THE SIGNIFICANCE OF CERVICAL AND TRANSCRANIAL ULTRASOUND IN THE ACUTE AND SUBACUTE PHASE OF DISSECTION OF THE CAROTID ARTERIES. A DIDACTIC EXAMPLE.

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ABSTRACT

Dissection of the carotid arteries is a common cause of ischemic stroke among younger patients. In many cases, a dissection of the carotid artery may lead to (pseudo-)occlusion of the affected vessel. Moreover, an initially occluded artery may be recanalised as the wall hematoma is absorbed and reduced in volume. On the contrary, a dissected artery may later be occluded following an expansion of the initial wall hematoma or the formation of an intraluminal thrombus due to intraluminal low-flow condition. In addition, risk of a consequent stroke may as well be related to hemodynamic insufficiency due to a stenosis or occlusion. The attribution of collateral arterial networks as well as flow parameters in the affected vessels may help the clinician estimate the risk of stroke due to insufficient blood perfusion. Although CTA and MRA of the cervical arteries may reveal or confirm the diagnosis of a cervical artery dissection, they lack the ability to inform as regarding hemodynamic changes, while their use as a follow-up tool is limited. Ultrasound of the cervical and intracranial arteries on the contrary is an excellent option, which can be repeatedly performed to follow a cervical artery dissection allowing the clinician to control for ongoing changes of the dissected artery and their consequences in the hemodynamic properties of the subsequent arteries. Here we present a patient with rapid evolution of dissection of carotid artery, as well as the therapeutic decisions in accordance to ultrasound findings.

Keywords: Transcranial Doppler, Color-Coded Ultrasound of the Carotid Arteries, Carotid Artery Dissection, Collateral Artery, Ischemic Stroke

Η ΣΗΜΑΣΙΑ ΤΟΥ ΤΡΑΧΗΛΙΚΟΥ ΚΑΙ ΔΙΑΚΡΑΝΙΑΚΟΥ ΥΠΕΡΗΧΟΥ ΣΤΗΝ ΟΞΕΙΑ ΚΑΙ ΥΠΟΞΕΙΑ ΦΑΣΗ ΔΙΑΧΩΡΙΣΜΟΥ ΤΩΝ ΚΑΡΩΤΙΔΙΚΩΝ ΑΡΤΗΡΙΩΝ. ΕΝΑ ΔΙΔΑΚΤΙΚΟ ΠΑΡΑΔΕΙΓΜΑ.

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Περίληψη

Ο διαχωρισμός των τραχηλικών αρτηριών είναι ένα κοινό αίτιο ισχαιμικού αγγειακού εγκεφαλικού επεισοδίου (ΑΕΕ) μεταξύ ασθενών νεότερης ηλικίας. Σε πολλές περιπτώσεις το διαχωριστικό ανεύρυσμα μιας καρωτίδας μπορεί να οδηγήσει σε (ψευδο-)απόφραξη αυτής. Επιπλέον, ένα αρχικώς αποφραγμένο αγγείο μπορεί να επανασυραγγοποιηθεί, καθώς το τοιχωματικό αιμάτωμα απορροφάται και μειώνεται σε όγκο. Αντίστροφα, ένα αγγείο με διαχωριστικό ανεύρυσμα μπορεί στην πορεία να αποφραχθεί εντελώς, καθώς επεκτείνεται το αρχικό τοιχωματικό αιμάτωμα ή σχηματίζεται ενδοαυλικός θρόμβος λόγω της μειωμένης ροής αίματος στο αγγείο. Επιπλέον, ο κίνδυνος ενός επαπειλούμενου ΑΕΕ μπορεί να σχετίζεται με αιμοδυναμική ανεπάρκεια του αγγείου λόγω στένωσης ή απόφραξής του. Η συνεισφορά παράπλευρων αρτηριακών δικτύων, όπως και οι παράμετροι ροής στα προσβεβλημένα αγγεία, μπορούν να βοηθήσουν τον κλινικό ιατρό να εκτιμήσει τον κίνδυνο λόγω ανεπαρκούς αιμάτωσης. Αν και η CTA και η MRA των αγγείων του τραχήλου μπορούν να αποκαλύψουν ή να επιβεβαιώσουν τη διάγνωση διαχωριστικού ανευρύσματος, δεν διαθέτουν

την ικανότητα να μας πληροφορήσουν σχετικά με πιθανές αιμοδυναμικές αλλαγές, ενώ και ο ρόλος τους ως εργαλείο παρακολούθησης είναι περιορισμένος. Ο υπέρηχος των τραχηλικών και ενδοκράνιων αρτηριών, εν αντιθέσει, αποτελεί εξαιρετικό εργαλείο, που μπορεί να επαναλαμβάνεται συχνά για παρακολούθηση του διαχωριστικού ανευρύσματος, επιτρέποντας στον κλινικό ιατρό να παρακολουθεί τις συνεχείς αλλαγές στην προσβεβλημένη αρτηρία, καθώς και τις συνέπειές τους στις αιμοδυναμικές παραμέτρους περιφερικότερα της βλάβης. Εδώ παρουσιάζεται ένα παράδειγμα ενός ασθενούς με ταχεία εξέλιξη του διαχωριστικού ανευρύσματος, καθώς και θεραπευτικές αποφάσεις που λήφθηκαν επί τη βάση των υπερηχογραφικών ευρημάτων.

Λέξεις-κλειδιά: Διακρανιακός υπέρηχος, υπέρηχος καρωτίδων, διαχωριστικό ανεύρυσμα καρωτίδας, παράπλευρη κυκλοφορία, ισχαιμικό αγγειακό εγκεφαλικό επεισόδιο

INTRODUCTION

Dissections of the cervical arteries are a common cause of juvenile stroke among people under 45 years of age, where it comprises 25% of all cases.[1] The overall incidence of carotid arteries dissection (CAD) is estimated at 2.5-3 per 100 000,[2] while the annual incidence of vertebral arteries dissection is 1-1.5 per 100 000.[3]

Dissections of the cervical arteries can be trauma-associated, however they most commonly occur spontaneously without any recognisable trigger and are characterised as idiopathic. Anatomical and structural causes such as Eagle syndrome have been related to spontaneous CAD,[4] while underlying collagen diseases have been correlated to cervical arteries dissection.[5] Moreover, infectious diseases may lead to vascular inflammation and CAD,[6] while a seasonal variability of CAD with a higher frequency in winter[7] is suggestive of an infection-related vascular inflammation as a possible trigger for a CAD.

Treatment of CAD is still a matter of debate. As the majority of ischemic strokes after a CAD is a result of artery-to-artery embolisation, antiplatelet therapy seems to be non-inferior to oral anticoagulation in the acute setting, the latter is indicated in cases with (pseudo-) occlusion or reduced post-stenotic flow, intraluminal thrombus as well as in cases of recurrent ischemic stroke despite antiplatelet therapy.[8]

CTA and MRA are the diagnostic modalities mostly used to recognise a CAD. MRA may be superior to CTA, as it can identify intramural hematoma, while CTA is readily available. Colour Doppler of the carotid arteries depends on the operator and it is time consuming, which may be problematic in the acute setting. However, colour Doppler of the carotid arteries is a main imaging tool for following-up a CAD, especially in the subacute period where a revascularisation and remodelling of the occluded artery is expected.[9] Moreover, transcranial Doppler may be useful in estimating the risk of a subsequent stroke in patients with microembolic signals or altered intracranial flow with insufficient vascular collateralisation.[10]

Herein we are demonstrating the central role of Doppler of carotid arteries and transcranial Doppler in follow-up of a patient with idiopathic CAD, controlling the hemodynamic changes of the intracranial circulation as well as informing the therapeutic decisions and prognosis of this patient.

CASE REPORT

A 37-years-old female patient was admitted in our clinic due to a transient left-sided hypesthesia of the face and upper limb and dysarthria. Patient reported of an intermittent incomplete vision loss of the right eye during the week before her admission, which was fully remitted. The symptoms were also accompanied from headache. Patient was also diagnosed and treated for M. Crohn. Initial imaging with CT scan of the brain revealed no abnormalities. A CT-angiography of extra- and intracranial arteries showed an occlusion of the right carotid artery. An additional MRI/MRA of the brain confirmed the diagnosis of internal carotid artery dissection, beginning at base of the scull, while two small ischemic lesions with restricted diffusion in the deep white matter of the right parietal lobe were correlated to her initial transient neurological deficits (**Figure 1**).

A dual antithrombotic treatment was initiated and patient remained asymptomatic and was later discharged. No direct cause of the dissection could be identified. The underlying pathology of chronic inflammation in the setting of M. Crohn as well as a recent upper respiratory tract inflammation reported from the patient were seen as a probable cause or trigger factors of the spontaneous CAD.

One week later a colour Doppler ultrasound of the carotid arteries was performed revealing reduced systolic flow (40cm/sec) and absent diastolic flow in proximal ACI, while poststenotic a reduced flow was shown in the distal ACI suggestive of a recanalisation of the obstructed vessel. Transcranial doppler revealed an almost normal flow in the right MCA, although compared to the contralateral MCA a slightly decreased maximal systolic speed value and pulsatility index was noted (maximal systolic speed of 70cm/sec vs 95cm/sec, PI 0.48 vs 0.64), suggestive of a probable low-grade vasodilation in right hemisphere. Of interest a marked elevation of the maximal systolic speed of the right PCA in P1- and P2-segment was

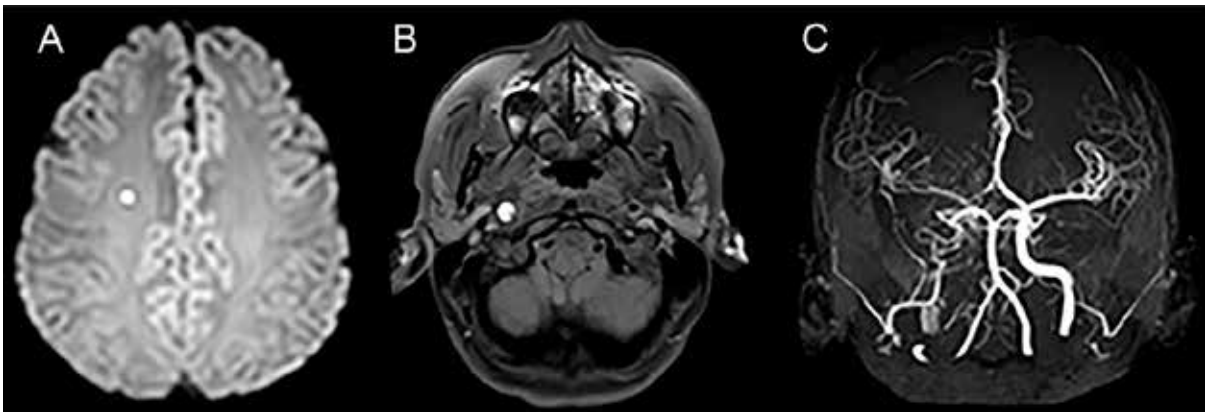

Figure 1. MRI and MRA imaging in the acute phase. **A.** DWI imaging revealing an acute stroke in accordance with the symptoms of the patient. **B.** STIR sequence showing dissection and wall hematoma in scull base. **C.** Time-Of-Flight imaging showing no flow in right internal carotid artery.

noted, while the contralateral PCA exhibited normal flow parameters (max. systolic speed 120cm/sec vs 50cm/sec). Moreover, transorbital colour doppler ultrasound of the right ophthalmic artery revealed a retrograde flow with increased diastolic speed value and decreased resistance index, while the contralateral ophthalmic artery showed an anterograde flow with increased resistance index and normal systolic flow (**Figure 2**). Although a hemodynamic infarct was deemed as unlikely given the good collaterali-

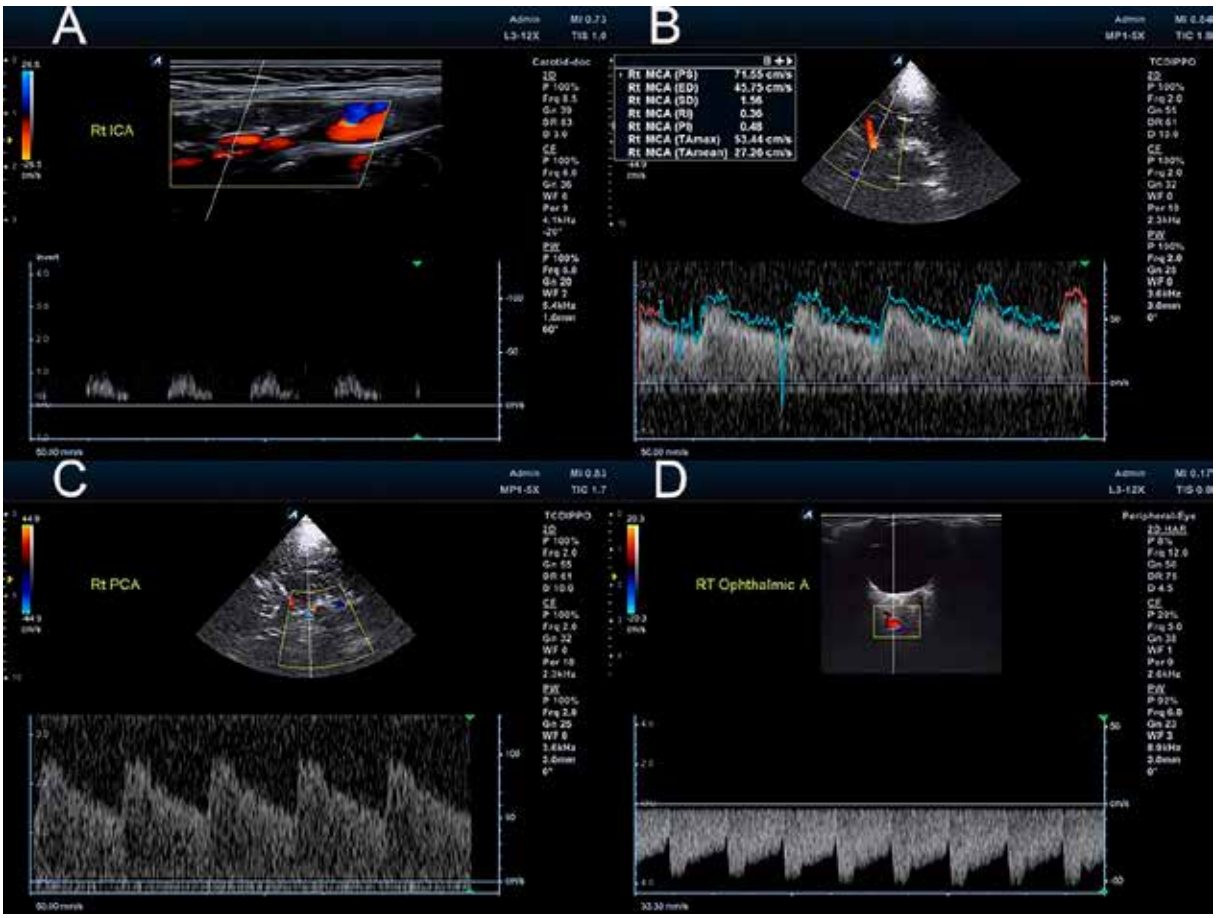

Figure 2. Color-coded doppler ultrasound of the carotid one week after the initial diagnosis. **A.** Pathological flow in the right internal carotid artery suggestive of recanalisation of priorly occluded vessel. **B.** Slightly educed maximum systolic speed and PI of the right MCA suggestive of a good collateral supply of the MCA and distal vasodilation. **C.** Increased maximum systolic speed of the right PCA suggestive of an hyperdynamic flow of the supplying the leptomeningeal arteries as a collateral arterial network. **D.** Retrograde flow of the right ophthalmic artery exhibiting a similar flow profile to right MCA, suggestive of its role as a collateral artery supplying the right MCA.

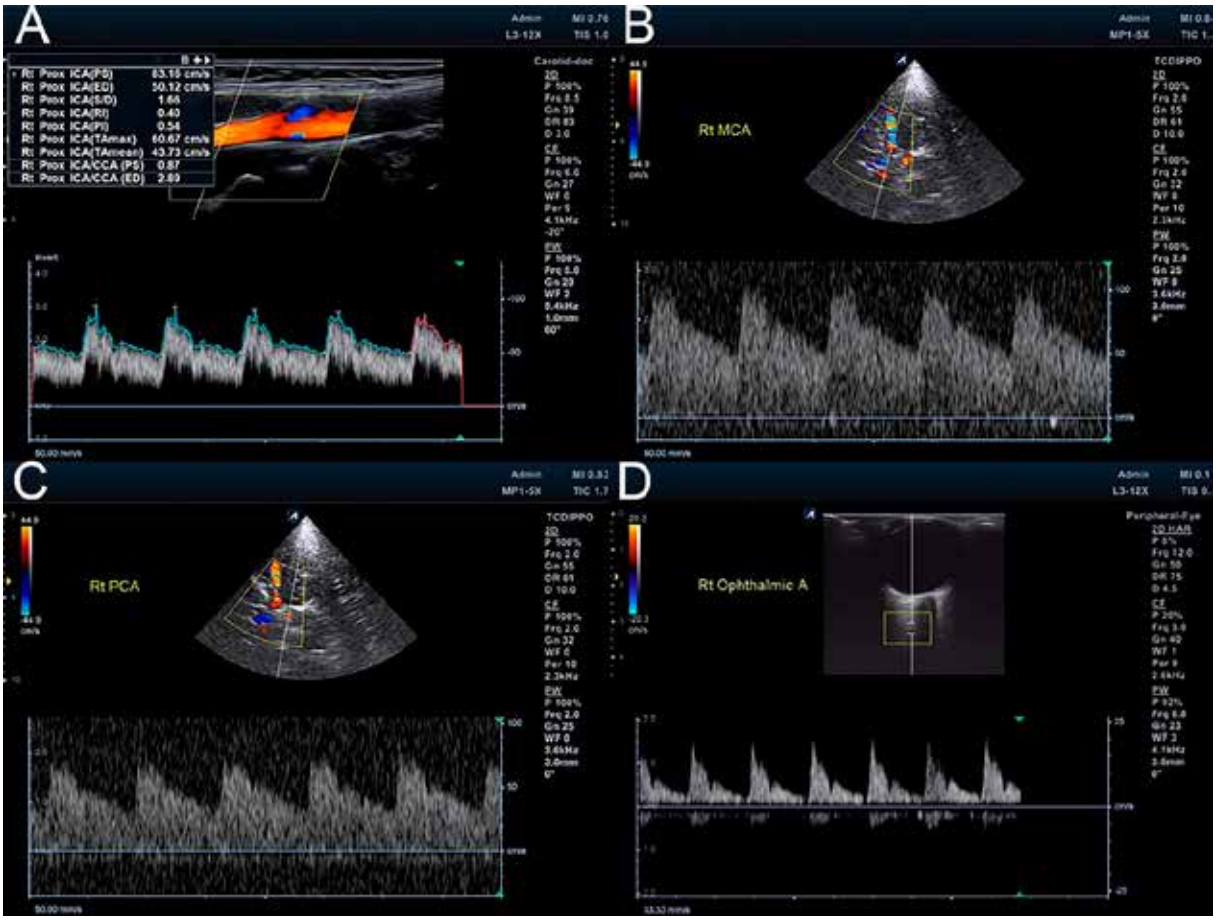

Figure 3. Color-coded doppler ultrasound of the carotid three weeks after the initial diagnosis. **A.** Normalisation of flow parameters in the right internal carotid artery. **B.** Right MCA showing a slightly increased maximal systolic speed and PI, suggestive of a normalisation in flow parameters in right MCA and its distal arterial network. **C.** Normalisation of the initial increased maximal systolic speed of the right PCA, suggestive of normal flow in the collateral leptomeningeal arteries. D. Anterograde flow in the right ophthalmic artery showing a normal flow profile suggestive of a deactivation of collateral arterial supply of the intracranial ICA.

sation, patient exhibited a high embolic risk due to vessel wall abnormalities and abnormal flow in the ACI. There was no change of treatment and patient remained in dual antiplatelet therapy.

Colour doppler ultrasound as well as transcranial Doppler was repeated two weeks later. A fully recanalised ACI was shown with no recognisable vessel wall abnormalities. Transcranial doppler revealed a normalisation of the flow parameters of the right MCA, which were now comparable to the left MCA. Of interest the right PCA showed completely normal flow parameters, while the right ophthalmic artery showed an anterograde flow with increased RI and reduced diastolic flow (**Figure 3**). After normalisation of flow parameters and remission of vessel wall haematoma treatment was changed to single antiplatelet therapy, which was better tolerated given the patient's history of M. Crohn. Patient remained asymptomatic, a new colour doppler of the carotid arteries, as well as a transcranial doppler 3 months later revealed no further changes.

DISCUSSION

A dissection of the internal carotid artery is the result of a tear between inner tunica intima layer and the middle tunica media layer leading to a trauma of vasa vasorum with a resulting hematoma in the vessel wall. An ipsilateral stroke can be a result either from a thromboembolic event or due to hypoperfusion in the setting of a severe stenosis of the vascular lumen.[11]

Many risk factors for spontaneous CAD have been identified, such as genetic predisposition with monogenetic connective tissue disorders such as Ehler-Danlos or Marfan syndrome or complex constellations of multiple candidate genes[12-14] have been related to CAD. Furthermore anatomical abnormalities[15] and inflammation of the vessel wall as seen by autoimmune diseases[16,17] or recent infections[7] may act as trigger factors leading to dissection and formation of the haematoma.

The diagnostic approach for a cervical artery dissection depends usually on angiography. While CTA is readily available, there are some disadvantages

related to this modality. Exposure to radiation and iodinated contrast may be a limiting factor, especially in the acute setting. Furthermore, there are no sensitive or specific findings of a CTA suggestive of a carotid artery dissection and a false-negative or false-positive CTA can often occur.[18] MRA on the other hand is superior to CTA in identifying the intramural hematoma with the appropriate protocol, however limitations of MRA such as availability or restrictions related to patient, such as pacemakers, may restrict its use. Furthermore, false positive of false negative results due to technical reasons such as turbulent flow may also appear.[18] In addition, both of these methods are inappropriate as routinely used follow-up methods controlling the evolution of wall hematoma and recanalisation of carotid arteries.

On the other hand, colour Doppler ultrasound of carotid and vertebral arteries is noninvasive and there are only a few limitations for its use. However, its result and interpretation depend on the operator, while depiction of distal dissections may be impossible. In cases with strong clinical suspicion of a carotid artery dissection another imaging modality should be used to confirm the findings of the ultrasound, while exclusion of CAD using colour duplex sonography seems to be reliable.[19]

However, although colour Doppler ultrasound may be of limited value in the acute setting, it seems extremely useful in the subacute phase as a noninvasive, readily available, low-cost follow-up tool. In the first weeks after CAD a remodelling of the dissected vessel takes place, leading to new clinical symptoms or changes of treatment.[9] Furthermore, transcranial Doppler may be an excellent tool to study the hemodynamic status and activation of collateral networks of intracranial circulation, as well as the reserved capacity of the arterial network, thus estimating the risk of subsequent stroke due to hemodynamic insufficiency. Additionally, detection of microembolic signals may predict the risk of an embolic stroke.[10]

Treatment approach of a patient with CAD may be challenging. Among randomised trials CADISS (Cervical Artery Dissection in Stroke Study) showed no statistical significant difference between Vitamin-K antagonists (VKA) and antithrombotic treatment,[20] while TREAT-CAD (Biomarkers and Antithrombotic Treatment in Cervical Artery Dissection) failed to prove noninferiority of Aspirin to VKA.[21] A metanalysis comparing VKA to DOAC showed a comparable efficacy and safety for stroke prevention [22], while a recent metanalysis showed that antiplatelet treated patients had higher odds for death or disability compared to anticoagulated patients, while on the other hand a lower incidence of symptomatic intracranial and extracranial hemorrhage was noted[23]. A treatment algorithm has been proposed, where bleeding risk and radiologic features of high-risk patients determine therapeutic choices. In high bleeding-risk patients an antiplatelet monotherapy is proposed. In all other patients the presence of high-risk features, such as intraluminal thrombus or occlusive dissection may lead to anticoagulation or dual antiplatelet treatment, while in the absence of high-risk radiological features an antiplatelet monotherapy may be considered.[8] Thus the presence of imaging features is essential for therapeutic decisions, highlighting the role of ultrasound as a follow up tool for monitoring the dynamic changes of a CAD.

In our patient the initial occlusive dissection was considered as a high-risk feature, while the presence of M. Crohn was a limiting factor for anticoagulation. A dual antiplatelet therapy was chosen. However, as a rapid regression of the wall hematoma and a recanalisation of the occluded vessel was shown using colour coded ultrasound as a follow up tool combined with normalisation of the intracranial circulation, a de-escalation of the treatment was deemed safe. Transcranial ultrasound revealed an altered intracranial circulation with activation of collateral vascular networks (ophthalmic artery and leptomeningeal arteries supplied from ipsilateral PSI) and vasodilation in the affected MCA area, as shown by the slightly decreased RI of the right MCA compared to the contralateral MCA. However, no significantly reduced intracranial post-stenotic flow was detected suggestive of a moderate to low risk for hemodynamic stroke in the acute setting with rapid normalisation in the following subacute period.

CONCLUSIONS

Dissection of the cervical arteries is a common cause of juvenile stroke. Patients are at risk of embolic as well as of hemodynamic stroke. A dissected cervical artery shows a dynamic remodelling in the following weeks. Colour doppler is an excellent imaging modality to follow these changes, while transcranial doppler may reveal an insufficiency of collateral vascular networks, suggestive of a high risk for hemodynamic stroke. Our case highlights the importance of ultrasound as an imaging modality, revealing the rapid changes taking place in the immediate subacute period, as well as its unique ability to detect hemodynamic changes not shown with other imaging modalities. These findings may inform therapeutic decisions especially in high-risk patients, individualising treatment according to their actual needs and risks.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

References

[1] Leys D, Bandu L, Hénon H, et al. Clinical outcome in 287 consecutive young adults (15 to 45 years) with ischemic stroke. Neurology. 2002 Jul 9;59(1):26-33.

[2] Schievink WI, Mokri B, Whisnant JP. Internal carotid artery dissection in a community. Rochester, Minnesota, 1987-1992. Stroke. 1993;24(11):1678-80.

[3] Schievink WI. Spontaneous dissection of the carotid and vertebral arteries. N Engl J Med. 2001;344(12):898-906.

[4] Baldino G, Di Girolamo C, De Blasis G, et al. Eagle Syndrome and Internal Carotid Artery Dissection: Description of Five Cases Treated in Two Italian Institutions and Review of the Literature. Ann Vasc Surg. 2020 Aug;67:565.e17-565.e24.

[5] Grond-Ginsbach C, Debette S. The association of connective tissue disorders with cervical artery dissections. Curr Mol Med. 2009;9(2):210-4.

[6] Hunter MD, Moon YP, Miller EC, et al. Influenza-Like Illness is Associated with Increased Short-Term Risk of Cervical Artery Dissection. J Stroke Cerebrovasc Dis. 2021;30(2):105490.

[7] Paciaroni M, Georgiadis D, Arnold M, et al. Seasonal variability in spontaneous cervical artery dissection. J Neurol Neurosurg Psychiatry. 2006 May;77(5):677-9.

[8] Yaghi S, Engelter S, Del Brutto VJ, et al. Treatment and Outcomes of Cervical Artery Dissection in Adults: A Scientific Statement From the American Heart Association. Stroke. 2024;55(3):e91-e106.

[9] Traenka C, Streifler J, Lyrer P, et al. Clinical Usefulness of Serial Duplex Ultrasound in Cervical Artery Dissection Patients. Cerebrovasc Dis. 2020;49(2):206-15.

[10] Brunser AM, Lavados PM, Hoppe A, et al. Transcranial Doppler as a Predictor of Ischemic Events in Carotid Artery Dissection. J Neuroimaging. 2017:27(2):232-6.

[11] Marciniec M, Sapko K, Kulczyński M, et al. Non-traumatic cervical artery dissection and ischemic stroke: A narrative review of recent research. Clin Neurol Neurosurg. 2019;187:105561.

[12] Pezzini A, Del Zotto E, Archetti S, et al. Plasma homocysteine concentration, C677T MTHFR genotype, and 844ins68bp CBS genotype in young adults with spontaneous cervical artery dissection and atherothrombotic stroke. Stroke. 2002;33(3):664-9.

[13] Pezzini A, Del Zotto E, Archetti S, et al. The ICAM-1 E469K gene polymorphism is a risk factor for spontaneous cervical artery dissection. Neurology. 2006;66(8):1273-5.

[14] von Pein F, Välkkilä M, Schwarz R, et al. Analysis of the COL3A1 gene in patients with spontaneous cervical artery dissections. J Neurol. 2002;249(7):862-6.

[15] Venturini G, Vuolo L, Pracucci G, et al. Association between carotid artery dissection and vascular tortuosity: a case-control study. Neuroradiology. 2022;64(6):1127-34.

[16] Pezzini A, Del Zotto E, Mazziotti G, et al. Thyroid autoimmunity and spontaneous cervical artery dissection. Stroke. 2006;37(9):2375-7.

[17] Caso V, Paciaroni M, Parnetti L, et al. Stroke related to carotid artery dissection in a young patient with Takayasu arteritis, systemic lupus erythematosus and antiphospholipid antibody syndrome. Cerebrovasc Dis. 2002;13(1):67-9.

[18] Provenzale JM, Sarikaya B, Hacein-Bey L, et al. Causes of misinterpretation of cross-sectional imaging studies for dissection of the craniocervical arteries. AJR Am J Roentgenol. 2011;196(1):45-52.

[19] Benninger DH, Georgiadis D, Gandjour J, et al. Accuracy of color duplex ultrasound diagnosis of spontaneous carotid dissection causing ischemia. Stroke. 2006;37(2):377-81.

[20] Markus HS, Levi C, King A, et al. Antiplatelet Therapy vs Anticoagulation Therapy in Cervical Artery Dissection: The Cervical Artery Dissection in Stroke Study (CADISS) Randomized Clinical Trial Final Results. JAMA Neurol. 2019;76(6):657-64.

[21] Engelter ST, Traenka C, Gensicke H, et al. Aspirin versus anticoagulation in cervical artery dissection (TREAT-CAD): an open-label, randomised, non-inferiority trial. Lancet Neurol. 2021;20(5):341-50.

[22] Essibayi MA, Lanzino G, Keser Z. Vitamin K antagonist versus novel oral anticoagulants for management of cervical artery dissection: Interactive systematic review and meta-analysis. Eur Stroke J. 2022;7(4):349-57.

[23] Avramiotis NS, Schaub F, Thilemann S, et al. Antithrombotic drugs for carotid artery dissection: Updated systematic review. Eur Stroke J. 2025 Jun;10(2):339-49.