7%, an NPV of 81.8%, and an accuracy of 64.9%. WBC count was at the cut-off point of 14000/mm^3, resulting in a sensitivity of 58.8%, a specificity of 80.0%, a PPV of 71.4%, an NPV of 69.6%, and an accuracy of 70.3%. CRP was at the cut-off point of 5.0 mg/L, resulting in a sensitivity of 82.4%, a specificity of 80.0%, a PPV of 78.9%, an NPV of 88.9%, and an accuracy of 83.8%. And PCT was at the cut-off point of 1300 pg/mL, resulting in a sensitivity of 76.5%, a specificity of 100.0%, a PPV of 100.0%, an NPV of 83.3%, and an accuracy of 89.2%.

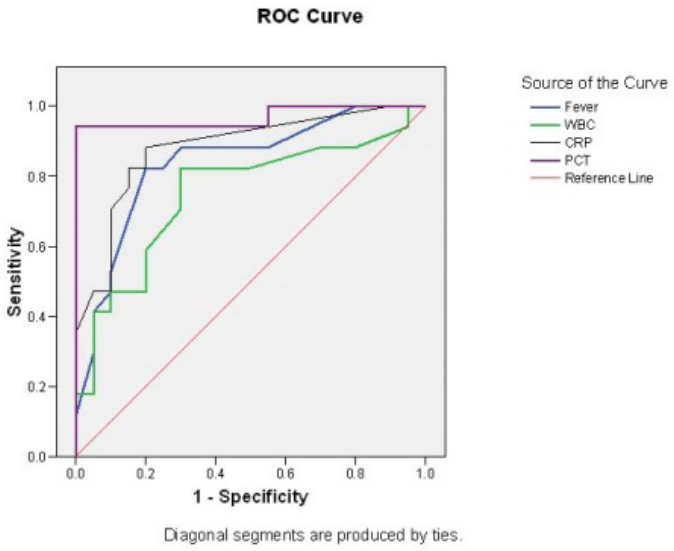

Figure 2. ROC curves for fever, WBC, CRP, and Procalcitonin (PCT)

Figure 2 shows the area under the curve (AUC) of fever, WBC, CRP, and PCT. AUC was higher in PCT followed by CRP, fever, and WBC.

in a sensitivity of 88.2% and a specificity of 45.0%, and WBC count at the cut-off point of 14000 /mm^3 resulted in a sensitivity of 58.8% and a specificity of 80.0%, CRP at cut-off point of 5.0 mg/L resulted in a sensitivity of 82.4% and a specificity of 80.0% and PCT at the cut-off point of 1300 pg/mL resulted in a sensitivity of 76.5% and a specificity 100.0%. Prat et al. used a the cut-off point of 1 ng/mL for PCT and 20 mg/L for CRP, the sensitivity and specificity in distinguishing between UTIs with and without renal damage were 92.3% and 61.9% for PCT and 92.3% and 34.4% for CRP. In their study, PCT during the presentation showed a significant correlation (P<0.001) with the presence of renal scars in children with UTI. In their study, they also reported that PCT values are more specific than CRP and leukocyte count to diagnose patients who may develop renal damage [14]. Ayazi et al. in their study reported that PCT was positive in 69.2% of patients with upper UTI and 52.2% with lower UTI and the sensitivity and specificity obtained for PCT and CRP were 70.6% and 45.5% and 96.2% and 4.3% respectively [4]. Benador et al. also measured serum procalcitonin levels, a recently described marker of infection. In their study on predicting renal lesions at admission, CRP had a sensitivity of 100% and a specificity of 26.1%, and PCT had a sensitivity of 70.3% and a specificity of 82.6%, respectively [12]. Ayazi et al. also evaluated the diagnostic accuracy of the quantitative CRP, ESR, and WBC count in UTI. In their study, the sensitivity and specificity of CRP were 96% and 11.1% when using urine culture as the gold standard, it was 55% and 40% when using ESR as the gold standard and it was 69% and 52% when using WBC counts as the gold standard. They also reported that the accuracy of CRP, ESR, and WBC counts when considering the DMSA as the gold standard were 58.3%, 62.8%, and 64.5%, respectively [4]. Xu et al. in their study reported that PCT values were correlated with the degree of renal involvement, whereas the CRP values failed to show such a significant correlation. PCT had 90.47% sensitivity and 88.0% specificity in predicting nephropathy, while CRP had 85.71% sensitivity and 48% specificity in differentiating upper and lower UTI [5]. Nuyan et al. investigated the use of DMSA scan in the localization of renal parenchymal involvement in UTI and reported that the sensitivity of local findings was 57.14% and WBC 23.80%, ESR 33.33%, CRP 14.28%, and antibody-coated bacteria 71.42% in the localization of UTI [15]. Chen et al. and Park et al also reported that PCT has better sensitivity and specificity than CRP and WBC count to distinguish between APN and lower UTI [11, 16]. This finding is consistent with the present study.

Conclusion

It can be concluded that serum PCT and CRP are good diagnostic markers of APN in febrile UTI in children; though, this study was conducted in a single center, tertiary care hospital for a short study period with very small sample size. However, PCT is a better marker to differentiate APN and lower UTI compared to CRP. Therefore, patients with UTI should initially be evaluated by serum PCT and CRP for early diagnosis of APN which can help prevent future prognosis.

Ethical Considerations

Compliance with ethical guidelines

There were no ethical considerations to be considered in this research.

Funding

This research did not receive any grant from funding agencies in the public, commercial, or non-profit sectors.

Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interest.

References

[1] Shaw KN, McGowan KL, Gorelick MH, Schwartz JS. Screening for urinary tract infection in infants in the emergency department: Which test is best? Pediatrics. 1998; 101(6):E1. [DOI:10.1542/peds.101.6.e1] [PMID]

[2] Sheu JN, Chang HM, Chen SM, Hung TW, Lue KH. The role of procalcitonin for acute pyelonephritis and subsequent renal scarring in infants and young children. J Urol. 2011; 186(5):2002-8. [DOI:10.1016/j.juro.2011.07.025] [PMID]

[3] Hiraoka M, Hashimoto G, Tsuchida S, Tsukahara H, Ohshima Y, Mayumi M. Early treatment of urinary infection prevents renal damage on cortical scintigraphy. Pediatr Nephrol. 2003; 18(2):115-8. [DOI:10.1007/s00467-002-1023-y] [PMID]

[4] Ayazi P, Mahyar A, Hashemi HJ, Daneshi MM, Karimzadeh T, Salimi F. Comparison of procalcitonin and C-reactive protein tests in children with urinary tract infection. Iranian Journal of Pediatrics. 2009; 19(4):381-6. [Link]

J Ped Nephrol
Journal of Pediatric Nephrology

[5] Xu RY, Liu HW, Liu JL, Dong JH. Procalcitonin and C-reactive protein in urinary tract infection diagnosis. BMC Urol. 2014; 14:45. [DOI:10.1186/1471-2490-14-45] [PMID] [PMCID]

[6] Garin EH, Olavarria F, Araya C, Broussain M, Barrera C, Young L. Diagnostic significance of clinical and laboratory findings to localize site of urinary infection. Pediatr Nephrol. 2007; 22(7):1002-6. [DOI:10.1007/s00467-007-0465-7] [PMID]

[7] Resswurm S, Wiederhold M, Oberhoffer M, Stonans I, Zipfel PF, Reinhart K. Molecular aspects and nautral sources of procalcitonin. Clin Chem Lab Med. 1999; 37(8):789-97. [DOI:10.1515/CCLM.1999.119] [PMID]

[8] Wald E. Urinary tract infections in infants and children: A comprehensive overview. Curr Opin Pediatr. 2004; 16:85-8. [DOI:10.1097/00008480-200402000-00016] [PMID]

[9] Biggi A, Dardenelli L, Pomero G, Cussino P, Noello C, Sernia O. Acute renal cortical scintigraphy in children with first urinary tract infection. Pediatr Nephrol. 2001; 16(9):733-8. [DOI:10.1007/s004670100657] [PMID]

[10] Pecile P, Miorin E, Romanello C, Vidal E, Contardo M, Valent F. Age-related renal parenchymal lesions in children with first febrile urinary tract infections. Pediatrics. 2009; 124(1):23. [DOI:10.1542/peds.2008-1192] [PMID]

[11] Chen SM, Chang HM, Hung TW, Chao YH, Tasi JD, Lue KH. Diagnostic performance of procalcitonin for hospitalized children with acute pyelonephritis presenting to the pediatric emergency department. Emerg Med J. 2013; 30(5):406-10. [DOI:10.1136/emermed-2011-200808] [PMID]

[12] Benador N, Siegrist CA, Genedrel D, Geneder C, Benador D, Assicot M. Procalcitonin is a marker of severity of renal lesions in pyelonephritis. Pediatrics. 1998; 102(6):1422-5. [DOI:10.1542/peds.102.6.1422] [PMID]

[13] Simon L, Gauvin F, Amre DK, Louis PS, Lacroix J. Serum procalcitonin and C-reactive protein levels as markers of bacterial infection: A systematic review and meta-analysis. Clin Infect Dis. 2004; 39:206-17. [DOI:10.1086/421997] [PMID]

[14] Prat C, Dominguez J, Rodrigo C, Gimenez M, Azura M, Jimenez O, et al. Elevated serum procalcitonin values correlate with renal scarring in children with urinary tract infection. Pediatr Infect Dis J. 2003; 22(5):438-42. [DOI:10.1097/00006454-200305000-00010] [PMID]

[15] Nuyan N, Bircan ZE, Hasanoglu E, Bayhan H, Rota H. The importance of 99mTc DMSA scanning in the localization of childhood urinary tract infection. Int Urol Nephrol. 1993; 25(1):11-7. [DOI:10.1007/BF02552249] [PMID]

[16] Park JS, Byun YH, Lee JY, Lee JS, Ryu JM, Choi SJ. Clinical utility of procalcitonin in febrile infants younger than 3 months of age visiting a pediatric emergency room: A retrospective single-center study. BMC Pediatr. 2021; 21(1):109. [DOI:10.1186/s12887-021-02568-5] [PMID] [PMCID]