European Journal of Radiology Open 10 (2023) 100462

Contents lists available at ScienceDirect

European Journal of Radiology Open

journal homepage: www.elsevier.com/locate/ejro

Acute intracranial internal carotid artery occlusion: Extension and location of the thrombus as an influencing factor in Computed Tomography angiography findings

Miriam Fernández-Gómez[a,1,2], Félix Gallo-Pineda[a,1,3], Carlos Hidalgo-Barranco[a], Laura Amaya-Pascasio[b], Cristina delToro-Pérez[b], Patricia Martínez-Sánchez[b,*,4], Gracia Castro-Luna[c,5]

[a] Division of Interventional Neuroradiology, Torrecardenas University Hospital, Almería, Spain
[b] Stroke Unit, Neurology Department, Torrecardenas University Hospital, Almería, Spain
[c] Department of Nursing, Physiotherapy, and Medicine, University of Almeria, Spain

HIGHLIGHTS

- Isolated intracranial ICA occlusion can mimic extracranial affectation in CTA (pseudo-occlusion).
- Thrombus's location and extension appear to influence the presence of extracranial pseudo-occlusion.
- Patency of anterior choroidea, posterior communicating, and ophthalmic arteries are involved in CTA findings.

ARTICLE INFO

Keywords:
CTA
Internal carotid artery
Pseudo-occlusion

ABSTRACT

Purpose: Acute intracranial internal carotid artery (ICA) occlusion can mimic an extracranial affectation on Computed Tomography angiography (CTA). This fact could be explained by the extension of the thrombus in the ICA concerning its arterial branches. This study aims to determine how this factor may influence imaging findings.

Methods: A retrospective study was conducted from a single-center database of patients undergoing mechanical thrombectomy due to ICA occlusion between October 2017 and March 2022 ($n = 77$). Patients with acute intracranial ICA occlusion were included ($n = 29$) and divided into two groups, according to ICA opacification on CTA: the discernible extracranial ICA or group D, and the pseudo-occlusion or group P. Patency of posterior communicating, anterior choroidal, and ophthalmic arteries on digital subtraction angiography were collected to determine thrombus extension. Sensitivity and specificity were calculated for CTA.

Results: Significant differences were found in DSA between group P ($n = 17$) and group D ($n = 12$) in the frequency of patency of major artery branches: the presence of posterior communicating (PCOM) and anterior choroidal arteries (AChA) was observed in 2 patients in group P vs. 10 in group D ($p < 0.001$); whereas the patency of the ophthalmic artery (OA) was visualized in 10 patients in group P vs. 12 in group D, $p = 0.023$). For the diagnosis of isolated intracranial ICA occlusion, CTA had a sensitivity of 43.5% and a specificity of 97.2%.

Conclusions: The location and extent of the thrombus in the intracranial ICA concerning major artery branches may influence CTA findings.

* Corresponding author.
E-mail address: patrindalo@hotmail.com (P. Martínez-Sánchez).
[1] Both authors contributed equally to this manuscript.
[2] ORCID: 0000-0002-3962-3921
[3] ORCID: 0000-0002-3442-7892
[4] ORCID: 0000-0003-1945-4435
[5] ORCID: 0000-0001-6928-9728

https://doi.org/10.1016/j.ejro.2022.100462
Received 19 November 2022; Accepted 7 December 2022

1. Introduction

In recent years, the treatment of acute ischemic stroke (AIS) due to large vessel occlusion has changed radically thanks to mechanical thrombectomy, getting a significant morbidity and mortality reduction [1–4]. According to the American Heart and Stroke Association's recommendations, candidates' selection for mechanical thrombectomy is based on clinical and imaging findings. Non-invasive vascular imaging, such as Computed Tomography angiography (CTA) or Magnetic Resonance angiography is used for occlusion identification [5].

Establishing the occlusion site is vital for planning mechanical thrombectomy and for the previous choice of devices to get a shorter procedure time and higher technical success rate [6,7]. In internal carotid artery (ICA) occlusion is essential to differentiate between extracranial and intracranial location, as well as the detection of an underlying lesion that requires angioplasty or stenting [6]. Nevertheless, sometimes it is not always easy to prove. Between 45% and 67% of intracranial ICA occlusions, cervical ICA is non-opacified in CTA. This finding is caused by slow arterial flow and can simulate an extracranial occlusion (pseudo-occlusion) [7–10]. The location and extent of the thrombus concerning anterior choroidea, posterior communicating and ophthalmic arteries could explain the presence of this radiological sign.

The main objective of CTA in AIS is the detection of arterial occlusion location in eligible patients for mechanical thrombectomy [11]. For this purpose, two image acquisition protocols are defined in the previous scientific reports: single-phase CTA (sCTA) and multiphase CTA (mCTA) with acquisitions of two additional phases [6,11–15]. Most published clinical trials are based on the findings of single-phase CTA for patient selection.

The purpose of our study is to assess the effect of the location and extension of the thrombus in the intracranial ICA, concerning its major arterial branches, in the occurrent cervical pseudo-occlusion in CTA.

2. Materials and methods

2.1. Patient selection

This observational study was a single-center retrospective analysis of patients undergoing mechanical thrombectomy due to AIS caused by ICA occlusion from October 2017 to March 2022. The inclusion criteria were the presence of acute intracranial ICA occlusion on digital subtraction angiography (DSA). Patients with non-valuable CTA were removed. This study was approved by the local ethics committee and was performed in accordance with the ethical standards as laid down in the Declaration of Helsinki.

2.2. CTA and DSA acquisition and post-processing protocols

CTA was acquired using a 64 CT slice scanner (General Electric, Siemens, or Philips) in the thrombectomy center or the neighboring centers. The image acquisition protocol used for single or multiphase CTA was as follows [12]:

Intravenous canalization and 80 cubic centimeters contrast media administration (Ioversol 350 milligram/cubic centimeter) through an injection pump at a 4 milligram/second flow rate, followed by saline.

-Acquisition of the arterial phase, from the aortic arch to the vertex, by monitoring the bolus of contrast with ROI (Region Of Interest) in the aortic arch. This first arterial phase is equivalent to the single CTA protocol.

-Acquisition of the second phase (peak venous phase), from skull base to cerebral vertex, 4 s after the first phase.

-Acquisition of the third phase (late venous phase), from skull base to cerebral vertex, 4 s after the second phase.

CTA lecture was developed in the 'PhilipsVue' viewerpacs, 2020, Amsterdam. Image post-processing consisted of maximum intensity projection with five or ten millimeters of slab thickness and the multiplanar reconstruction (MPR) to get axial, coronal, and sagittal planes.

DSA was performed in an Artis Zee biplane (Siemens) for visualizing the occlusion site before mechanical thrombectomy. Coronal, sagittal and/or oblique planes were acquired during 10 ml contrast administration through a catheter inserted in the common carotid and internal carotid arteries. DSA was used as a 'Gold standard' to allow more precise localization of the occlusion site than CTA [16,17].

2.3. CTA and DSA analysis

Two neuroradiologists analyzed separately the single or the first phase of the multiphase CTA and DSA of each patient, and occlusion site location was classified into intracranial or extracranial. In case of discordance between them, a consensus was reached.

Patients with isolated intracranial ICA occlusion on DSA were divided into two groups according to the extracranial ICA opacification

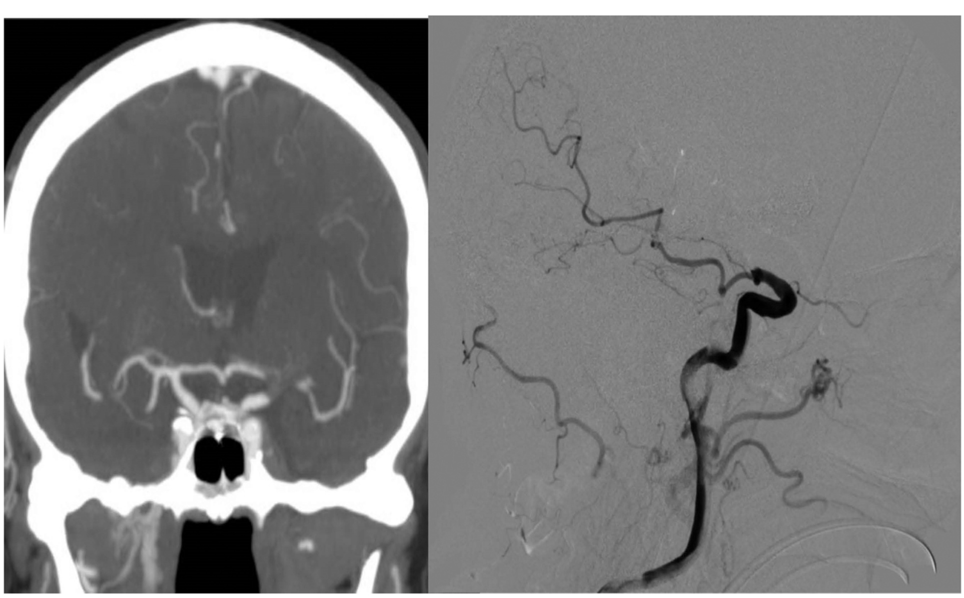

Fig. 1. Patient with acute terminal ICA occlusion, with contrast meeting with the proximal face of the clot in the arterial phase of the CTA. DSA shows a distal ICA occlusion, with patency of the posterior communicating, anterior choroidea, and ophthalmic arteries.

Table 1
Demographic variables, comorbidities, and clinical severity in patients with acute intracranial internal carotid artery occlusion.

	Pseudo-occlusion ICA group n = 17	Discernible ICA group n = 12	p
Male sex, n, (%)	5 (29.4%)	8 (66.7%)	0.067
Age, median (IQR), years	75 (13.5)	78 (16.5)	0.394
Arterial Hypertension, n, (%)	13 (76.5%)	6 (50%)	0.409
Diabetes Mellitus, n, (%)	4 (23.5%)	4 (33.3%)	0.671
Dyslipidemia, n, (%)	5 (29.4%)	7 (58.3%)	0.121
Previous Atrial Fibrillation, n, (%)	5 (29.4%)	4 (33.3%)	1
Novo Atrial Fibrillation, n, (%)	4 (23.5%)	3 (25%)	1
Previous CHD, n, (%)	3 (17.6%)	2 (16.7%)	1
Previous stroke, n, (%)	0 (0%)	3 (25%)	0.05
NIHSS, median, (IQR)	18 (7)	18 (11)	0.499

IQR = Interquartile range, CHD = coronary heart disease, NIHSS = National Institute of Health Stroke Scale, * statistical significance $p < 0.05$

on the single or first phase of multiphase CTA: group P when extracranial ICA was not opacified (pseudo-occlusion), and group D when extracranial ICA was discernible.

On DSA, thrombus location and extension were evaluated. First, the location was categorized as intracranial or extracranial. Second, we reviewed the opacification of the three major artery branches of ICA: the anterior choroidal artery (AChA), the posterior communicating (PCOM), or fetal posterior cerebral artery (fPCA), and the ophthalmic artery (OA). The absence of visualization of these branches indicated an occlusion at the origin of these vessels or proximal to the ostium.

2.4. Statistical analysis

After performing the Kolmogorov-Smirnov normality test, nonparametric tests were used for statistical analysis. Fisher's test was used when comparing the means between two qualitative variables. In the case of comparing a qualitative variable and a quantitative variable, the U-Mann-Whitney test was used. CTA sensitivity and specificity were calculated for isolated intracranial ICA occlusions. DSA was considered the gold standard.

3. Results

From October 2017 to March 2022, a total of 77 patients were eligible for mechanical thrombectomy due to acute intra or extracranial ICA occlusion reported on DSA. 29 of them were diagnosed with isolated intracranial ICA occlusion: 17 patients formed the group P and 12 were added to the group D (Fig. 1). Table 1 details each group's demographic, comorbidity, and clinical severity variables.

In our sample all patients with pseudo-occlusion (group P) presented in CTA with a progressive contrast decay in extracranial ICA (in other words, an ill-defined occlusion) (Fig. 2. and Fig. 3).

In DSA findings, we found statistically significant differences between both groups in the permeability of PCOM, AChA, and OA (Table 2): opacification of the PCOM and the AChA was observed in 2 patients (12%) of the group P and in 10 patients (83%) of the group D. The OA was visualized in 10 patients (59%) in group P and 12 patients (100%) in group D.

For the diagnosis of isolated intracranial ICA occlusion, sCTA or the first phase of mCTA had a sensitivity of 43.5% and a specificity of 97.2%.

4. Discussion

In recent clinical trials, acute intracranial ICA occlusion accounts for approximately 25–30% of patients who are candidates for mechanical thrombectomy [11,14]. Nevertheless, the form of presentation on CTA can confuse [11,16].

The term pseudo-occlusion is used when the extracranial ICA does not opacify on CTA, mimicking a more proximal occlusion in patients with isolated intracranial ICA occlusion [18]. In our study, all patients with pseudo-occlusion had a progressive gradual decrease of contrast in the cervical ICA on CTA, with apparent patency of the bulb. This finding is secondary to the combination of contrast with retained blood; it receives different terms in the scientific literature, being 'flame-shaped' occlusion the most used [7,9–10,18–20].

In the diagnosis of intracranial ICA occlusion, with regards to the reliability of the "flame sign", Prakkamakul et al. described a sensitivity and specificity of 45.5% and 100% respectively [19]. Conversely, Kim et al. observed that this pattern, also termed as 'beak pattern', was significantly higher in the pseudo-occlusion group than in the group of patients with true cervical ICA occlusion (82.9% vs. 16.1%, $p < 0.001$) [9]. Nevertheless, Choi et al. could not demonstrate significant

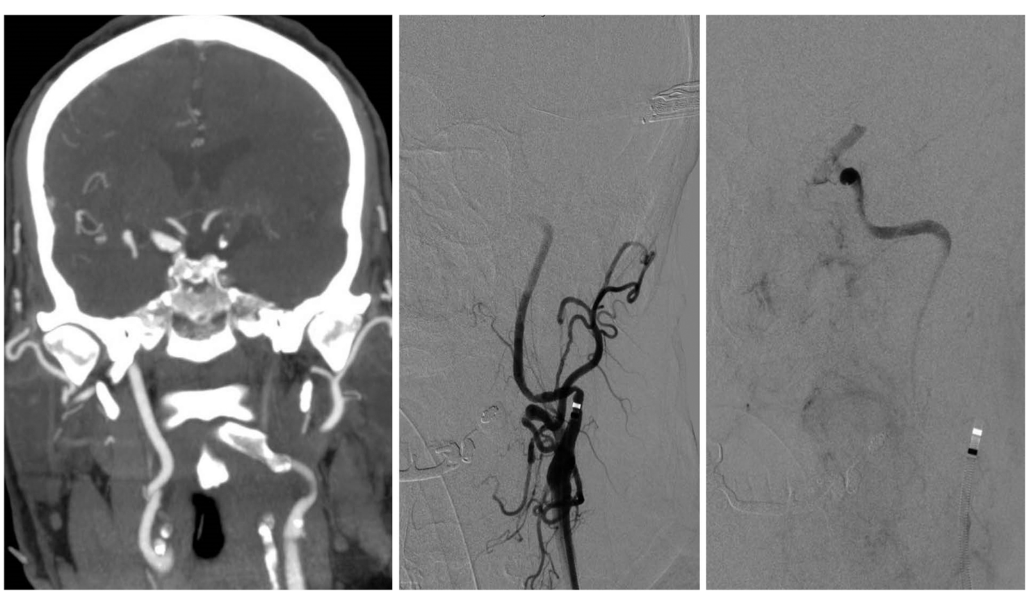

Fig. 2. Patient with extracranial ICA pseudo-occlusion in CTA due to intracranial occlusion. DSA shows a distal ICA occlusion, distal to the ophthalmic artery, with the absence of opacification of the anterior choroidea and the posterior communicating arteries.

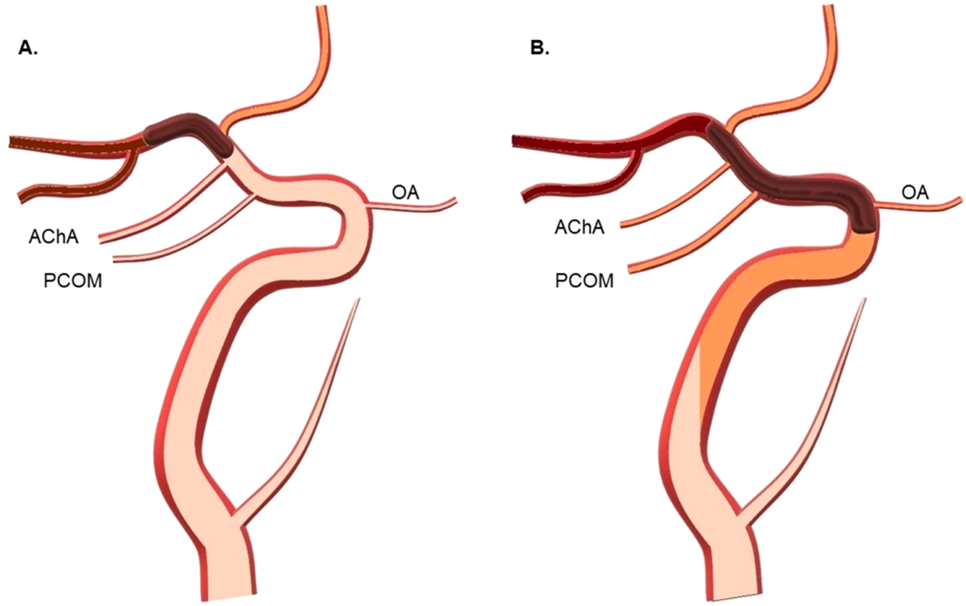

Fig. 3. A. Intracranial ICA occlusion with the presence of thrombus distal to the three main branches: ophthalmic artery (OA), posterior communicating artery (PCOM), and anterior choroidal artery (AChA). Note the opacification of the extracranial segment of the ICA. B. The thrombus occludes the three main branches of the ICA, conditioning non-enhancing blood retention.

Table 2
DSA findings in patients with intracranial ICA occlusion.

Opacified arteries on DSA	Pseudo-occlusion ICA (n = 17)	Discernible ICA (n = 12)	p
Posterior communicating artery (or fetal posterior cerebral artery)	2 (11.7%)	10 (83.3%)	< 0.001*
Anterior choroidea artery,	2 (11.7%)	10 (83.3%)	< 0.001*
Ophthalmic artery	10 (56.2%)	12 (100%)	0.023*

DSA = Digital subtraction angiography, ICA = Internal carotid artery, * statistical significance $p < 0.05$

differences in "flame sign" prevalence comparing pseudo-occlusions with true occlusions groups [6]. In other studies, such as Grossberg et al., the flame-shaped occlusion was also found in patients with cervical arterial dissection [20]. Therefore, this radiological sign is not exclusive to extracranial ICA pseudo-occlusions, being found in true cervical occlusions [21].

According to our results, the extent and location of the thrombus in the intracranial ICA appear to influence the findings found on CTA. Arterial branches originating from the intracranial ICA (PCOM/fPCA, AChA, and OA) function as escape routes for blood and contrast when occlusion distal occurs. However, when the occlusion is located proximal or at the origin of these branches, the anterograde blood flow would be affected by the absence of this outlet. This all translates into the absence of opacification of these vessels during selective DSA before thrombectomy.

Our results demonstrate that most patients with pseudo-occlusion had an absence of opacification of the PCOM/fPCA, the AChA and the OA. On the other side, all patients with discernible intracranial ICA occlusion had a filling of the OA in the DSA.

In agreement with *Waheram* et al., most patients with pseudo-occlusion presented a thrombus extending in the same location (or proximal) to the origin of the PCOM [8]. However, OA involvement was less frequently reported in their study.

Our study has several limitations: a retrospective analysis, one single-center participation, and a relatively small sample size. Nevertheless, this is one of the most extensive series comparing discernible intracraneal ICA occlusion vs. extracranial pseudo-occlusion in patients undergoing thrombectomy with significant results obtained.

5. Conclusions

In conclusion, the presence of extracranial pseudo-occlusion on CTA seems to be related to the location and extension of the thrombus intracranially, mainly in the communicating and ophthalmic segment of the ICA. The free outflow of blood in perfused vessels (AChA, PCOM, OA) may help delineate the thrombus contour on CTA.

Prospective and multicenter studies are needed to confirm these results in larger samples.

Statements and declarations

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Almeria provincial research ethics committee. The authors have no relevant financial or non-financial interests to disclose.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] R.G. Nogueira, A.P. Jadhav, D.C. Haussen, A. Bonafe, R.F. Budzik, P. Bhuva, D. R. Yavagal, M. Ribo, C. Cognard, R.A. Hanel, C.A. Sila, A.E. Hassan, M. Millan, E. I. Levy, P. Mitchell, M. Chen, J.D. English, Q.A. Shah, F.L. Silver, T.G. Jovin, Thrombectomy 6 to 24 hours after stroke with a mismatch between deficit and infarct, NEJM N. Engl. J. Med. 378 (2018) 11–21.

[2] G.W. Albers, M.P. Marks, S. Kemp, S. Christensen, J.P. Tsai, S. Ortega-Gutierrez, R. A. McTaggart, M.T. Torbey, M. Kim-Tenser, T. Leslie-Mazwi, A. Sarraj, S.E. Kasner, S.A. Ansari, S.D. Yeatts, S. Hamilton, M. Mlynash, J.J. Heit, G. Zaharchuk, S. Kim, J. Carrozzella, Y.Y. Palesh, A.M. Demchuk, R. Bammer, P.W. Lavori, J.P. Broderick, M.G. Lansberg, Thrombectomy for stroke at 6 to 16 hours with selection by perfusion imaging, NEJM N. Engl. J. Med. 378 (2018) 708–718.

[3] O.A. Berkhemer, P.S.S. Fransen, D. Beumer, L.A. van den Berg, H.F. Lingsma, A. J. Yoo, W.J. Schonewille, J.A. Vos, P.J. Nederkoorn, M.J.H. Wermer, M.A.A. van Walderveen, J. Staals, J. Hofmeijer, J.A. van Oostayen, G.J. Lycklama à Nijeholt, J. Boiten, P.A. Brouwer, B.J. Emmer, S.F. de Bruijn, D.W.J. Dippel, A randomized

trial of intraarterial treatment for acute ischemic stroke, NEJM N. Engl. J. Med. 372 (2015) 11–20.
[4] M. Goyal, A.M. Demchuk, B.K. Menon, M. Eesa, J.L. Rempel, J. Thornton, D. Roy, T.G. Jovin, R.A. Willinsky, B.L. Sapkota, D. Dowlatshahi, D.F. Frei, N.R. Kamal, W. J. Montanera, A.Y. Poppe, K.J. Ryckborst, F.L. Silver, A. Shuaib, D. Tampieri, M. D. Hill, Randomized assessment of rapid endovascular treatment of ischemic stroke, NEJM N. Engl. J. Med. 372 (2015) 1019–1030.
[5] W.J. Powers, A.A. Rabinstein, T. Ackerson, O.M. Adeoye, N.C. Bambakidis, K. Becker, J. Biller, M. Brown, B.M. Demaerschalk, B. Hoh, E.C. Jauch, C.S. Kidwell, T. M. Leslie-Mazwi, B. Ovbiagele, P.A. Scott, K.N. Sheth, A.M. Southerland, D. Summers, D.L. Tirschwell, Guidelines for the early management of patients with acute ischemic stroke: 2019 update to the 2018 guidelines for the early management of acute ischemic stroke a guideline for healthcare professionals from the American Heart Association/American Stroke Association. vol. 50, Stroke. Lippincott Williams and Wilkins; 2019;50:344–418.
[6] J.H. Choi, J. Jang, J. Koo, A. Kook-Jin, Y.S. Shin, B. Kim, Multiphasic computed tomography angiography findings for identifying pseudo-occlusion of the internal carotid artery, Stroke 51 (2020), 2558-62.
[7] M. Kappelhof, H.A. Marquering, O.A. Berkhemer, J. Borst, A. van der Lugt, W. H. van Zwam, J.A. Vos, G. Lycklama à Nijeholt, C.B.L.M. Majoie, B.J. Emmer, Accuracy of CT angiography for differentiating pseudo-occlusion from proper occlusion or high-grade stenosis of the extracranial ICA in acute ischemic stroke: a retrospective MR CLEAN substudy, AJNR Am. J. Neuroradiol. 39 (2018) 892–898.
[8] J. Wareham, R. Crossley, S. Barr, A. Mortimer, Cervical ICA pseudo-occlusion on single-phase CTA in patients with acute terminal ICA occlusion: what is the mechanism and can delay CTA aid diagnosis? JNIS J. Neurointerv. Surg. 10 (2018) 983–987.
[9] H.J. Kim, H.S. Kwak, G.H. Chung, S.B. Hwang, Differentiating pseudo-occlusion from true occlusion of the proximal internal carotid artery in acute ischemic stroke on CT angiography, Clin. Neurol. Neurosurg. 185 (2019), 105495.
[10] W.S. Jung, J.S. Lee, S. Solander, J.W. Choi, Pseudo-occlusion of the internal carotid artery in acute ischemic stroke: clinical outcome after mechanical thrombectomy, Sci. Rep. 10 (2020) 2832.
[11] B.K. Menon, B.C.V. Campbell, C. Levi, M. Goyal, Role of imaging in current acute ischemic stroke workflow for endovascular therapy, Stroke 46 (2015) 1453–1461.
[12] S. Dundamadappa, K. Iyer, A. Agrawal, D.J. Choi, Multiphasect angiography: a useful technique in acute stroke imaging- collaterals and beyond, Am. J. Neuroradiol. AJNR Am. J. Neuroradiol. 42 (42) (2021) 221–227.
[13] B.K. Menon, C.D. D'Esterre, E.M. Qazi, M. Almekhlafi, L. Hahn, A.M. Demchuk, M. Goyal, Multiphase CT angiography: a new tool for the imaging triage of patients with acute ischemic stroke, Radiology 275 (2015) 510–520.
[14] D. Volders, J.R. Shewchuk, M. Marangoni, N. Mhurchu, M. Heran, Beyond the collaterals: additional value of multiphase CTA in acute ischemic stroke evaluation, Neuroradiol. J. 32 (2019), 309-14.
[15] I. Kaschka, S. Kloska, T. Struffert, T. Engelhorn, P. Gölitz, N. Kurka, M. Khörmann, S. Schwab, A. Doerfler, Clot burden and collaterals in anterior circulation stroke: differences between single-phase CTA and multi-phase 4D-CTA, Clin. Neuroradiol. 26 (2014) 309–315, https://doi.org/10.1007/s00062-014-0359-6.
[16] G.B. Bradac, F. Venturi, G. Bosco, D. Garabello, M. Coriasco, G. Stura, G. Ventilii, M. Bergui, P. Cerrato, Acute occlusion of the distal internal carotid artery: single-center experience in 46 consecutive cases, review of the literature and proposal of a classification, Clin. Neuroradiol. 30 (2020) 67–76.
[17] V.I. Óriás, D. Szöllősi, M. Gyánó, D.S. Veres, S. Nardai, C. Csobay-Novák, B. Nemes, J.P. Kiss, K. Szigeti, S. Osváth, P. Sótonyi, Z. Ruzsa, Initial evidence of a 50% reduction of contrast media using digital variance angiography in endovascular carotid interventions, Eur. J. Radiol. Open 7 (2020), 100288, https://doi.org/10.1016/j.ejro.2020.100288.
[18] A. Diouf, R. Fahed, M. Gaha, M. Chagnon, N. Khoury, M. Kotowski, F. Guilbert, D. Landry, J. Raymond, D. Roy, A. Weill, Cervical internal carotid occlusion versus pseudo- occlusion at CT angiography in the context of acute stroke: an accuracy, interobserver, and intraobserver agreement study, Radiology 286 (2018), 1008-15.
[19] S. Prakkamakul, N. Pitakvej, N. Dumrongpisutikul, S. Lerdlum, Mid-cervical flame-shaped pseudo-occlusion: diagnostic performance of mid-cervical flame-shaped extracranial internal carotid artery sign on computed tomographic angiography in hyperacute ischemic stroke, Neuroradiology 59 (2017), 989-96.
[20] Z. Chen, M. Zhang, F. Shi, X. Gong, D. Liebeskind, X. Ding, C. Liu, R. Zhang, M. Lou, Pseudo-occlusion of the internal carotid artery predicts poor outcome after reperfusion therapy, Stroke 49 (2018) 1204–1209.
[21] J.A. Grossberg, D.C. Haussen, F.B. Cardoso, L.C. Rebello, M. Bouslama, A. M. Anderson, M.R. Frankel, R.G. Nogueira, Cervical carotid pseudo- occlusions and false dissections, Stroke 48 (2017) 774–777.