

ORIGINAL PAPER

Clinical presentation and impact of internal carotid artery kinking in children

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ABSTRACT

Introduction: The internal carotid artery (ICA) is the principal source of blood supply to the brain, eye, and internal ear. A wide spectrum of clinical symptoms associated with dolichoarteropathy of that vessel has been described, with kinking being the most frequently reported and clinically relevant type of carotid abnormalities of the geometrical course of the vessel. The aim of the study was to analyze the clinical picture of ICA kinking in children.

Material and methods: We retrospectively analyzed all pediatric patients hospitalized in our department with various indications from January 2021 to December 2023, by consulting all of the clinical records in search for those whose imaging tests revealed ICA kinking. Nineteen children with a confirmed diagnosis of ICA kinking were identified. Among all patients with detected ICA kinking, 13 (68.4%) at the time of admission presented with signs and symptoms that could be attributed to insufficient cerebrovascular circulation due to an anatomical abnormality of the ICA. The remaining 6 (31.6%) children were admitted for various clinical reasons and did not present symptoms that could have been linked with abnormal cerebral perfusion.

Results: Thorough medical history, clinical presentation, and associated features of patients are reported, and a discussion in light of previously published papers on the subject is presented.

Conclusions: We emphasize the importance of anamnesis and clinical awareness in any case of a pediatric patient with transient non-specific neurological manifestations that could suggest anomalies of ICA. An appropriate diagnostic approach can help to reduce possible risk, minimize costs and guide personalized management of these patients.

KEY WORDS:

children, internal carotid artery, kinking, dolichoarteropathies, transient ischemic attacks.

INTRODUCTION

Kinking is the most relevant type of dolichoarteropathy, defined as the anatomical defect of arteries, the essence of which is disruption of the geometrical course of the vessel. The internal carotid artery (ICA) is the major artery of the brain, eye, and internal ear, and the principal source of blood supply to these organs. It ascends vertically in the carotid sheath and at the base of the skull enters the carotid canal, passing through the cavernous sinus

and at the base of the brain dividing into the anterior and middle cerebral arteries. Anatomists in the 19th century described these arteries' remarkable feature of creating curvatures in their course. Clinical symptoms associated with this anomaly were observed by physicians at the same time, the first reports dating back to Coulson in 1852 [1]. At the beginning of the 20th century otolaryngologists were the first clinicians concerned with sigmoid tortuosity of the ICA, as an occasionally fatal hemorrhagic complication of simple procedures resulting in injury to

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an abnormally shaped artery segment was described [2]. In 1951 the first report linking cerebral ischemic symptoms and vertigo with elongation of the ICA was made by French authors. The year 1965 brought the proposal by Weibel and Fields to classify the anatomical anomalies of ICA into three types: tortuosity (i.e., elongation and ripple of the ICA with a C or S shape), coiling (i.e., elongation of the extracranial ICA resulting in a circular configuration or an exaggerated S-shaped curve) and kinking (i.e., acute angulation of the ICA) [2].

Kinking is the most frequently reported (5–25%) and clinically relevant type of carotid abnormality [3]. The exact prevalence in childhood is not well known, as studies on the subject are lacking. It is believed that in the majority of cases the disorder is asymptomatic, and if symptoms occur, the predominant presentation suggests cerebrovascular insufficiency. The clinical picture resembles acute encephalopathy, transient ischemic attacks (TIA) or infarction, with acute cerebral symptoms such as dizziness, dysphasia, hemiplegia, diplopia, acute visual impairment or even seizures [4]. Rarely, the anomaly may manifest as pulsatile tinnitus, hemilingual spasms, or a pulsatile cervical mass [4, 5].

Symptomatic cases are predominantly present in patients with sharp bending of the artery (i.e., high-grade kinking) and may vary in severity with the self-regulatory mechanisms of brain perfusion and development of collateral circulation, as well as the degree of angulation, which may be dynamically changed by specific head movements [2, 4, 6].

The etiology of dolichoarteriopathy of the internal carotid artery (DICA) remains under discussion. Major proposed hypotheses include embryological maldevelopment and age-related loss of elasticity of the vessel wall resulting in elongation and tortuosity of the artery (due to e.g. fibromuscular dysplasia or metaplastic transformation) [2, 7, 8]. Some authors suggest that both mechanisms may coexist in the same patient [9].

Among valuable diagnostic tools for DICA identification, Doppler ultrasonography (US) remains the most

widely used, followed by computed tomography angiography (CTA), magnetic resonance angiography (MRA), and digital subtraction angiography (DSA).

The aim of this study was to analyze the clinical picture of kinking in children.

MATERIAL AND METHODS

We retrospectively analyzed medical records of all pediatric patients hospitalized in our department with various indications from January 2021 to December 2023, in search of those whose imaging tests revealed ICA kinking. A diagnosis of DICA was made by a specialist in radiology using contrast computed tomography (CT) in the majority of cases and with MRA or US Doppler in a few, and cases were classified following the Weibel and Fields classification, which comprises three different types of anomaly (Figure 1) [2].

Type 1, tortuosity, is any S- or C-shaped elongation or undulation of the course of the artery with an open angulation $> 90^\circ$. Type 2, looping (coiling), is an elongation or redundancy of the ICA with 360° angulation of an artery on its transverse axis, resulting in an exaggerated C-, S-, or U-shaped curve or in a circular configuration. Kinking (type 3), the most frequent type of abnormality, results from sharp angulation $< 90^\circ$ of one or more ICA segments, associated with possible stenosis in the affected part of the artery. Kinking can be further divided into three grades of severity, based on the angle between the two kinking segments (Figure 2): grade I indicates an angle of $60\text{--}90^\circ$, grade II indicates an angle of $30\text{--}60^\circ$, and grade III an angle of $< 30^\circ$. Importantly, angulations are not fixed and may vary according to different positions of the head or neck [2, 4].

As the wider use of imaging technology becomes more common, many asymptomatic dolichoarteriopathies are being diagnosed. The exact prevalence of artery kinking varies among reports, ranging from 5 to 25% in different studies [4, 7, 8]. Data concerning the pediatric

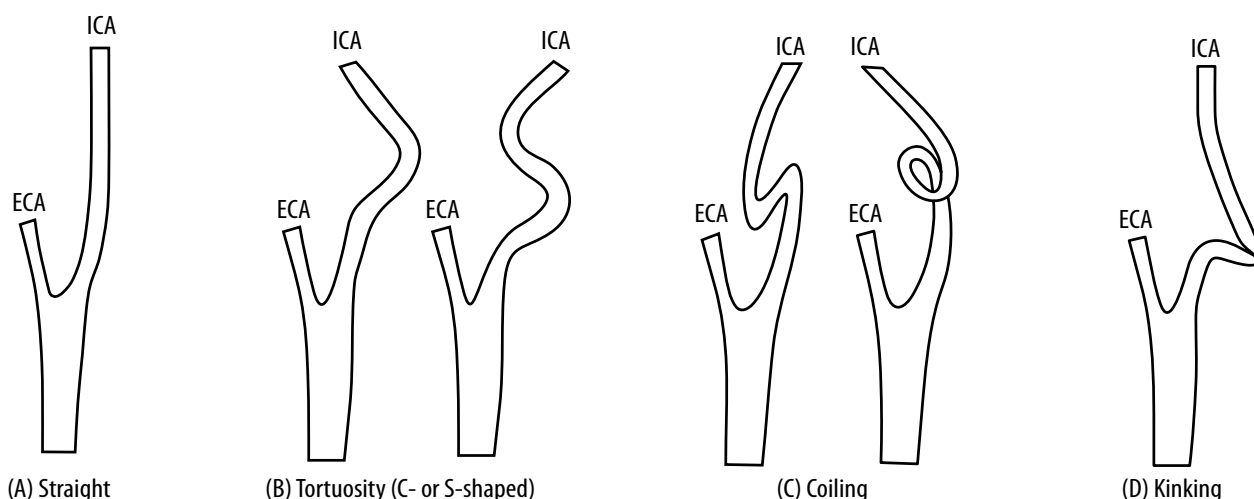


FIGURE 1. Anatomical classification of dolichoarteriopathies of the internal carotid artery

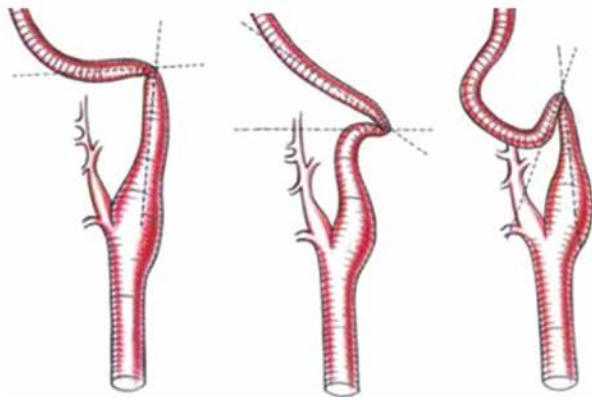


FIGURE 2. Metz's grading of the internal carotid artery kinking, from left to right: grade I, grade II and grade III

population are lacking, and the few published studies focus on small groups of asymptomatic pediatric patients, with the reported incidence of kinking ranging between 15.2% and 27% [9–12]. Clinical studies have shown that as the severity of kinking increases, its clinical symptoms become more pronounced and potentially more harmful, and most commonly occur due to transitory hypotension during sleep or sudden and extreme movement of the head and neck [13, 14].

Due to the high variability of kinking prevalence, the exact frequency of separate symptoms in the affected population is not known. A summary of symptoms associated with kinking is presented in the Table 1.

RESULTS

We identified 19 children with a confirmed diagnosis of ICA kinking. Age at diagnosis ranged between 7 months and 17 years with a median of 10.1 years. Fifteen children (73.7%) were male. Among all patients with detected DICA, 13 (68.4%) at the time of admission presented with signs and symptoms that could be attributed to insufficient cerebrovascular circulation due to anatomical abnormality of the ICA. The final diagnoses of those patients were as follows: TIA in 6, headache in 5, and syncope in 2. The remaining 6 (31.6%) children were considered asymptomatic, and admitted for various clinical reasons: 2 after the first seizure episode, 2 with infectious diseases – sepsis and influenza type A, 1 child with cerebral palsy and a history of headaches, and 1 with vertical toxoplasma infection. Peak admission time was in the autumn season from October to December ($n = 9$, 47.3%), followed by the winter time from January to March and summer season from April to June ($n = 4$, 21.0% each).

The detailed clinical presentation of patients is presented in Table 2.

During the clinical course, we individually adjusted the diagnostic tools used in each case, according to the required differential diagnosis. Among visual tests, CT was most widely used, due to the specific nature of the pa-

TABLE 1. Summary of clinical manifestation of ICA kinking

Kinking grade 1 and tortuosity	Kinking grades 2 and 3
Mild symptoms: dizziness, vertigo, syncopes, blackout, persistent tinnitus [15]	Severe symptoms: transient ischemic attack, stroke, hemiplegia and other cerebrovascular deficiencies [16, 17]

tients hospitalized, and usual need of rapid exclusion of focal central nervous system (CNS) lesions. In our reported group, 16 of 19 patients underwent contrast head CT, in 6 cases we used MRA, with 3 being the first imaging test, and in 3 patients the first imaging performed was color Doppler US (Figures 3 and 4).

Eleven patients underwent an electroencephalography test, and in 7 cases full cardiological assessment including echocardiography and electrocardiography (ECG) was performed. A 24-hour ECG recording was needed in 5 children to exclude cardiac arrhythmias as a cause of symptoms.

DISCUSSION

Dolichoarteriopathies of the ICA are common, the frequency in the general population estimated between 10 and 45% [13, 14]. Kinking itself, considered the most clinically important type of ICA elongation, has a prevalence ranging from 5 to 25% in different studies [4, 7, 8].

In children this problem is not sufficiently recognized, as still only a several cases have been reported to date [3, 4, 6, 8, 18]. In 1961, Metz *et al.* [3] focused on analyzing vast clinical data of 1000 angiographies performed in adults and children with suspected CNS diseases of a wide spectrum. Among 168 cases of confirmed kinking or looping of the ICA, all of which were asymptomatic, 4 were found in children aged 0–10 years, and another 6 in patients aged 11–20 years [3]. Almost a decade later, Japanese researchers reported a pediatric case series focusing on the symptomatic clinical presentation of DICA, which still is among the principal studies in children on this subject. Sarkari *et al.* [12] described 9 patients with uni- or bilateral loops or kinking of the ICA confirmed by arteriography, all of which were symptomatic in the form of vascular insufficiency. The most frequent symptoms were acute hemiparesis and seizures, followed by acute loss of vision/hemianopia and dysphasia.

Among the 19 patients in our cohort, 13 presented with symptoms attributed to a prolonged insufficient blood supply to specific brain regions. These included headache, dizziness, balance impairment, tinnitus, vision abnormalities, nausea and focal signs in the form of facial asymmetry, one-sided numbness and slurred speech. In this group we found an astonishingly high percentage of patient presenting with combined symptoms providing the basis for the diagnosis of transient ischemic attacks. Among the most prominent signs, headache was present

TABLE 2. Summary of clinical characteristics of analyzed patients

Patient No.	Age (years)	Sex	Past medical history	Acute symptoms	CT result	MRI result	EEG	ECG, TTE, 24hECG	Additional tests	Symptoms duration	Prior activity
1	15.3	M	Insignificant	Headache, dizziness, balance impairment, tinnitus, diplopia, nausea	n/p	RICA kinking (1 st) VA asymmetry	Age norm	n/p	Cervical arteries US Doppler – result analogous to MR	Several dozen minutes	Intensive walk in the mountains
2	16.4	M	Episodes of dizziness after rapid verticalization	Headache, dizziness, numbness ULL	RICA coiling LICA kinking (2 nd)	n/p	Age norm	ECG – N	Cervical arteries US Doppler – result analogous to CT	Several dozen minutes	Jumping on trampolines
3	10.1	M	Insignificant	Blurred vision	LICA kinking (1 st)	Few 2–3 mm foci of increased intensity, w/o enhancement of vascular origin in left frontal lobe; bilateral hypoplasia of PCoA	n/p	n/p	n/p	Hours	Tilted head – video games
4	5.0	M	Insignificant	Loss of consciousness for 1 min, scotoma	RICA kinking (2 nd)	n/p	Borderline abnormal	ECG – N, TTE – N, 24hECG – N	n/p	1 minute	Tilted head – rolling
5	12.7	M	Similar signs 1 year prior (headache with numbness in the ULL and tongue, visual disturbances)	Headache, narrowed vision, hemitemporal blindness, numbness of tongue and ULL, slurred speech	n/p	LICA kinking (2 nd) RICA kinking (2 nd) bilateral PCoA aplasia	Age norm	n/p	MTHFR gene double heterozygous mutation (A1298C/C677T)	20 minutes	No
6	17.5	F	Insignificant	Headache, dizziness, tinnitus, numbness of URL and jaw, slurred speech	LICA kinking (3 rd) RICA kinking (1 st)	n/p	n/p	ECG – N, TTE – N, 24hECG – N	Congenital prothrombotic conditions – N	4 minutes	Prolonged standing position

TABLE 2. Cont.

Patient No.	Age (years)	Sex	Past medical history	Acute symptoms	CT result	MRI result	EEG	ECG, TTE, 24hECG	Additional tests	Symptoms duration	Prior activity
7 Figure 3	14.4	F	Episodic headaches	Headache, numbness of tongue and ULL, slurred speech	LICA kinking (2 nd)	n/p	Age norm	ECG – N, TTE – N, 24hECG – N	Cervical arteries US Doppler – N Congenital prothrombotic conditions – N	2 hours	Long distance run
8	15.8	M	Insignificant	Headache, scotoma, numbness of ULL	Normal	LICA kinking (1 st); severe hypoplasia of right PCoA	n/p	ECG – N, 24hECG – N TTE – slightly increased right ventricle	n/p	2 hours	No
9	14.3	M	Similar symptoms twice in past (headache, abnormal vision, right-sided limbs numbness, slurred speech)	Headache, dizziness, numbness of upper and lower right limbs	Normal	RICA kinking (1 st)	n/p	ECG – N, TTE – N	n/p	2 hours	No
10	8.4	M	Insignificant	Headache, balance impairment, facial asymmetry	Bilateral kinking (1 st)	Bilateral kinking (1 st) bilateral hypoplasia of PCoA	n/p	ECG – N, TTE – N, 24hECG – N	SARS-CoV-2 high titers in serology tests Cervical arteries US Doppler – N	2 hours	No
11	13.5	F	Few months of dizziness after rapid verticalization	Dizziness	Kinking RICA (1 st) bilateral kinking of VA (1 st)	n/p	n/p	ECG – N, TTE – N	Cervical arteries US Doppler – result analogous to CT	Minutes	Rapid standing
12	4.4	M	Insignificant	Headache, dizziness	LICA kinking (1 st)	n/p	Age norm	n/p	SARS-CoV-2 acute infection (PCR test)	1 hour	No
13	9.4	F	One event of syncope	Headache, dizziness, balance impairment	Bilateral ICA kinking (2 nd) coiling of RVA kinking of LVA (3 rd)	n/p	Age norm	n/p	Cervical arteries US Doppler – LICA kinking	Several hours	No

TABLE 2. Cont.

Patient No.	Age (years)	Sex	Past medical history	Acute symptoms	CT result	MRI result	EEG	ECG, TTE, 24hECG	Additional tests	Symptoms duration	Prior activity
14	0.8	M	Maternal toxoplasmosis infection at 22 hbd with spiramycin therapy	Dehydration, type A influenza infection	RICA kinking (2 nd)	n/p	n/p	n/p	n/p	Hours	No
15	2.8	M	Insignificant	Generalized tonic-clonic seizures with spontaneous cessation	LICA (2 nd)	n/p	Generalized discharges in sleep	n/p	n/p	Minutes	No
16 Figure 4	0.7	M	Inborn toxoplasmosis	Nystagmus	Bilateral kinking: RICA (3 rd), LICA (2 nd)	n/p	Generalized discharges spike and wave, sharp wave – slow wave	n/p	n/p	Permanent	No
17	2.4	F	Insignificant	Generalized tonic-clonic seizures with spontaneous cessation	bilateral ICA kinking (2 nd)	n/p	Generalized discharges spike and wave	n/p	n/p	Seconds	No
18	3.2	M	Insignificant	High degree fever, auricular pain and excessive sleepiness	LICA kinking (3 rd)	n/p	n/p	n/p	n/p	Days	No
19	15.5	M	Cerebral palsy – spastic tetraplegia; spine stabilization prior to admission, followed by five months of immobilization	Unspecific, widespread and multifocal pain, sporadic headaches, sleep disturbances, mood disorders	Bilateral kinking of ICA (2 nd)	n/p	Age norm	n/p	Psychiatric consultation – anxiety depression diagnosis	Repetitive, minutes – hours	No

T¹ – kinking of grade I acc. to Metz, 2nd – kinking of grade II acc. to Metz, 3rd – kinking of grade III acc. to Metz, 24hECG – 24-hour electrocardiogram recording, ECG – electrocardiogram, LICA – left internal carotid artery, LVA – left vertebral artery, n/p – not performed, N – normal result, PCoA – posterior communicating artery, RICA – right internal carotid artery, RVA – right vertebral artery, ULL – upper left limb, URL – upper right limb, VA – vertebral artery, w/o – without

in every such case, abnormal vision as well as numbness each in four, ataxia and balance impairment in two, dizziness in one patient and limitation of consciousness in one patient. Interestingly, in three patients an evident association with intense physical activity preceding the symptoms was found, and distinct head tilt during presentation in another two needs to be stressed.

Multiple authors have underlined the relation between severity of symptoms and the type of DICA, with kinking being particularly associated with more severe symptoms as its angulation increases [4, 8]. We did not find any clear evidence of such an association in our group, but this hypothesis needs further research as it might influence the possible therapy.

In our material there was clear overrepresentation of 9 cases (47.4%) being noted during the autumn season, which might be explained by the hypothesis of insufficient fluid uptake, often found in children during school time.

Foiadelli *et al.* [8] reported a case series of seven pediatric patients with a highly variable clinical presentation of ICA kinking, and high prevalence of perinatal complications among the group. They speculated that the anomaly might result from an embryological malformation caused by different factors, from intrauterine infection to gestational diabetes and genetic abnormalities, and be one of the possible causes of psychomotor delay and cognitive impairment seen in their group.

Only 2 patients in our cohort came from pregnancies complicated by *Toxoplasma* infection in mothers; the remaining 17 pregnancies were uneventful. One of these infants showed cognitive and motor delay, which seems to be a sequela of inborn *Toxoplasma* infection rather than kinking itself. Although some authors have linked chronic cerebrovascular insufficiency related to DICA as a direct cause of psychomotor delay, cognitive impairment and even seizures in children, it seems that this problem

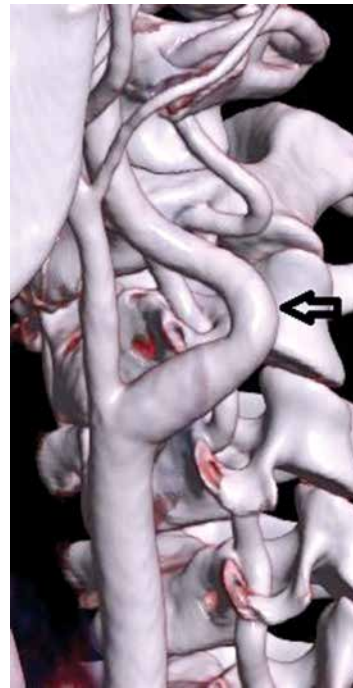


FIGURE 3. Three-dimensional reconstruction of computed tomography showing grade II kinking of the right internal carotid artery found in the seventh patient

might represent a continuum with genetic etiology leading to DICA as well as the above clinical symptoms [4].

Populational studies on etiology are lacking. As this anomaly is observed across all ages from infants to elderly individuals, it was suggested that DICA is more likely to be the result of an alteration in embryologic development rather than degenerative vascular remodeling only [8]. Nevertheless, with the increasing number of reports of DICA found in the elderly described by other authors, one should keep in mind that genetically determined as well as acquired factors may contribute to its pathogenesis

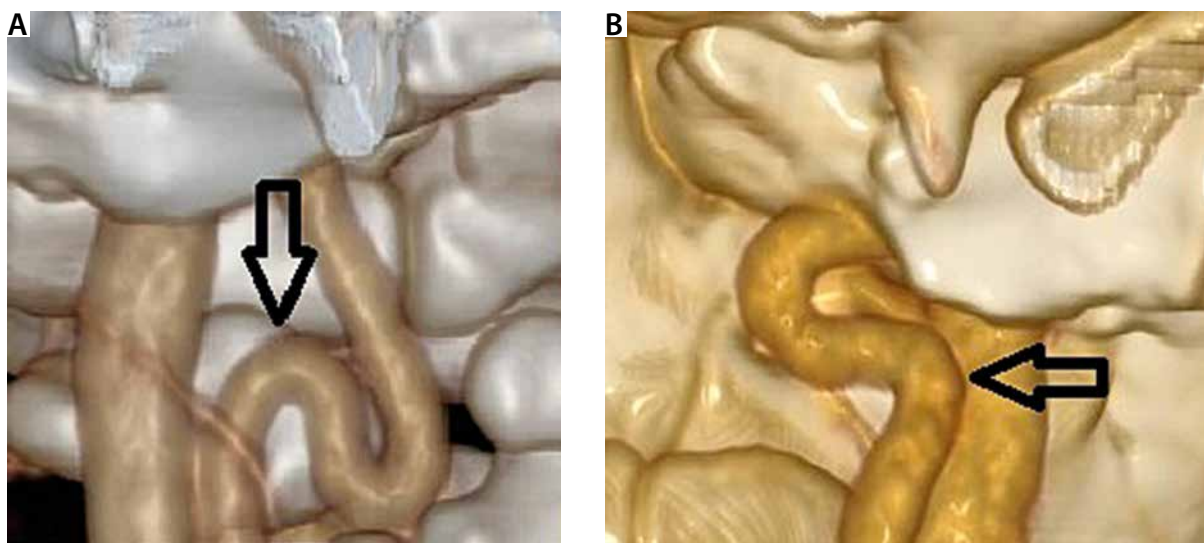


FIGURE 4. Three-dimensional reconstruction of computed tomography showing bilateral kinking found in the sixteenth patient: grade III of right internal carotid artery (left side), grade II of left internal carotid artery (right side)

[7, 10, 18]. In 2021 Di Pino *et al.* [10] presented results from an extensive investigation on prevalence of DICA among different age groups, with a total of 2856 subjects studied with echo-color Doppler. They developed a hypothesis explaining the bimodal distribution of their results, which supports the congenital nature of the anomaly that resolves with somatic growth, and its reappearance or worsening being linked with anatomical changes due to advanced age.

It needs to be stressed that, unlike in the cited report by Sarkari *et al.* [12], we did not find a clear association between abnormal EEG and existence or location of kinking. The mentioned authors emphasized focal slowing found in the EEG, with focal epileptic spikes on the same side of the kinking, present in 2/3 of cases.

In contrast, in our study of 19 patients, EEG was performed in 11, with 2 abnormal results, 2 borderline, and the remaining 7 within the age norm. The abnormal results were found in a child with grade II unilateral kinking (bilateral focal discharges in temporal and occipital lobe) and in a patient with grade III bilateral kinking and complex abnormalities localized in the right hemisphere as well as independently generalized abnormalities. Results described as borderline in the form of generalized episodic slowing were found in a patient with grade II unilateral kinking, and another child with bilateral kinking of the same grade. Patients with the EEG result within the age norm were found to have ICA grade I unilateral kinking (2 cases), grade II unilateral kinking (2 patients), and grade II bilateral kinking in the remaining 3 patients.

In 1 case, EEG abnormalities may have been linked to underlying brain abnormalities due to prenatal complications. Unlike Sarkari *et al.* [12], we did not find a spatial correlation or other association between the grade of kinking and electroencephalographic features. Focal or generalized EEG slowing and discharges were evident in previously healthy patients presenting with acute-onset symptoms. Similar observations were reported by Foiadelli *et al.* [18].

Data concerning treatment options in the pediatric population are lacking [4, 19–21]. Being frequently asymptomatic, those anomalies are associated with a benign prognosis and recommendation of conservative treatment [4]. On the opposite side of the scale lies a group of symptomatic DICA, with the prevalence of kinking of 4–16%, and high variability of clinical presentation and its severity [4]. As in some cases DICA may be associated with complications ranging from disabling to even fatal, surgical treatment to prevent occlusion of the carotid artery may be required [4, 7]. In adult patients, physicians may decide on conservative or surgical treatment, based on the degree of cerebrovascular insufficiency, the hemodynamic significance of the tortuosity, as well as the presence of increased intimal thickness in the maximal bending zone. Symptomatic kinking with significant stenosis may benefit from a surgical approach, which includes

carotid endarterectomy and angioplasty with stenting. Only one study has compared medical versus surgical treatment in symptomatic adult patients with isolated carotid artery elongation, confirming better results for stroke prevention with surgical correction compared with medical treatment alone (i.e., aspirin) [19]. Nevertheless, indications for DICA surgical treatment remain controversial, with no clear evidence supporting the extension of this approach to asymptomatic patients [19, 20]. Given the results of the study by Di Pino *et al.* [10] mentioned above, considering the use of surgical methods of treatment for children would be highly questionable.

The diagnosis of DICA can be made with different imaging techniques. At present, MRA and digital subtraction angiography (DSA) are considered the gold standard for the diagnosis of DICA. Toyota *et al.* [22] reported the morphological differences in carotid angiograms and their relation to age [4, 21]. DSA can provide hemodynamic data and illustrate the morphology of DICA, but does not provide evidence of the pathological changes of the arterial wall.

Nonetheless, these techniques have limitations in the pediatric population, in which deep sedation for younger patients is usually required to avoid movement artifacts. Color Doppler US of the supra-aortic trunks is a fast, non-invasive, reliable, and easily repeatable tool that can provide useful information for the morphological evaluation of cervical vessels when more advanced methods are not available [4, 22–24]. An important limitation is the dependence of the examination on the patient's anatomical conditions, and those in small children may pose a significant problem in adequate imaging of dolichoarterial disease.

In our group, 16 of 19 patients underwent contrast head CT; in 6 cases we used MRA, and in 3 patients the first imaging performed was color Doppler US. An additional advantage of the latter method is the possibility of dynamic assessment of anatomical conditions in real time, thus enabling the evaluation of the relationship between the patient's head position and intravascular flow disturbances in elongated ICA with kinking resulting in stenosis.

The wide use of CT in our department is dictated by the specific nature of the patients hospitalized and the usual need of rapid exclusion of focal CNS lesions.

Worth mentioning is the clinical significance of 2 frequently described anatomical variants regarding intracranial arteries, found among our patients – posterior communicating artery (PCoA) hypoplasia and vertebral artery (VA) asymmetry. PCoA hypoplasia was found in adults to have a pathophysiological role in stroke with or without carotid artery occlusion [25]. Single branch of circle of Willis occlusion might not lead to ischemia as the collateral supply of that region will take over the function. Nonetheless, PCoA hypoplasia, either independently or in association with anterior communicating artery and

vertebral artery anomalies, may predispose to ischemia and was suggested as a risk factor for ischemic stroke [24–29].

Among our patients, in 4 we found coexistence of ICA kinking and PCoA hypoplasia, and in one distinctive vertebral artery asymmetry. These associations might be considered as additional aggravating factors influencing proper cerebral circulation.

In 2014, Becker *et al.* [6] published a report emphasizing the possible clinical impact of aberrant vessels on the course of routine surgical procedures on the neck. It demonstrated the considerably increase risk of vessel injury during pharyngeal surgery and interventional procedures in children with variations in the course of the ICA, especially if the surgeon was not forewarned by preoperative imaging [6]. It needs to be stressed that in the era of universal availability of imaging and wide use of these tools, considering the high prevalence of asymptomatic DICA, every patient who undergoes procedures on the head and neck should be provided with ICA visualization studies.

CONCLUSIONS

We emphasize the importance of anamnesis and clinical presentation in the case of a pediatric patient presenting with transient non-specific neurological manifestations, which could suggest ICA anomalies. Color Doppler US is a fast, non-invasive, and easily repeatable imaging tool, appropriate for the morphological evaluation of DICA, especially in cases when CTA or MRA is not available [24]. Considering the high proportion of symptomatic patients in our cohort, and prior physical intense activity in a minority of them, it is important to confirm this diagnosis. As physical activity is becoming more and more promoted as part of a healthy lifestyle, patients should be warned what type of sports and positions may be potentially harmful. An appropriate diagnostic approach can reduce costs and guide personalized management of these patients.

DISCLOSURES

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3. Financial support and sponsorship: None.
4. Conflicts of interest: None.

REFERENCES

1. Coulson W. Peculiar disposition of the large vessels, producing a tremor at the root of the neck. *Trans Path Soc Lond* 1852; 3: 302.
2. Weibel J, Fields WS. Tortuosity, coiling, and kinking of the internal carotid artery. I. Etiology and radiographic anatomy. *Neurology* 1965; 15: 7-18.
3. Metz H, Bannister R, Murray-Leslie R, et al. Kinking of the internal carotid artery. *Lancet* 1961; 277: 424-426.
4. Yu J, Qu L, Xu B, et al. Current understanding of dolichoarteriopathies of the internal carotid artery: a review. *Int J Med Sci* 2017; 14: 772-784.
5. Schechter DC. Dolicho carotid syndrome: cerebral ischemia related to cervical carotid artery redundancy with kinking: part I. *N Y State J Med* 1979; 9: 1391-1397.
6. Becker C, Ridder GJ, Pfeiffer J. The clinical impact of aberrant internal carotid arteries in children. *Int J Pediatr Otorhinolaryngol* 2014; 78: 1123-1127.
7. Brandt T, Morcher M, Hausser I. Association of cervical artery dissection with connective tissue abnormalities in skin and arteries. *Front Neurol Neurosci* 2005; 20: 16-29.
8. Beneš V, Mohapl M. Alternative surgery for the kinked internal carotid artery. *Acta Neurochir* 2001; 143: 1267-1272.
9. Beigelman R, Izaguirre AM, Robles M, et al. Are kinking and coiling of carotid artery congenital or acquired. *Angiology* 2010; 61: 107-112.
10. Di Pino L, Franchina A, Costa S, et al. Prevalence and morphological changes of carotid kinking and coiling in growth: an echocolor Doppler study of 2856 subjects between aged 0 to 96 years. *Int J Cardiovasc Imaging* 2021; 37: 479-484.
11. Sacco S, Totaro R, Baldassarre M, et al. Morphological variations of the internal carotid artery: prevalence, characteristics and association with cerebrovascular disease. *Int J Angiol* 2007; 16: 59-61.
12. Sarkari N, Holmes J, Bickerstaff E. Neurological manifestations associated with internal carotid loops and kinks in children. *Neurol Neurosurg Psychiatry* 1970; 33: 194-200.
13. Stanton P Jr, McClusky D Jr, Lamis P. Hemodynamic assessment and surgical correction of kinking of the internal carotid artery. *Surgery* 1978; 84: 793-802.
14. Fields W. Selection of patients with ischemic cerebrovascular disease for arterial surgery. *World J Surg* 1979; 3: 147-154.
15. Aleksic M, Schutz G, Gerth S, et al. Surgical approach to kinking and coiling of the internal carotid artery. *J Cardiovasc Surg* 2004; 45: 43-48.
16. Cartwright M, Hickling W, Roach E. Ischemic stroke in an adolescent with arterial tortuosity syndrome. *Neurology* 2006; 67: 360-361.
17. Grego F, Lepidi S, Cognolato D, et al. Rationale of the surgical treatment of carotid kinking. *J Cardiovasc Surg* 2003; 44: 79-85.
18. Foiadelli T, Ippolito R, Corbetta R, et al. Clinical variability in children with dolichoarteriopathies of the internal carotid artery. *Childs Nerv Syst* 2020; 36: 621-628.
19. Ballotta E, Thiene G, Baracchini C, et al. Surgical vs medical treatment for isolated internal carotid artery elongation with coiling or kinking in symptomatic patients: a prospective randomized clinical study. *J Vasc Surg* 2005; 42: 838-846.
20. Smirnova I. On the advisability of surgical treatment of children with kinking of the internal carotid artery. *Angiol Sosud Khir* 2007; 13: 101-107.
21. Voevoda MI, Kulikov IV, Maksimov VN, et al. Association of Sp4 gene polymorphism with pathological tortuosity of internal carotid arteries. *Kardiologiya* 2009; 49: 46-49.
22. Toyota A, Csiba L, Kollar J, et al. Morphological differences in carotid angiograms and their relation to age. *Orv Hetil* 1995; 136: 1551-1554.
23. Macchi C, Gulisano M, Giannelli F, et al. Kinking of the human internal carotid artery: a statistical study in 100 healthy subjects by echocolor Doppler. *J Cardiovasc Surg* 1997; 38: 629-637.
24. Pellegrino L, Prencipe G, Vairo F. Dolicho-arteriopathies (Kinking, coiling, tortuosity) of the carotid arteries: study by color Doppler ultrasonography. *Minerva Cardioangiol* 1998; 46: 69-76.

25. Chuang Y, Liu C, Pan P, et al. Posterior communicating artery hypoplasia as a risk factor for acute ischemic stroke in the absence of carotid artery occlusion. *J Clin Neurosci* 2008; 15: 1376-1381.
26. Zhou W, Lu M, Li J, et al. Functional posterior communicating artery of patients with posterior circulation ischemia using phase contrast magnetic resonance angiography. *Exp Ther Med* 2019; 17: 337-343.
27. Wardlaw J, Dennis M, Warlow C, et al. Imaging appearance of the symptomatic perforating artery in patients with lacunar infarction: occlusion or other vascular pathology? *Ann Neurol* 2001; 50: 208-215.
28. Chuang Y, Huang Y, Hu H, et al. Toward a further elucidation: role of vertebral artery hypoplasia in acute ischemic stroke. *Eur Neurol* 2006; 55: 193-197.
29. Bhanu S, Pentyala S, Sankar D. Incidence of hypoplastic posterior communicating artery and fetal posterior cerebral artery in Andhra population of India: a retrospective 3-Tesla magnetic resonance angiographic study. *Anat Cell Biol* 2020; 53: 272-278.