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Original Article

Clinical Characteristics of Children with Acute Post-Streptococcal Glomerulonephritis and Re-Evaluation of Patients with Artificial Intelligence

Akut Post-Streptokokal Glomerülonefritli Çocukların Klinik Özellikleri ve Hastaların Yapay Zeka ile Yeniden Değerlendirilmesi

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ABSTRACT

Objective: Acute post-streptococcal glomerulonephritis (APSGN) is a common cause of acute glomerulonephritis in children. The condition may present as acute nephritic and/or nephrotic syndrome and rarely as rapidly progressive glomerulonephritis. ChatGPT (OpenAI, San Francisco, California, United States of America) has been developed as a chat robot supported by artificial intelligence (AI). In this study, we evaluated whether AI can be used in the follow-up of patients with APSGN.

Methods: The clinical characteristics of patients with APSGN were noted from patient records. Twelve questions about APSGN were directed to ChatGPT 3.5. The accuracy of the answers was evaluated by the researchers. Then, the clinical features of the patients were transferred to ChatGPT 3.5 and the follow-up management of the patients was examined.

Results: The study included 11 patients with an average age of 9.08±3.96 years. Eight (72.7%) patients had elevated creatinine and 10 (90.9%) had hematuria and/or proteinuria. Anti-streptolysin O was high in all patients (955±353 IU/mL) and C3 was low in 9 (81.8%) patients (0.56±0.34 g/L). Hypertensive encephalopathy, nephrotic syndrome, and rapidly progressive glomerulonephritis were observed in three patients. Normal creatinine levels were achieved in all patients. Questions assessing the definition, epidemiologic characteristics, pathophysiologic mechanisms, diagnosis, and treatment of APSGN were answered correctly by ChatGPT 3.5. All patients were diagnosed with APSGN, and the treatment steps applied by clinicians were similarly recommended by ChatGPT 3.5.

Conclusions: The insights and recommendations offered by ChatGPT for patients with APSGN can be an asset in the care and management of patients. With AI applications, clinicians can review treatment decisions and create more effective treatment plans.

Keywords: Acute postinfection glomerulonephritis, artificial intelligence, ChatGPT

ÖZ

Amaç: Akut post-streptokokal glomerülonefrit (APSGN) çocuklar arasında akut glomerülonefritin önde gelen nedenidir. Akut nefritik sendrom, nefrotik sendrom ve hızlı ilerleyen glomerülonefrit şeklinde ortaya çıkabilir. ChatGPT (OpenAI, San Francisco, California, Amerika Birleşik Devletleri) yapay zeka destekli bir sohbet robotu olarak geliştirilmiştir. Bu çalışmada, yapay zekanın APSGN'nin tanı, tedavi ve takibinde kullanılıp kullanılamayacağı ilk kez değerlendirilmiştir.

Yöntemler: APSGN tanısı alan hastaların klinik özellikleri hasta dosyalarından not edildi. APSGN hakkında genel bilgileri sorgulayan on iki soru ChatGPT 3.5'e yöneltildi. Cevapların doğruluğu iki araştırmacı tarafından değerlendirildi. Daha sonra hastaların klinik ve laboratuvar özellikleri ChatGPT 3.5'e aktarılarak hastaların takibinin yapay zeka tarafından nasıl yönetileceği incelendi.

Bulgular: Çalışmaya toplam 11 hasta dahil edildi. Hastaların yaş ortalaması 9,08±3,96 yıldı. Sekiz (%72,7) hastada kreatinin yüksekliği ve 10 (%90,9) hastada hematüri ve/veya proteinüri vardı. Anti-streptolisin O tüm hastalarda yüksek (955±353 IU/mL) ve C3 9 (%81,8) hastada düşüktü (0,56±0,34 g/L). Üç farklı hastada hipertansif ensefalopati, nefrotik sendrom ve hızlı ilerleyen glomerülonefrit gözlendi. Tüm hastalarda normal kreatinin değerlerine ulaşıldı. APSGN'nin tanımı, epidemiyolojik özellikleri ve patofizyolojik mekanizmaları, tanı ve tedavisini değerlendiren sorular chatGPT 3.5 tarafından doğru yanıtlandı. Ayrıca, tüm hastalara APSGN tanısı konmuş ve klinisyenler tarafından uygulanan tedavi adımları ChatGPT 3.5 tarafından benzer şekilde önerilmiştir.

Sonuçlar: ChatGPT tarafından APSGN için sağlanan bilgi ve rehberlik, hastaların bakım ve yönetiminde değerli bir kaynak olabilir. Yapay zeka uygulamaları ile klinisyenler kararlarını gözden geçirebilir ve daha etkili tedavi planları oluşturabilirler.

Anahtar kelimeler: Akut postenfeksiyon glomerülonefrit, yapay zeka, ChatGPT

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INTRODUCTION

Acute post-streptococcal glomerulonephritis (APSGN) is the leading cause of acute glomerulonephritis in children resulting from group A beta-hemolytic streptococcal infection[1]. It is frequently observed in children aged 4-12 years[2]. Enhancements in socioeconomic conditions, sanitation practices, healthcare systems, and the rational use of antibiotics for group A streptococcal infections have reduced the prevalence of APSGN in high-income nations. Nevertheless, it remains a significant public health issue in developing countries[3].

APSGN typically occurs 1-2 weeks after a throat infection and 3-6 weeks after skin infections[4]. It shows seasonal variation, with pharyngeal infections being more prevalent in winter and skin infections in summer[5]. APSGN may be subclinical or may be observed in severe clinical spectra, including acute nephritic and/or nephrotic syndrome and rarely as rapidly progressive glomerulonephritis. Edema, tea/cola-colored urine, decreased urine output, and hypertension may be present at presentation. In addition to general measures such as rest, fluid, and salt restriction, immunosuppressive therapies, and renal replacement therapies may be necessary in some cases[4].

ChatGPT (Chat Generative Pre-trained Transformer, OpenAI, San Francisco, California, United States of America), which has gained momentum in the medical field and started to be used daily in many branches, was developed as a chat robot supported by artificial intelligence (AI)[6]. Trained on vast Internet text, it can generate human-like language and cover various topics[7,8]. In medicine, ChatGPT can help identify research topics, assist with clinical and lab assessments, and keep healthcare professionals updated on new developments[9].

Pediatrics focuses on the health of infants, children, and adolescents. Early diagnosis and appropriate management are vital, and effective clinical decision-making is crucial for patient outcomes[10]. Evaluating ChatGPT's ability to support clinical decision-making in pediatrics is essential because of the unique challenges in this field[11].

In this study, the clinical characteristics, laboratory parameters, complications, and prognosis of pediatric patients diagnosed with APSGN were evaluated. We also examined whether ChatGPT can be used for APSGN management.

MATERIALS and METHODS

Research Framework and Participant Group

This was a retrospective observational study with a cross-sectional design in which the demographic, clinical, and laboratory characteristics of patients aged 0-18 years who were followed up with a diagnosis of APSGN in the department of pediatric nephrology between September 2023 and March 2024 were analyzed from patient records.

Demographic characteristics such as age and sex, history of streptococcal infection, presence of macroscopic hematuria, and physical examination findings such as edema and blood pressure at presentation were analyzed. Complete urinalysis, spot urine protein-to-creatinine ratio, serum creatinine, estimated glomerular filtration rate (eGFR), serum albumin, and electrolyte levels (Na, K, Ca and P) were noted to evaluate renal function. Throat culture results, anti-streptolysin O (ASO) titer, and complement levels of C3 and C4 were analyzed. Urinary system ultrasonography was performed for increased renal parenchymal echogenicity and corticomedullary differentiation. If available, a renal biopsy report was obtained. Treatments and medications administered to the patients were noted. Posttreatment hematuria, proteinuria, blood pressure, serum creatinine, and complement C3 levels were analyzed.

Definitions

Blood pressure was measured using a manual auscultation device after a 10-min rest, with two measurements taken in the same arm using the appropriate cuff. The average of these readings was recorded. All measurements were performed by the same pediatric nephrologist during each outpatient visit. Hypertension was diagnosed based on the 2017 guidelines[12]. The presence of more than 5 erythrocytes per high-power field (HPF) in centrifuged urine indicates microscopic hematuria, whereas dark brown urine, resembling cola or tea, indicates macroscopic hematuria. Macroscopic hematuria lasting longer than 4 weeks is defined as persistent macroscopic hematuria. A spot urine protein-to-creatinine ratio >0.2 mg/mg indicates proteinuria, whereas a ratio exceeding 2 mg/mg is considered nephrotic-level proteinuria[13]. Nephrotic-level proteinuria accompanied by edema, hypoalbuminemia (less than 2.5 g/dL), and hypercholesterolemia (greater than 200 mg/dL) is defined as nephrotic syndrome[14]. eGFR was determined using a modified Schwartz formula[15]. Nephritic syndrome has been defined as the sudden onset of glomerular damage features manifested as hematuria, proteinuria, oliguria, edema, hypertension, and elevated creatinine. Moreover, nephritic syndrome,

which is characterized by a rapid decline in kidney function over a matter of days, has been defined as rapidly progressive glomerulonephritis[16].

AI

Using the local internet network of Konya City 12 open-ended questions about APSGN were directed to ChatGPT 3.5 in English (Table 1). No additional training was provided to the AI before the questions and clinical information of the cases were routed to it. No query was made to APSGN or any other subject, and the application was used immediately after the computer was turned on. The accuracy of the AI answers to the questions was evaluated by two researchers according to internationally accepted publications and guidelines. Each answer was categorized as "incorrect", "missing information", "correct" according to the evaluation result. Then, the characteristics of the patients included in the study were transferred to ChatGPT 3.5, and diagnosis and follow-up of the patients were managed using AI was examined. We evaluated whether there was a difference between the clinicians and AI follow-up.

The study received approval from the KTO-Karatay University Rectorate Dean of the Faculty of Medicine non-Drug and non-Medical Device Research Ethics Committee Presidency (decision no: 2024/57, date: 16.01.2024).

Statistical Analysis

In presenting descriptive statistics, continuous data were reported as mean±standard deviation, whereas categorical data were presented as counts (percentages). The Shapiro-Wilk test was used to assess the normality of the numerical data in the groups. Statistical analyses were performed using International Business Machines Statistical Package for Social Sciences statistics version 22.

RESULTS

Clinical and Laboratory Characteristics of Patients

The study included 11 patients, with a male-to-female ratio of 1.2. The mean age was 9.08±3.96 years (range, 5-16.3 years). The present complaints included bloody urine (n=7, 63.6%), edema (n=3, 27.3%), and headache/seizure (n=1, 9.1%). All patients had upper respiratory tract infection (URTI) before the onset of symptoms. The mean duration after URTI until the onset of symptoms was 10.1±2.8 (7-15) days.

At the time of presentation, the mean systolic and diastolic blood pressure z-score was 1.21±0.43 (0.56-2.33) and the mean diastolic blood pressure Z-score was 1.39±0.37 (0.67-2.33), and approximately half of the patients (n=5, 45.5%) had hypertension. Malignant hypertension was detected in one patient. Mean creatinine was 1.12±1.1 mg/dL (0.48-2.42) and mean eGFR was 78.7±31.8 mL/min/1.73m^2 (50.6-117.2). The mean serum albumin was 3.46±0.60 g/dL (2.3-4.1) and hypoalbuminemia was found in 3 (27.2%) patients. Throat culture samples were obtained from all patients, and group A β hemolytic streptococcus was grown in 4 (36.3%) patients. ASO was high in all patients [mean 955±353 IU/mL (488-1614)]. The mean complement C3 level was 0.56±0.34 g/L (0.19-1.17) and 9 (81.8%) patients had low complement levels. All patients had varying degrees of hematuria. The mean erythrocyte count was 525±915.4/HPF (10-3171) and spot urine protein/creatinine value was 2.85±2.16 mg/mg (0.19-6.94). Proteinuria was present in 10 patients (90.9%). In addition to rest, fluid, and salt restriction, angiotensin-converting enzyme inhibitors were started in 5 (45.5%) patients with hypertension associated with proteinuria (Table 2).

Table 1. Questions directed to ChatGPT 3.5.

	Questions
1.	What is the definition of acute post streptococcal glomerulonephritis?
2.	What is the epidemiology of acute post streptococcal glomerulonephritis?
3.	How is the pathophysiology of acute post streptococcal glomerulonephritis?
4.	What is the relationship between acute post streptococcal glomerulonephritis and complement system?
5.	What are the clinical manifestations of acute post streptococcal glomerulonephritis?
6.	How is acute post streptococcal glomerulonephritis diagnosed?
7.	What are the indications for renal biopsy in acute post streptococcal glomerulonephritis?
8.	How is the treatment of acute post streptococcal glomerulonephritis?
9.	What are the drugs that can be used in the treatment of acute post streptococcal glomerulonephritis?
10.	What are additional immunosuppressives other than steroids in acute post streptococcal glomerulonephritis?
11.	How should clinical and laboratory findings be monitored in the follow-up of acute post streptococcal glomerulonephritis?
12.	What is the prognosis of acute post streptococcal glomerulonephritis?

Table 2. Demographic and clinical features of the study group.			
	n (%)	**Mean ± SD**	**Min-max**
Sex			
Male	6 (54.5)		
Age (years)		9.08±3.96	5-16.3
URTI history	11 (100)		
Time after URTI (days)		10.1±2.8	7-157-15
At presentation			
Complaints			
Hematuria	7 (63.6)		
Edema	3 (27.3)		
Headache/seizure	1 (9.1)		
Blood pressure			
SBP (z-score)		1.21±0.43	0.56-2.33
DBP (z-score)		1.39±0.37	0.67- 2.33
HT	5 (45.2)		
Laboratory results			
Blood			
Creatinine (mg/dL)		1.12±1.1	0.48-2.42
eGFR (mL/min/1.73m^2)		78.7±31.8	50.6-117.2
Albumin (g/dL)		3.46±0.6	2.3-4.1
Hypoalbuminemia	3 (27.2)		
ASO (IU/mL)		955±353	488-1614
Complement C3 (g/L)		0.56±0.34	0.19-1.17
Low	9 (81.8)		
Na (mEq/L)		137.2±3.8	131-143
K (mEq/L)		5.10±0.62	4.0-6.2
Ca (mg/dL)		8.84±0.40	7.9-9.3
P (mg/dL)		5.02±0.87	3.8-6.6
Urine			
Erythrocye (/HPF)*		525±915	10-3171
Hematuria	11 (100)		
Protein/creatinine (mg/mg)		2.85±2.16	0.19-6.94
Proteinuria	10 (90.9)		
Throat culture			
A group β hemolytic streptococcus	4 (36.3)		
Treatments			
Drugs			
ACEi	5 (45.5)		
Esmolol	1 (9.1)		
Diuretics	1 (9.1)		
Steroids	2 (18.2)		
Cyclophosphamide	2 (18.2)		
RRT			
HD	1 (9.1)		
At last control			
Blood			
Creatinine (mg/dL)		0.54±0.15	0.38-0.89
Complement C3 (g/L)		1.13 ± 0.21	0.94 - 1.39
Low	0 (0)		
Na (mEq/L)		138.3±2.73	135-144
K (mEq/L)		4.77±0.67	4.0-6.0
Ca (mg/dL)		9.26±0.49	8.1-10.0
P (mg/dL)		4.85±0.53	3.7-5.6
Urine			
Erythrocye (/HPF)*		27±72	1-271
Hematuria	8 (72.2)		
Protein/creatinine (mg/mg)		0.71±2.38	0.10-8.39
Proteinuria	7 (63.6)		

*Since the results were not homogeneously distributed for urine erythrocytes, the median value was given instead of the mean. URTI: Upper respiratory tract infection, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, HT: Hypertension, eGFR: Estimated glomerular filtration rate, ASO: Anti-streptolysin-O, ACEi: Angiotensin converting enzyme inhibitor, RTT: Renal replacement therapy, HD: Hemodialysis, Na: Sodium, K: Potassium, Ca: Calcium, P: Phosphorus

A patient with malignant hypertension presented to the emergency department because of headache and seizures. Cranial imaging showing posterior reversible encephalopathy syndrome. In the intensive care unit, intravenous esmolol and diuretics were initiated, and no hypertensive need remained during follow-up. Renal biopsy was performed in a patient whose serum creatinine was 2.42 mg/dL at admission and increased to 5.35 mg/dL within 4 days was thought to have rapidly progressive glomerulonephritis. The biopsy showed intense mesangial proliferation, matrix increase, and increased interstitial inflammation. Immunofluorescence staining revealed C3 and immunoglobulin G deposition in glomeruli. Crescent formation was observed in 55.5% and fibrinoid necrosis in 12.5% of the evaluated glomeruli. The patient received intravenous pulse methylprednisolone for 3 days, followed by oral prednisolone at a dose of 2 mg/kg/day, with a maximum dose of 60 mg/day. Intermittent hemodialysis was performed for a total of 14 days because of uremia. Pulse cyclophosphamide was started in a patient who did not have the expected creatinine decrease with hemodialysis, 3 doses have been administered so far, and it is planned to complete a total

Table 3. Clinical and laboratory characteristics of three patients and responses given by artificial intelligence.

Case presentation	Diagnosis	Treatment
5.4-year-old girl presents to the emergency department due to seizures following a headache for a few days. Eyelid edema is noted in the postictal period. It is learned that she had an upper respiratory tract infection about 14 days ago. On examination, her blood pressure is 145/89 mmHg (above 99th percentile for both). Laboratory findings show serum creatinine 1.32 mg/dL, serum albumin 3.3 g/L, Na 133 mmol/L, K 5.9 mmol/L, Ca 8.7 mg/dL, and P 5.3 mg/dL. Urinalysis reveals a red blood cell-count of 211 /HPF and a spot urine protein/creatinine ratio of 2.07 mg/mg. Complement C3 level is 0.19 g/L, and anti-streptolysin O (ASO) level is 1322 IU/mL. The throat culture shows no growth.	Based on the provided clinical information, the diagnosis of this patient is likely posterior reversible encephalopathy syndrome (PRES) with hypertension and seizure. The causes of PRES appears to be acute poststreptococcal glomerulonephritis (APSGN). This diagnosis is supported by the history of upper respiratory tract infection, significantly elevated ASO titer, low serum C3 level, and hematuria.	Hospitalization: Given the severity of the presentation, the patient should be hospitalized in intensive care unit for close monitoring and management. Management of hypertension: Aggressive control of hypertension is essential to prevent complications. Intravenous antihypertensive medications are commonly used in PRES to help lower blood pressure. Management of hyperkalemia: Given the high serum potassium level (6.9 mEq/L), measures to lower potassium levels should be initiated promptly, such as dietary restriction of potassium and possibly administration of potassium-lowering medications like loop diuretics or potassium binders. Inhaled salbutamol and insulin treatments can also be used if hyperkalemia persists.
14.4-year-old boy presents with complaints of bloody urine. It is learned that he had an upper respiratory tract infection about 10 days ago. On examination, his blood pressure is 145/91 mmHg (above 99th percentile for both). Laboratory findings show serum creatinine 2.42 mg/dL, serum albumin (2.3 g/L, Na 135 mmol/L, K 6.2 mmol/L, Ca 7.9 mg/dL, and P 6.6 mg/dL. Urinalysis reveals a red blood cell-count of 237 /HPF and a spot urine protein/creatinine ratio of 6.94 mg/mg. Complement C3 level is 0.52 g/L, and ASO level is 1614 IU/mL. The throat culture shows no growth. The patient's serum creatinine rises to 5.35 mg/dL within 4 days.	Based on the provided clinical information, the diagnosis of this patient is likely rapidly progressive glomerulonephritis (RPGN) with severe kidney impairment and hypertension. The causes of RPGN appears to be APSGN. This diagnosis is supported by the history of upper respiratory tract infection, significantly elevated ASO (anti-streptolysin O) titer, low serum C3 level, and hematuria.	Hospitalization: Given the severity of the presentation, the patient should be hospitalized for close monitoring and management. Management of hypertension: Aggressive control of hypertension is essential to prevent further kidney damage. Antihypertensive medications such as angiotensin-converting enzyme inhibitors (ACE inhibitors) or angiotensin receptor blockers (ARBs) are commonly used in RPGN to help reduce proteinuria and lower blood pressure. Management of hyperkalemia: Given the high serum potassium level (6.2 mEq/L), measures to lower potassium levels should be initiated promptly, such as dietary restriction of potassium and possibly administration of potassium-lowering medications like loop diuretics or potassium binders. Inhaled salbutamol and insulin treatments can also be used if hyperkalemia persists. Renal replacement therapy: With severe kidney impairment (serum creatinine 5.35 mg/dL), renal replacement therapy such as hemodialysis or peritoneal dialysis may be required to manage uremia and electrolyte abnormalities. Corticosteroids or immunosuppressive therapy: In cases of RPGN, particularly if there is evidence of crescentic glomerulonephritis on renal biopsy, corticosteroids and immunosuppressive agents such as cyclophosphamide may be initiated to suppress inflammation and prevent further kidney damage.

Table 3. Continued		
Case presentation	**Diagnosis**	**Treatment**
7.9-year-old girl presents with complaints of bloody urine. It is learned that she had an upper respiratory tract infection 12 days ago. On examination, her blood pressure is 132/92 mmHg (above 99th percentile for both). Laboratory findings show serum creatinine 0.48 mg/dL, serum albumin 2.6 g/L, Na 131 mmol/L, K 5.5 mmol/L, Ca 8.5 mg/dL, and P 5.7 mg/dL. Urinalysis reveals a red blood cell-count of 588 / HPF and a spot urine protein/creatinine ratio of 6.02 mg/mg. Complement C3 level is 1.07 g/L, and ASO level is 988 IU/mL. The throat culture shows no growth. ACE inhibitors were started for the patient, and blood pressure returned to normal, but hematuria and proteinuria persisted. During follow-up, significant edema develops in the face and legs, and serum albumin levels drop to 1.5 g/L. A kidney biopsy was performed, which showed mesangial IgG and C3 deposits, no IgA deposits, a starry sky appearance, and endocapillary proliferation.	Based on the provided clinical information, the diagnosis of this patient is likely nephrotic syndrome with hypoalbuminemia, proteinuria and edema. The causes of nephrotic syndrome appears to be APSGN. This diagnosis is supported by the history of upper respiratory tract infection, significantly elevated ASO titer, hematuria and a starry sky appearance in biopsy.	Hospitalization: Given the severity of the presentation, the patient should be hospitalized for close monitoring and management. Management of hypertension: Aggressive control of hypertension is essential to prevent further kidney damage. Antihypertensive medications such as angiotensin-converting enzyme inhibitors (ACE inhibitors) or ARBs are commonly used in APSGN to help reduce proteinuria and lower blood pressure. Management of hyperkalemia: Given the high serum potassium level (6.2 mEq/L), measures to lower potassium levels should be initiated promptly, such as dietary restriction of potassium and possibly administration of potassium-lowering medications like loop diuretics or potassium binders. Inhaled salbutamol and insulin treatments can also be used if hyperkalemia persists. Corticosteroids or immunosuppressive therapy: In cases of nephrotic syndrome, corticosteroids such as prednisolone for 6-8 weeks may be initiated to suppress inflammation and prevent further kidney damage.
ACE: Angiotensin converting enzyme, IgG: Immunoglobulin G, Na: Sodium, K: Potassium, Ca: Calcium, P: Phosphorus		

of 6 doses. Daily treatment with 10 mg of prednisolone is continued. Another patient who had hypoalbuminemia (2.3 g/dL) on admission and developed nephrotic syndrome during follow-up underwent renal biopsy. Unlike the first patient, no evidence of crescent or necrosis was observed. Treatment was continued with oral 2 mg/kg/day of pulse methylprednisolone. A patient with decreased proteinuria and improved hypoalbuminemia is being treated with a steroid taper. The clinical characteristics of the AI for these three patients and their responses are shown in Table 3.

In all patients with elevated serum creatinine levels, normal serum creatinine levels were reached after a mean of 12.5±4.9 days. At the last follow-up, the mean serum creatinine level of the study population was 0.54±0.15 mg/dL (0.38-0.89). Complement C3 levels returned to normal in all patients. Microscopic hematuria persisted in 8 patients (72.7%) (median 27±72/HPF erythrocytes on urinalysis). Except for the patient with rapidly progressive glomerulonephritis, proteinuria levels decreased significantly in all patients compared with baseline (median spot urine protein/creatinine 0.71±2.38 mg/mg). In a patient with rapidly progressive glomerulonephritis, the spot urine protein/creatinine ratio was 8.39 mg/mg (Table 2).

Evaluations Using AI

ChatGPT 3.5 answered questions evaluating the definition, epidemiologic characteristics, pathophysiologic mechanisms, diagnosis, and treatment of APSGN as "correct". Questions directed to ChatGPT and responses provided by ChatGPT are presented in Supplemental File 1.

When the clinical and laboratory characteristics of all patients were directed to the program, they were diagnosed with APSGN using ChatGPT 3.5. In terms of treatment and follow-up, the practices performed by ChatGPT 3.5 and clinicians were highly similar. Rest, fluid, and salt restriction were recommended to all patients by ChatGPT 3.5. The initiation of an angiotensin-converting enzyme inhibitor is recommended for hypertension and/or proteinuria. In patients with malignant hypertension, intravenous anti-hypertensives were initiated, and the patient was recommended to be followed up in the intensive care unit. In patients with hyperkalemia, a potassium-poor diet, inhaled salbutamol, and oral potassium binders are recommended. Steroid treatment was recommended for patients with nephrotic syndrome, but no recommendation was made regarding the route of administration or dosage. The patient with a rapid creatinine increase was also diagnosed with rapidly

progressive glomerulonephritis by ChatGPT 3.5 and was recommended to start steroid and cyclophosphamide treatments without any opinion on the dose and route of administration. No kidney biopsy was advised for any patient. Except for those presented in Table 2, the clinical characteristics of other patients referred to ChatGPT and the responses provided by ChatGPT are presented in Supplemental File 2.

DISCUSSION

APSGN is the most common glomerulonephritis in childhood caused by some strains of group A β-hemolytic streptococci following urticaria or skin infection, and develops with immune complex deposition in the kidney. Patients may experience sudden onset of bloody urination, edema, hypertension, and clinical findings of acute renal failure[17]. In our study, all patients had URTI before kidney involvement. Group A β-hemolytic streptococcus positivity was demonstrated in throat culture in some patients, but all patients had markedly elevated ASO levels, which is a marker of previous infection. Although macroscopic hematuria was seen in 63.6% of the patients who presented with hematuria, all patients had hematuria. Although nephrotic syndrome was observed in one patient and rapidly progressive glomerulonephritis in another, most patients presented with acute nephritic syndrome.

Precautions should be taken for acute renal failure due to APSGN. Penicillin is recommended for streptococcal infections. However, antibiotic treatment had no impact on the progression of the disease[18]. In our study, only penicillin was used in patients with a history of throat culture. Activity should not be restricted except in the acute period. Salt restriction should be performed during kidney impairment and hypertension. In selected cases, antihypertensive drugs, such as an angiotensin-converting enzyme inhibitor and/or calcium channel blockers, may be used[18]. Although normotension can be achieved with oral antihypertensives, malignant hypertension and related complications that may require the use of intravenous antihypertensives may also develop[19]. In our study, one of our patients presented to the hospital with headache, seizures, mild periorbital edema, and significantly elevated blood pressure according to age, sex, and height. The patient was diagnosed with posterior reversible encephalopathy on magnetic resonance imaging. Although serum creatinine was normal at presentation, the patient had a history of URTI, elevated ASO, and low complement C3. On follow-up, laboratory findings normalized, and normotension was achieved without the need for long-term antihypertensives. It was thought that the patient had acute renal failure with oliguria before presentation to the hospital and presented to the hospital with seizure in the late period when renal function started to improve. Apart from general recommendations and antihypertensive drugs for APSGN, immunosuppressive treatments may be indicated for patients with a noisy picture[20]. In our study, two patients who developed nephrotic syndrome and rapidly progressive glomerulonephritis were initiated on steroids and cyclophosphamide, respectively.

Among patients with APSGN, 95% recover without developing permanent problems. If the acute phase has a very severe course and glomerular hyalinization is caused, kidney failure may be observed in 5% of the cases[18]. In our study, except for the patient diagnosed with rapidly progressive glomerulonephritis, the hematuria level decreased significantly, and improvement was observed in the proteinuria levels in other patients. Even in our patient with severe initial findings due to rapidly progressive glomerulonephritis, serum creatinine levels regressed to normal values, but nephrotic proteinuria persisted.

ChatGPT is a language model developed by OpenAI. It is an AI system that is highly skilled in natural language processing and specializes in understanding, analyzing, and generating text data. It can interact with users in a natural language and generate meaningful responses[21]. The design and development phases of ChatGPT are complex. It is based on an architecture called "Generative Pre-trained Transformer". This architecture was pre-trained on datasets containing large amounts of text. These datasets are obtained from diverse sources, including books, articles, web pages, and forums. ChatGPT can be customized to specific tasks or datasets, typically by tweaking a pre-trained model. This fine-tuning process allows the model to produce more specific and accurate answers on a given topic[22].

Thanks to rapid technological advancement, ChatGPT versions have been rapidly updated in recent years as ChatGPT-3.0, 3.5, 4.0, and 4.0-Turbo, respectively. While ChatGPT-3.5 offers higher accuracy and consistency than ChatGPT-3.0, ChatGPT-4.0 can be trained with a larger training dataset and more parameters, resulting in more complex and nuanced responses. ChatGPT-4.0 also gained the ability to process text and visual inputs simultaneously. ChatGPT-4.0 Turbo is optimized for speed and cost, offering faster response times, especially in real-time applications. Although ChatGPT 4.0 and 4.0-turbo require a monthly fee, the previous versions can be used free of charge by anyone[23]. For this reason, ChatGTP 3.5, which is publicly and freely available,

was used in this study, and the economic burden associated with the use of AI was avoided. However, since ChatGPT-3.5 is trained on data up to September 2021, the accuracy of answers given after this date may be affected, especially in cases that query more recent developments in medical issues[24]. It is indisputable that the answers given by AI would contain much more up-to-date information if ChatGPT 4.0 or the 4.0-Turbo versions had been used in our study.

ChatGPT is used in many medical departments. In the field of pediatric dentistry, ChatGPT is used to identify caries lesions, improve diagnostic imaging accuracy and efficiency, improve treatment esthetics, simulate outcomes, and predict oral diseases. The ability to provide immediate feedback and clarify doubts has been shown to help improve health status and oral hygiene by providing patients with relevant information. However, it should be noted that ChatGPT is not completely free of errors or limitations, and the plausibility of incorrect answers can be surprising. Therefore, it is emphasized that ChatGPT outputs should be checked manually by clinicians[25]. However, in our study, questions evaluating the definition, epidemiologic characteristics, pathophysiologic mechanisms, diagnosis, and treatment of APSGN were answered correctly by ChatGPT 3.5. Answers to these questions can also be obtained using traditional search engines such as Google or medical/scientific databases such as PubMed or UpToDate. However, ChatGPT provides general medical information derived from various sources and responds very quickly[23]. Both PubMed and UpToDate present pages of data when information on a medical topic is sought, which may take users hours to sift through to find the desired information. Thus, ChatGPT saves users significant time. In a study in which ChatGPT asked junior and senior specialist questions about the thyroid, ChatGPT was shown to produce responses quickly[26]. However, unlike these search engines, ChatGPT does not provide references. This lack of citations is a potential weakness of ChatGPT. In a study comparing ChatGPT and UptoDate, ChatGPT could not provide references for some questions. In addition, the accuracy score of the responses provided by ChatGPT in this study was significantly lower than that of UptoDate[27].

There are some studies stating that the use of ChatGPT in the medical field is beneficial. For example, ChatGPT can play a role in various fields, including pediatric radiology. In this study, various case scenarios related to pediatric radiological imaging methods were directed to ChatGPT, and the responses of AI were evaluated. ChatGPT provided suggestions about imaging modalities that could be applied for each clinical scenario. It was able to provide information on whether imaging techniques that do not use radiation can be used in the current scenario. If radiation is to be used, it provides information on the optimum dose. It has been pointed out that ChatGPT can provide valuable information, but the final interpretation and diagnosis should always be made by a radiologist[22]. In another medical field, the integration of AI into the field of pediatrics has the potential to transform healthcare with new and effective approaches for supporting diagnoses, treatment plans, and specific clinical decisions[28]. This study explored ChatGPT's effectiveness as a decision-making tool in pediatrics by posing 8 clinical symptom-related questions. Two pediatricians independently assessed ChatGPT's open-ended responses. The findings indicated that ChatGPT could enhance clinical workflows and support decision-making in pediatrics[11]. In our study, when the features of the cases were assessed, treatments administered by clinicians to all patients with a diagnosis of APSGN and the ChatGPT recommendations. However, it did not mention the route of administration or dosage of the recommended drugs. In the field of pediatrics, the route of administration and dosage of each drug are of great importance. Although this situation seems to be a limitation of ChatGPT, ChatGPT will be used by medical specialists, as in this study. In any event, it is suggested to use ChatGPT's recommendations with questioning. It should be used together with the clinician and should be considered as an assistant to the clinician. Therefore, we believe that the lack of ChatGPT's information about drug administration routes and dosages is an acceptable deficiency.

CONCLUSION

Further investigations and advancements in ChatGPT's capabilities related to pediatric care could potentially enhance patient management and healthcare delivery. In our study, the information and guidance provided by ChatGPT on APSGN may be a valuable resource for patient care and management. However, under current conditions, the recommendations provided by ChatGPT applications must be manually checked and evaluated by clinicians. New updates and developments are required for AI to be routinely used.

Ethics

Ethics Committee Approval: The study received approval from the KTO-Karatay University Rectorate Dean of the Faculty of Medicine non-Drug and non-Medical Device Research Ethics Committee Presidency (decision no: 77998, date: 16.01.2024).

Informed Consent: This was a retrospective observational study with a cross-sectional design in which the demographic, clinical, and laboratory characteristics of patients aged 0-18 years who were followed up with a diagnosis of APSGN in the Department of Pediatric Nephrology between September 2023 and March 2024 were analyzed from patient records.

Author Contributions

Surgical and Medical Practices: E.L., Concept: E.L., M.S., Design: E.L., M.S., Data Collection and/or Processing: E.L., Analysis and/or Interpretation: E.L., M.S., Literature Search: E.L., M.S., Writing: E.L., M.S.

Conflict of Interest: The authors have no conflict of interest to declare.

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