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Evaluation of Cerebrovascular Events Followed in Pediatric Intensive Care Unit

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ABSTRACT

AIM: To evaluate the effect of intensive care follow-up and treatment methods on the prognosis of 28 patients admitted to the pediatric intensive care unit (PICU) due to stroke.

MATERIAL and METHODS: The data of patients aged between 28 days and 18 years followed up between 2011 and 2021 were recorded retrospectively.

RESULTS: Thirteen (48.1%) patients were diagnosed with hemorrhagic stroke (HS), 11 (40.7%) patients were diagnosed with acute ischemic stroke (AIS), and three (11.1%) patients were diagnosed with cerebral sinus vein thrombosis. One patient was followed up for non-ruptured arteriovenous malformation (AVM) and was excluded from the HS group. The HS group consisted of eight patients with ruptured AVMs and five patients with ruptured intracranial aneurysms. The patients had male predominance, and seizures and headache were the most common complaints on admission. The rate of admissions due to seizures was higher in the AIS group. In the HS group, there was more involvement of the right side of the brain. Middle cerebral artery (MCA) involvement was higher in the AIS group. The AIS group had longer PICU hospitalization days and mechanical ventilator days. While unfractionated heparin was preferred for the treatment in the AIS group, endovascular embolization was preferred in the HS group. Decompressive surgery was performed in five patients. The overall mortality rate was 7.1%.

CONCLUSION: Although cerebrovascular events are rare in the pediatric population, achieving low mortality and morbidity is possible with the correct diagnostic and treatment methods.

KEYWORDS: Acute ischemic stroke, Aneurysm, COVID-19 era, Embolization, Hemorrhagic stroke, Thrombosis

ABBREVIATIONS: ACA: Anterior cerebral artery, **AIS:** Acute ischemic stroke, **ALT:** Alanine aminotransferase, **AST:** Aspartate aminotransferase, **AVM:** Arteriovenous malformation, **CT:** Computed tomography, **CTA:** Computed tomography angiography, **CVE:** Cerebrovascular events, **EVD:** External ventricular drainage, **GCS:** Glasgow Coma Scale, **HS:** Hemorrhagic stroke, **IA:** Intracranial aneurysm, **ICD-10:** International Statistical Classification of Diseases, 10th version, **INR:** International normalized ratio, **MCA:** Middle cerebral artery, **MELAS:** Mitochondrial encephalomyopathy, lactic acidosis and stroke-like episodes, **MRA:** Magnetic resonance angiography, **MRI:** Magnetic resonance imaging, **MTHFR:** Methylene tetrahydrofolate reductase, **PICU:** Pediatric intensive care unit, **SVT:** Cerebral sinus vein thrombosis, **TPA:** Tissue plasminogen activator, **UH:** Unfractionated heparin

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INTRODUCTION

Stroke is defined as an acute neurological deficit caused by cerebrovascular events (CVEs) in childhood, occurring between the ages of 28 days and 18 years and lasting at least 24 h (32). Although it is observed much less frequently in children than in adults, stroke is an important cause of mortality and morbidity (24,51). Stroke is classified into three groups: arterial ischemic stroke (AIS), characterized by parenchymal infarction matching the existing arterial site; cerebral sinus vein thrombosis (SVT), characterized by thrombosis of intracranial veins and sinuses; and hemorrhagic stroke (HS), characterized by intracranial bleeding not associated with ischemic infarction (14,42). The incidence of ischemic and HSs in childhood ranges between 2.0 and 5.9/100.000 persons per year, whereas the estimated incidence of SVT has been shown to be less than 1 in 100.000 (11,18,30,51). In a prospective observational study involving 287 children admitted to the emergency department with acute-onset focal neurological deficit, stroke was responsible for 7% of the etiologies (33). Its incidence peaks in individuals under the age of 1 year and adolescents (18). It has been reported that childhood strokes have a better prognosis than that observed in adults. Approximately 20% of cases have a poor neurological prognosis; recurrence occurs in 20% of cases; and in 10% of cases, stroke results in mortality (12,38,45,54).

In this study, patients followed in the pediatric intensive care unit (PICU) due to CVEs were evaluated in terms of demographic data, neurological examination findings, PICU follow-ups, characteristics of the CVEs, laboratory parameters and imaging methods, and treatments. We aimed to evaluate the role of follow-up and treatment modalities used in the intensive care follow-up of childhood stroke cases in improving the neurological prognosis and reducing morbidity rates. The patients were divided into three groups: the AIS, HS, and SVT groups, and comparisons were made between the AIS and HS groups.

MATERIAL and METHODS

In this study, 28 patients, aged between 28 days and 18 years, who were hospitalized due to CVEs in a 16-bed PICU between 2011 and 2021 were included. Ethics Committee approval was obtained for the study, and all procedures were performed according to the Declaration of Helsinki (Bakirkoy Dr. Sadi Konuk Training and Research Hospital, IRB:2021-19-10, Date:04.10.2021). Our PICU is a tertiary intensive care unit where all kinds of critically ill children are treated, except for the postoperative follow-up of patients who have undergone cardiac surgery. However, our hospital has no specialized team for diagnosing and treating childhood strokes. The data of the patients were accessed from the hospital database records using the codes of the International Statistical Classification of Diseases, 10th version (ICD-10). Patients with missing data were excluded from the study. Diagnoses were supported by radiological imaging in patients with acute neurological deficits exceeding 24 hours. Accordingly, irreversible brain tissue ischemia due to arterial occlusion for AIS, intracranial hemorrhage without ischemia for HS, and thrombosis of the intracranial sinuses and veins for SVT were considered. Demographic data (i.e., sex, age, the presence of chronic disease, and complaint at admission), neurological examination findings (i.e., neurological findings on admission and the presence of pupillary reflex and pathological Babinski reflex), trauma history, PICU follow-ups (Glasgow Coma Scale [GCS] scores at baseline and before discharge), the number of hospitalization days in the PICU, the number of mechanical ventilator days, mortality, characteristics of the CVEs (affected area/circulation and involved vessel/sinus), laboratory parameters (i.e., white blood cell count, platelet count, hemoglobin, international normalized ratio [INR], fibrinogen, d-dimer, urea, creatinine, aspartate aminotransferase [AST], alanine aminotransferase [ALT], and sodium levels), imaging methods used for diagnosis (i.e., computed tomography [CT], magnetic resonance imaging [MRI], CT angiography [CTA], MR angiography [MRA], and venography), treatments (i.e., antiepileptic therapy, antihypertensive therapy, hyperosmolar therapy, and antithrombotic therapy), radiological interventions (i.e., interventional mechanical thrombectomy and endovascular embolization), and surgical treatments (external ventricular drainage [EVD] and decompressive surgery) were recorded.

Statistical Analysis

Number Cruncher Statistical System (NCSS) 2007 (Kaysville, Utah, USA) was used for all statistical analyses. Descriptive statistical methods (i.e., means, standard deviations, medians, minimum values, maximum values, frequencies, and percentages) were used to evaluate the data. The distribution of quantitative data was tested using the Shapiro–Wilk test and graphical examinations. The independent sample t-test was used to compare normally distributed quantitative variables of two groups, and the Mann–Whitney U test was used to compare two groups with non-normally distributed quantitative variables. Pearson's chi-square test, Fisher's exact test, and the Fisher–Freeman–Halton exact test were used to compare qualitative data. Because the number of patients in the groups was low, the Mann–Whitney U test was used for numerical measurements that did not meet the normal distribution conditions; Pearson's chi-square test was used for categorical data, if the number of observations was sufficient; and in some cases, the corrected chi-square test was used. Test selection was made completely according to the types of variables and the number of cases. *P*-values <0.05 were used to indicate statistical significance.

RESULTS

In this study, 28 patients [17 males (60.7%) and 11 females (39.3%)] were included. Eleven (40.7%) patients were diagnosed with AIS, three (11.1%) with SVT, and 13 (48.1%) with HS. In the HS group, eight (61.5%) patients had a ruptured arteriovenous malformation (AVM) and five (38.5%) had a ruptured intracranial aneurysm (IA). One patient complained of subcutaneous hemorrhage in the right frontal region and was followed up for non-ruptured AVM. This particular patient was excluded from the HS group because there was no parenchymal finding. The distributions of the descriptive features of all patients are shown in Table I. The descriptive

Table I: The Distributions of the Descriptive Features of all Cases

		n (%)
Gender	Male	17 (60.7)
	Female	11 (39.3)
Age (month)	*Mean±Sd*	112.29±69.20
Chronic disease	No	23 (82.1)
	Yes	5 (17.9)
Complaint at admission	Headache	8 (28.6)
	Vomiting	7 (25.0)
	Convulsion	13 (46.4)
	Others	9 (32.1)
	Respiratory arrest	1 (11.1)
	Cardiac arrest	1 (11.1)
	Syncope	2 (22.2)
	Diplopia	1 (11.1)
	Restlessness	1 (11.1)
	Unconsciousness	1 (11.1)
	Subcutaneous hemorrhage	1 (11.1)
	Inability to speak	1 (11.1)
	Weakness in the arms and legs	1 (11.1)
Neurological deficit	No	6 (21.4)
	Yes	22 (78.6)
Pupillary reflex	No	2 (7.1)
	Yes	26 (92.9)
Pathological Babinski reflex	No	27 (96.4)
	Yes	1 (3.6)
Trauma	No	24 (85.7)
	Yes	4 (14.3)

features of the three patients in the SVT group are shown in Table II. Accordingly, the mean age of the group was 124.67 ± 109.13 months, and no chronic diseases and no history of trauma were found in the patients. The PICU hospitalization duration ranged from 4 to 81 days, with a mean duration of 36.00 ± 40.11 days. The course of any case did not result in mortality. The comparison of the descriptive features of the AIS and HS groups is shown in Table III. The rate of admission due to seizure complaints in the AIS group was significantly higher ($p=0.001$; $p<0.01$). A higher rate of the involvement of the right side of the brain was observed in the HS group ($p=0.030$; $p<0.05$). Middle cerebral artery (MCA) involvement was more common in the AIS group ($p=0.033$; $p<0.05$). The comparison of the laboratory parameters between the two groups is shown in Table IV. The comparison of the groups in terms of imaging methods is shown in Table V. These data comprised all imaging methods performed after admission to the hospital. Accordingly, the proportion of patients for whom CT was preferred for imaging in the HS group and that of patients for whom MRA was preferred in the AIS group were significantly higher than in the other group ($p=0.031$; $p<0.05$, $p=0.047$; $p<0.05$, respectively). The comparison of the preference for the treatment methods between the two groups is shown in Table VI. These data comprised all treatment methods performed during admission to the PICU.

Table II: The Descriptive Features of the Three Cases in the SVT Group

	Gender	Age (months)	PICU stay (days)	MV stay (days)	Complaint at admission	Baseline and before discharge GCS	Neurologic deficit	Involved sinus	Affected area	INR	Fibrinogen	D dimer	Imaging methods	Treatment
Case 1	M	2	81	19	Cardiac arrest	3/15	Diffuse damage	Sigmoid, Transvers, Inferior sagittal sinus	Left	1.13	198	7.48	CT, MRI, CTA, MRA	Antiepileptic, Antihypertensive, Antiedema
Case 2	F	161	4	1	Headache	14/15	Focal deficit	Sigmoid sinus	Left	0.96	316	0.16	CT, MRI, MRA	Antiepileptic, Antiedema
Case 3	F	211	23	-	Convulsion	8/15	Focal deficit	Transvers sinus	Bilateral	1.26	373	1.44	MRI, MRA, VG	Antiepileptic, Antiedema

***PICU:** Pediatric intensive care, **MV:** Mechanical ventilator, **GCS:** Glasgow coma scale, **INR:** International normalized ratio (normal: 0.8-1.2), Fibrinogen (normal: 200-400 mg/dL), D dimer (normal: 0-0.5 µg FEU/mL), **CT:** Computed tomography, **MRI:** Magnetic resonance imaging, **CTA:** CT angiography, **MRA:** MR angiography, **VG:** Venography.*

Table III: The Comparison of the Descriptive Features of the HS and AIS Groups

		HS (n=13) n (%)	AIS (n=11) n (%)	p-value
Gender	Male	9 (69.2)	6 (54.5)	
	Female	4 (30.8)	5 (45.5)	
Age (months)	Med±Sd	127.92±63.94	89.55±68.55	
Chronic disease	No	11 (84.6)	8 (72.7)	
	Yes	2 (15.4)	3 (27.3)	
Complaint at admission	Headache	6 (46.2)	1 (9.1)	
	Vomiting	6 (46.2)	1 (9.1)	
	Convulsion	2 (15.4)	10 (90.9)	[a]**0.001***
	Others	5 (38.5)	1 (9.1)	
Neurological deficit	No	4 (30.7)	1 (9.09)	
	Yes	9 (69.3)	10 (90.91)	
Pupillary reflex		12 (92.3)	11 (100.0)	
Pathological Babinski reflex		1 (7.7)	0 (0.0)	
Trauma		2 (15.4)	2 (18.2)	
GCS on admission	Med±Sd	11.54±4.93	9.91±4.55	
GCS before discharge	Med±Sd	14.69±0.63	14.33±1.32	
PICU stay	Med±Sd	14.15±18.64	16.18±13.01	
MV stay	Med±Sd	8.50±9.90	17.00±4.32	

Table III: Cont.

		HS (n=13) n (%)	AIS (n=11) n (%)	p-value
Affected area	Right	9 (69.2)	2 (18.2)	[b]**0.030***
	Left	3 (23.1)	4 (36.4)	
	Bilateral	1 (7.7)	5 (45.5)	
Involved vessel	ACA	2 (15.4)	1 (9.1)	
	MCA	2 (15.4)	7 (63.6)	[c]**0.033***
	PICA	2 (15.4)	3 (27.3)	
Mortality	Exitus	0 (0.0)	2 (18.2)	
	Discharge	13 (100.0)	9 (81.8)	

*[a] Pearson Chi-Square Test, [b]Fisher Freeman Halton Test, [c]Fisher Exact Test, *p<0.01*
***HS:** Hemorrhagic stroke, **AIS:** Acute ischemic stroke, **GCS:** Glaskow coma scale, **PICU:** Pediatric intensive care unit, **Mv:** Mechanical ventilatory, **ACA:** Anterior cerebral artery, **MCA:** Middle cerebral artery, **PICA:** Posterior inferior cerebral artery.*

Table IV: The Comparison of Laboratory Parameters Between Groups

		HS (n=13)	AIS (n=11)
WBC	Median (Min-Max)	14.22 (5.98-25.00)	17.89 (6.21-24.70)
PLT	Median (Min-Max)	276 (130-427)	299 (203-386)
HGB	Median (Min-Max)	11.7 (10-13.9)	11.9 (9-16.5)
INR	Median (Min-Max)	1.2 (0.9-1.6)	1 (0.9-1.5)
Fibrinogen	Median (Min-Max)	286 (194-523)	299.5 (168-571)
D-dimer	Median (Min-Max)	0.9 (0.2-3.6)	0.4 (0.2-9.4)
Urea	Median (Min-Max)	22 (14-40)	27 (8.6-64.3)
Creatinine	Median (Min-Max)	0.5 (0.3-0.8)	0.4 (0.2-1.8)
AST	Median (Min-Max)	22 (12.8-71)	32 (16.3-50.7)
ALT	Median (Min-Max)	12.8 (8-26)	15.1 (9-22.9)
Na	Median (Min-Max)	137 (133-141)	140.1 (132-164)

***WBC:** White blood cell (normal: 4.31-11.00x10^3/µL), **PLT:** Platelet (normal: 206-369x10^3/µL), **HGB:** Hemoglobin (normal: 10.7-13.4 g/dL), **INR:** International normalized ratio (normal: 0.8-1.2), Fibrinogen (normal: 200-400 mg/dL), D-dimer (normal: 0-0.5 µg FEU/mL), Urea (normal: 15-36 mg/dL), Creatinine (normal: 0.32-0.59 mg/dL), **AST:** Aspartate aminotransferase (normal: 0-40 U/L), **ALT:** Alanine aminotransferase (normal: 0-41 U/L), **Na:** Sodium (normal: 132-141 mmol/L).*

DISCUSSION

In the study, 28 patients hospitalized in the PICU due to CVEs were evaluated. The low number of such patients was due to the necessity of following up cases in the intensive care units due to their need for intubation. Yock-Corrales et al. stated that 25 (36%) of 95 cases were followed under intensive care conditions (58). Consistent with the literature, the cases had male predominance (60.7%), and seizure (46.4%) and headache (28.6%) were the most common complaints on admission (9,19,43,47). Moreover, some patients complained of diplopia, inability to speak, and weakness in the arms and legs, although a small number. Childhood strokes may also present with localized manifestations, such as hemiparesis, hemifacial weakness, speech or language disorders, visual disturbances, and ataxia (15,17). Neurological deficit was detected in 78.6% of the cases on admission in this study, and the rate was found to be higher than that reported in the literature (47).

Three patients (11.1%) were diagnosed with SVT. Childhood SVTs are usually observed in both sexes equally (23). One of our patients was male and the other two were female. Headache, diplopia, and seizures were the complaints of the female cases, whereas the male case was hospitalized in the PICU after cardiopulmonary resuscitation. Seizure is the

Table V: The Comparison of the Groups In Terms of Imaging Methods

	HS (n=13) n (%)	AIS (n=11) n (%)	p-value
CT	13 (100.0)	7 (63.6)	[d]**0.031***
MRI	11 (84.6)	11 (100.0)	
CTA	10 (76.9)	4 (36.4)	
MRA	5 (38.5)	9 (81.8)	[d]**0.047***
VG	3 (23.1)	7 (63.6)	

*[d]Fisher Exact Test, *p<0.05.*

***HS:** Hemorrhagic stroke, **AIS:** Acute ischemic stroke, **CT:** Computed tomography, **MRI:** Magnetic resonance imaging, **CTA:** Computed tomography angiography, **MRA:** Magnetic resonance angiography, **VG:** Venography.*

Table VI: The Comparison of Treatment Methods

	HS (n=13) n (%)	AIS (n=11 n (%)	p-value
Antiepileptic	11 (84.6)	8 (72.7)	
Antihypertensive	2 (15.4)	1 (9.1)	
Antiedema	12 (92.3)	10 (90.9)	
UH	0 (0.0)	11 (100.0)	[d]**0.001***
Surgical therapy	5 (38.5)	1 (9.1)	
EE	9 (69.2)	0.0	

*[d]Fisher Exact Test, *p<0.01*
***UH:** Unfractionated Heparin, **EE:** Endovascular embolization.*

most common presentation of SVT in the pediatric population, and seizures and coma are poor prognostic factors (6,26,44). The involvement of the sigmoid and transverse sinuses in female patients and the sigmoid, transverse, and inferior sagittal sinuses in male patients was more pronounced. Left-sided involvement was observed in two patients, and bilateral involvement was observed in one patient. Asphyxia, dehydration, sepsis, head and neck infections (i.e., otitis media, mastoiditis, and sinusitis), polycythemia, and heart diseases can be listed as predisposing factors for childhood SVTs (22,37,50). All three patients had no history of chronic illness and had not been exposed to trauma. No heart disease was found in echocardiographic imaging. There was no history of oral contraceptive use in female patients. There was no sign of dehydration in the first examinations performed in the emergency department. We considered mastoiditis and sepsis as the etiology in female patients and asphyxia in male patients. Genetic examinations could be performed to determine the prothrombotic status in two patients, and the results were normal. All three patients received antithrombotic therapy with unfractionated heparin (UH), and antiepileptic therapy and hyperosmolar therapy were administered. The current guidelines for treating children with SVT recommend therapeutic doses of heparin similar to those in adults (35). Decompressive surgery was also performed in the second case, whereas mechanical thrombectomy was performed in the third case. Interventional mechanical thrombectomy with appropriate patient selection has been shown to improve outcomes in multiple clinical studies (21). The delay in diagnosing stroke in the pediatric age group and the lack of a standardization of the neurointerventional procedure to be performed lead to delayed thrombectomy (40). Furthermore, the potential risk of blood vessel injury during thrombectomy as the vessels are still in the development process causes such interventions to be avoided in childhood (20,28). The prognosis in children appears worse than that in adults, and 20%–70% of patients have residual neurological deficits (10,50). Considering that our cases were alive and had a GCS of 15 before discharge, we can say that they were discharged with a good prognosis. Figure 1 shows the MRIs of the third case.

Eleven (40.7%) patients were diagnosed with AIS, and 13 (48.1%) patients had HS. The mean age of the HS group was higher than that of the AIS group. Furthermore, children with congenital heart disease constitute a significant fraction of pediatric AIS cases (40). One of our AIS cases had congenital heart disease, one had mitochondrial encephalomyopathy, lactic acidosis, and stroke-like episodes (MELAS syndrome), and one had a methylene tetrahydrofolate reductase (MTHFR) gene mutation in the further examinations. The case with an MTHFR gene mutation had a history of recurrent hospitalization. The patient's MRI is shown in Figure 2. In the HS group, eight (61.5%) patients had a ruptured AVM and five (38.5%) patients had a ruptured IA. AVMs are the most common cause of spontaneous intraparenchymal hemorrhage in children. Childhood AVMs account for 3% of all AVMs and are more prone to rupture than adult AVMs (25,27). Pediatric IAs are also rare, accounting for 1%–4% of all IAs in the general population (8,31,36).

In this study, similar to the literature, headache and vomiting were the most common complaints in the HS group (57), whereas the rate of admission due to seizures was higher in the AIS group (p=0.001; p<0.01). Although no difference in the stroke type and seizure rate was observed in some studies, a significant difference was seen in this study (46, 56). Particularly in HS, patients with and without seizure at admission have been reported (5). In both groups, most patients had neurological deficit findings at admission. Xie and jiang, in their study involving 169 patients, reported that 86.7% of the patients with the AIS subtype had acute paralysis, 15% lost consciousness, and 1.7% had herniation (55). While the mean GCS at baseline was higher in the HS group, the mean GCS before discharge was equal in both groups. Longer PICU hospitalization days and mechanical ventilator days were found in the AIS group; however, no significant differences were observed between the two groups. In the HS group, the posterior inferior cerebral arteries (PICAs) were involved in two patients, the MCA in one patient, and the anterior cerebral artery (ACA) in one patient. Although anterior circulation aneurysms are more common in the pediatric age group, posterior circulation aneurysms are

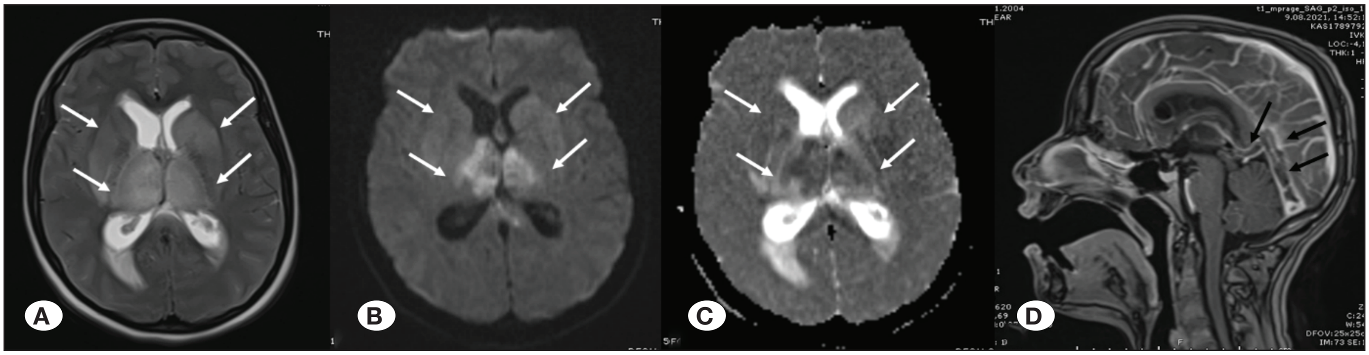

Figure 1: 17-year-old female patient. Arrows show bilateral thalamus and lentiform nuclei edema and cerebrospinal fluid leakage in the periventricular area in **A**, cytotoxic edema in diffusion weighted imaging (DWI) and apparent diffusion coefficient (ADC) in **B** and **C**, respectively, and deep vein thrombus filling straight sinus and the vein of Galen on sagittal T1-weighted imaging with contrast were detected on magnetic resonance imaging (MRI) in **D**.

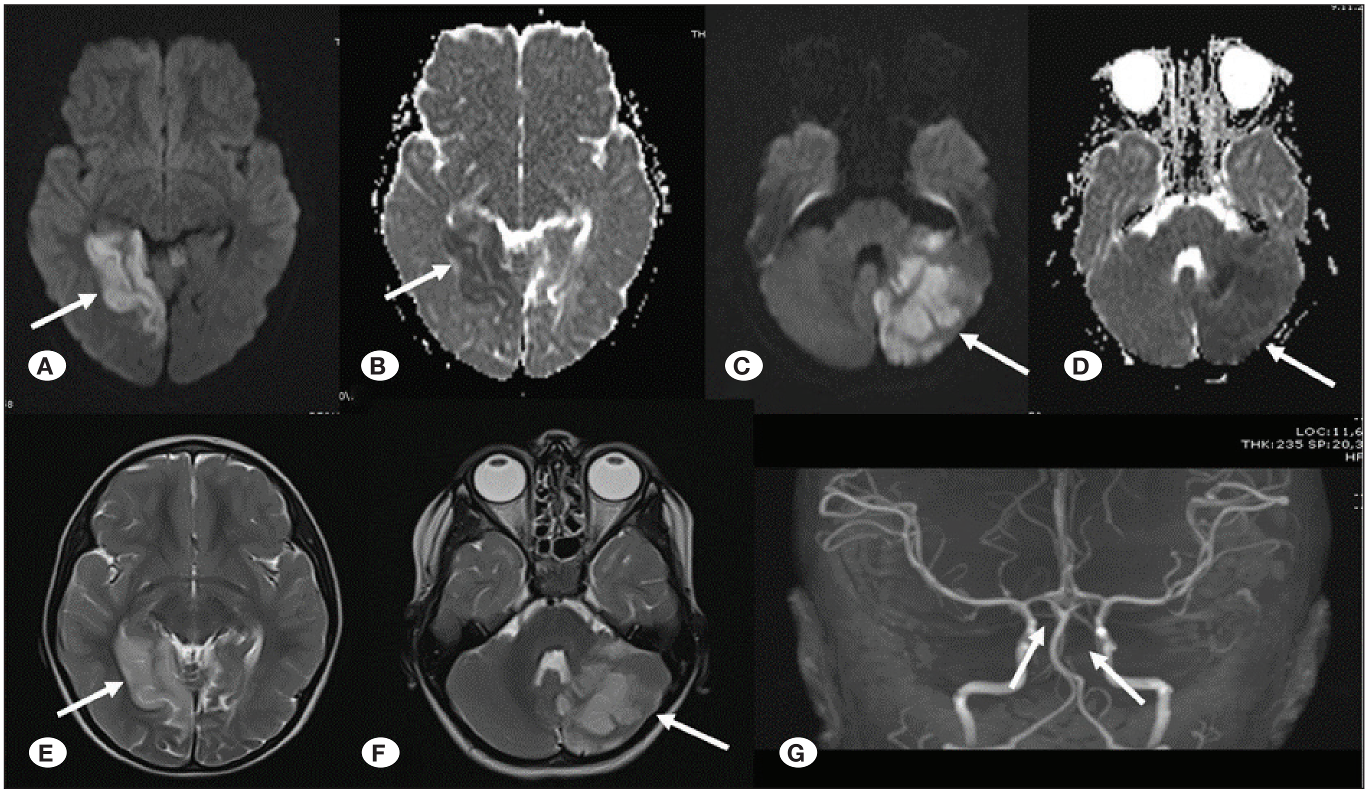

Figure 2: A 4-year-old male patient has a history of recurrent hospitalization and methylene tetrahydrofolate reductase (MTHFR) gene mutation. Arrows shows in diffusion weighted imaging (DWI) and apparent diffusion coefficient (ADC) imaging, diffusion restriction in the right temporooccipital location in **A** and **B,** and left cerebellar hemisphere in **C** and **D** which was consistent with acute infarction of the right posterior cerebral artery and left posterior inferior cerebellar artery. T2-weighted imaging showed increased signal secondary to parenchymal edema in these regions (arrows shows in **E** and **F**). In Time-of-Flight (TOF)-magnetic resonance angiography (MRA), bilateral posterior cerebral arteries were thin and bilateral posterior inferior cerebellar arteries could not be clearly distinguished (arrows show in **G**).

also seen considerably frequently (2,3). Nine MCA, five PICA, and three ACA cases were detected among all cases. The MCA involvement rate was higher in the AIS group than in the HS group (p=0.033; p<0.05). Although there were no cases resulting in mortality in the HS group, two (18.2%) cases died in the AIS group. Severe cerebral edema and multiorgan failure requiring multiple inotropes were the cause of death in both cases. The mortality rate for all cases in this study was 7.1%, which was lower than those reported in the literature. No significant differences in the laboratory parameters were observed between the two groups (p>0.05). In the study, the rate of using CT as an imaging method in the HS group and the rate of using MRA in the AIS group were statistically significantly higher than the counterparts (p=0.031, p<0.05; p=0.047, p<0.05, respectively). MRI is the imaging modality of choice for childhood strokes. Studies have reported that CT misses 47%–84% of all AIS cases (34,48). The Royal College of Pediatrics and Child Health recommends that every child with suspected stroke undergoes a CT scan within 1 h of hospital admission and that MRI should be the primary imaging modality, if possible (39). An easier access to CT and the lack of technical support for MRI in our hospital have made CT the primary imaging modality. Although we are not a stroke center and we do not have a defined and standardized policy for such cases, CT imaging was performed within the first hour of admission in our cases. Furthermore, angiographic procedures were highly preferred in our cases.

The common treatments used in both groups were antiepileptic therapy, antihypertensive therapy, and hyperosmolar therapy. The usage rate of hyperosmolar therapy was high in both groups. Although only two patients in the HS group had convulsions at admission, other patients were also given antiepileptic treatment for prophylaxis because, regardless of the subtype of stroke, seizures occur 18 times more frequently in the first 24 h in the pediatric age group than in adults (7). Moreover, prophylactic antiepileptic therapy is often recommended in HS (1,52). Intravenous recombinant tissue plasminogen activator (tPA) was not performed in any case. tPA has been shown to improve outcomes in adult AIS when administered within 4.5 h of the stroke onset (41). In children, stroke symptoms are not very specific and can be easily confused with other conditions, limiting the use of such hyperacute treatments. tPA was not used in our patients because the timeframe reported was exceeded. Antithrombotic therapies (i.e., UH, warfarin, and aspirin) are used for secondary prevention in both the acute and chronic stages of stroke treatment (16). UH was preferred more as antithrombotic therapy in the AIS group. In the HS group, endovascular embolization treatment was applied to nine patients, and the patient who complained of subcutaneous hemorrhage in the right frontal region had an unruptured AVM and had no parenchymal findings. When deciding the treatment modality to use, a risk/benefit analysis should be performed. Although surgical resection is considered the gold standard, particularly in treating AVMs, the radiological resolution success of embolization cannot be denied (4,13,49). In our patients, no complications were encountered during the early or late period after embolization. Seven patients underwent surgical intervention, of whom two underwent EVD insertion and five underwent decompressive surgery. Two patients with EVD were the patients who were followed up due to having HS. One of the five patients who underwent decompressive surgery were followed up due to having AIS, one was followed up due to having SVT, and three were followed up due to having HS. Both embolization and decompression therapy were performed in one patient (14-year-old female) in the HS group. This patient was admitted to our pediatric emergency department with a complaint of seizures; subarachnoid hemorrhage was detected on cranial CT; and embolization was performed to dissect the aneurysm detected in the right ACA on angiography. Imaging methods were repeated due to anisocoria developing on the second day of the intensive care follow-up of the patient, and decompression surgery was performed by the neurosurgeon due to the increase in the amount of bleeding. The patient was followed up on mechanical ventilation for 7 days and was hospitalized in our PICU for 10 days. It has been stated that decompressive surgery in adult patients having malignant MCA stroke reduces mortality and may be associated with better clinical outcomes (53). In the study by Lehman et al., 17 of 29 patients underwent surgical intervention for MCA stroke, and the patients were evaluated using the modified Rankin scale and the Glasgow outcome scale, and it was stated that such surgical interventions could lead to good results (29). The GCS of our patients who underwent surgical procedure was ≥12 before discharge. Figure 3 shows the MRA images of one patient with a ruptured aneurysm.

This study has some limitations. First, the number of patients was limited because this was a single-center study and included patients admitted to the PICU only. Moreover, it was a retrospective study, which limited the data obtained. Furthermore, data regarding the long-term follow-up of the cases after the intensive care unit could not be obtained.

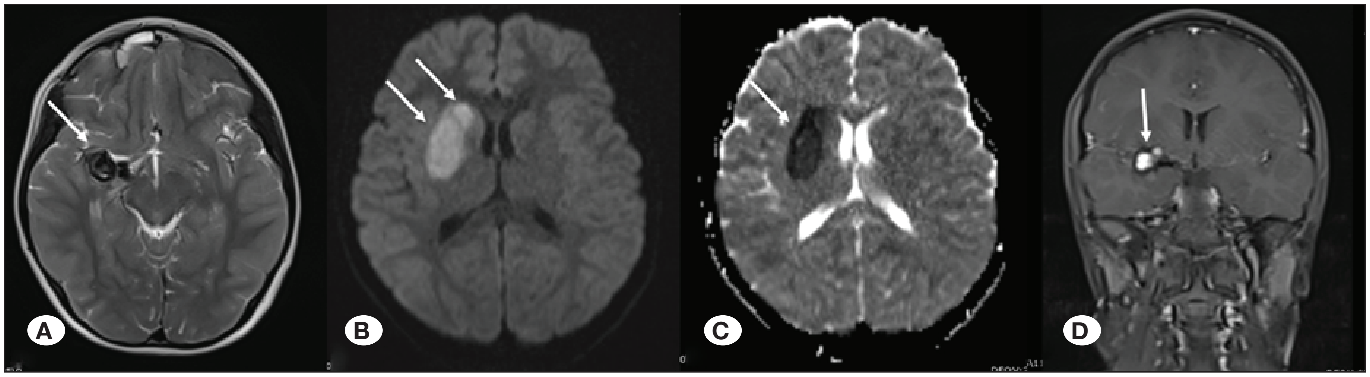

Figure 3: Arrow show in 14-year-old male patient had a hemorrhagic aneurysm in the right temporoparietal region in magnetic resonance imaging (MRI) T2-weighted sequences in **A**, diffusion weighted imaging (DWI) and apparent diffusion coefficient (ADC) examination revealed that ischemia developed in the right lentiform nucleus and caudate nucleus in **B** and **C**. Contrast-enhanced coronal MRI revealed a bleeding aneurysm in the right middle cerebral artery (MCA) localization in **D**.

CONCLUSION

In conclusion, stroke is one of the first diagnoses that should be considered in the presence of neurological deficits in children. Support from imaging methods should be sought, particularly in pediatric cases with neurological deficits accompanied by convulsions, vomiting, and headache. It's possible that male gender could be a risk of factor in childhood strokes, however, this study doesnot warrant any conclusive claims regarding this observation. Based on our cases, it seems that endovascular embolization may offer better outcomes for hemorrhagic stroke (HS) compared to surgical interventions. Multicenter studies with larger number of cases will provide insights into diagnostic strategies and accurate timing of treatment in order to reduce mobidity and mortality in pediatric stroke cases.

AUTHORSHIP CONTRIBUTION

Study conception and design: UKB, ES

Data collection: NA

Analysis and interpretation of results: MEM, FBP, UKB

Draft manuscript preparation: NA, ES

Critical revision of the article: UKB, FBP

Other (study supervision, fundings, materials, etc...): MEM, NA

All authors (UKB, NA, MEM, FBP, ES) reviewed the results and approved the final version of the manuscript.

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