Heliyon 10 (2024) e36741

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

A retrospective observation study for the diagnostic effect of dual-source CT angiography on traumatic subarachnoid hemorrhage patients

Mingyue Bao [1], Lei Ye [1], Peng Gao, Hongwei Cheng, Xing Zhang *

Department of Neurosurgery, First Affiliated Hospital of Anhui Medical University, Jixi 218, Hefei, 230022, PR China

A R T I C L E I N F O

Keywords:
Dual-source CT angiography
Traumatic subarachnoid hemorrhage
Diagnosis
Comparison
Cerebrovascular disease

A B S T R A C T

Identification of potential cerebrovascular disorder in the patient with traumatic subarachnoid hemorrhage (tSAH) is a key element to decrease the complication occurrence and mortality rate. In this study, we aim to compare the diagnostic values between dual-source computed tomography angiography (DSCTA) and traditional tomography angiography (CTA) in identification of potential cerebrovascular disorder among tSAH patients. A total of 113 tSAH patients with the hemorrhage involving more than 2 cisterns were recruited. Among that, 42 patients received DSCTA scans, and another 71 patients received traditional CTA scans. Subsequently, all patients received digital subtraction angiography (DSA) tests to confirm the presence of the cerebrovascular disorder. In DSCTA scan group, 21.4 % (9/42) patients were reported to have cerebrovascular disorders: seven patients had intracranial aneurysms; a patient had pseudoaneurysm with carotid artery cavernous sinus fistula; and a patient had Moyamoya disease. DSA tests had the same results with that with DSCTA scans. In the cohort receiving CTA scans, 19.7 % (14/71) patients were reported to had intracranial aneurysms. However, the positive results of DSA tests for this cohort were 22.5 % (16/71). Two inconsistent results between the CTA scan and DSA test were found, including an arteriovenous malformation and an arteriovenous fistula. In summary, DSCTA and CTA had similar positive rates but differ in diagnostic accuracy for identification of cerebrovascular disorders in tSAH patients.

1. Introduction

Traumatic subarachnoid hemorrhage (tSAH) is one of the leading cause of death in the patients with traumatic brain injury (TBI), and the incidence rate varies from 26 % to 53 % [1]. As a severe concomitant disease of TBI, tSAH significantly increases the mortality rate and aggravates the functional impairment, probably due to the severity of mechanical damage and neuro-inflammatory reaction in the phase of secondary brain injury [2,3]. Notably, tSAH attributes not only to the trauma, but also to the potential rupture of pre-existing cerebrovascular disorders, such as intracranial aneurysm (IA) and vessel malformation, which are probably the reason or result of the trauma [4]. Therefore, the latent cerebrovascular disorder usually results in clinical challenges in the subsequent

* Corresponding author. Department of Neurosurgery, The First Affiliated Hospital of Anhui Medical University, Jixi 218, Hefei, 230022, PR China.

E-mail address: zxahmu1h@163.com (X. Zhang).

[1] These author contribute equally to this work.

https://doi.org/10.1016/j.heliyon.2024.e36741
Received 19 December 2023; Received in revised form 19 August 2024; Accepted 21 August 2024
Available online 22 August 2024

treatment decision making, because such patient cohort suffers a higher re-rupture risk.

The hemorrhage in tSAH almost distributes the surrounding subarachnoid cisterns and sulcus of the contusion areas, and is significantly correlated with the severity of brain contusion. However, the hemorrhage location can be found at the cisterns of skull base in a part of tSAH patients, which is similar to that in the patients with aneurysmal SAH (aSAH) [5]. Therefore, it is necessary to make additional medical examinations to distinguish the pathogenesis of tSAH. Meanwhile, as the experiences on clinical practice, the number of cistern involvement assists to promote the diagnostic rate among tSAH patients with the comorbidity of IA. Therefore, it is essential to distinguish the actual pathogenesis of tSAH at the emergency condition.

Neuroimage test is essential for tSAH patients to screen out potential cerebrovascular disorder. Although digital subtraction angiography (DSA) is the gold standard for the diagnosis of IA, a time-efficient tool should be the primary consideration for the IA screening among tSAH patients [6]. Alternatively, computed tomography angiography (CTA) is considered as one of the time- and cost-effective choice for tSAH patients [7]. However, the diagnostic effect of the CTA is sometimes unsatisfactory due to the poor cerebrovascular contrast, which is probably resulted from the overwhelming density of the hematoma. Additionally, as the cerebral hypoperfusion occurs secondary to the vasospasm and intracranial hypertension, the poor contrast agent filling of the cerebral vessels may also reduce the quality of image [8]. In recent years, dual-source computed tomography angiography (DSCTA) has presented a higher diagnostic effect for the IA screening. It provides improved contrast solution over the conventional CTA by blending 2 energy data sets into a single image set [9]. However, the information concerning diagnostic effect of DSCTA in emergency conditions such as in tSAH patients is still limited.

In this study, we retrospectively observed a case series to briefly compare the diagnostic effect of DSCTA to traditional CTA in tSAH patients with the hemorrhage involvement of more than two cisterns.

2. Materials and methods

2.1. Patients

A total of 113 hospitalized patients who were diagnosed with tSAH were recruited in this study. All patients randomly accepted either CTA or DSCTA scans at admission. Among that, 42 tSAH patients were screened out with DSCTA scans, while another 71 tSAH patients, who were admitted to the hospital at the same period, received the traditional CTA scans. DSA tests were subsequently performed for all patients to confirm the presence of cerebrovascular disease. All patients were self-reported to have the traumatic history. The diagnosis of tSAH was made by a senior doctor according to the results of neuroimage and traumatic histories. We complied with the double-blind criteria (CTA/DSCTA technicians and researchers/clinicians) to prevent bias in interpreting the imaging results. Additionally, the inclusion criteria also contained the hemorrhage locations of more than 2 cisterns (including suprasellar cistern, lateral fissure, longitudinal fissure and ambient cistern). Those patients with disturbance of consciousness before the traumatic brain injury, or without the trauma-induce SAH were excluded from the study. Demographic data and clinical features were summarized at Table 1. This study was approved by the Ethics Committee (Approval No. PJ2023-14-35). Informed consents were obtained from participated patients or immediate relatives.

2.2. Contrast agent injection technology and scanning

The CTA scans were performed on a second-generation DSCT system (Siemens Somatom Definition, Forchheim, Germany). The non-ionic contrast medium (iopamidol, 37 g/100 ml, Patheon, Italia) was intravenously injected through the antecubital vein by a double-tube high-pressure injector (Stellant, Medred Co., USA), with a maximum volume of 70 ml and flow-rate of 2 ml/s. The acquisition parameters of DSCTA were coordinated as follows: the rotation speed of X ray tube 0.5 s/circle; tube A, tube voltage 140 kV, tube current 130 mA; tube B, tube voltage 80 kV, tube current 552 mA; slice thickness 0.5 mm; detector collimator range 64 × 0.6

Table 1
Basic information of the tSAH patients.

Parameters		DSCTA (n = 42)	CTA (n = 71)	*p* value
Gender (n)				0.65
	Male	23	51	
	Female	19	20	
Age (year)		(49.2 ± 15.5)	49.1 ± 14.2	0.96
Fisher classification		II-IV	II-IV	–
Glasgow coma scale (GCS) (n)				0.53
	13–15	6	9	
	9–12	15	33	
	3–8	21	29	
Causes of trauma (n)				0.78
	Traffic accident	23	44	
	Falling	8	12	
	Clooision	7	9	
	Blunt force injury	2	8	
	Unknown reason	2	4	

mm; scanned range, from the parietal to the C4; scanning time 7–10 s. All images were transferred to a workstation (MMWP; Siemens AG, Forchheim, Germany) for image processing and evaluation. After DSCTA acquisition, the linear mixing image sets were reconstructed automatically using a ratio of 0.6 (0.6 80 kVp + 0.4140 kVp). The bone-less image software Inspace was used to reconstruct three-dimensional images by volume rendering (VR) and maximum intensity projection (MIP). The image qualities were assessed independently by a senior radiologist and the results were read by a senior neurosurgeon and another radiologist.

2.3. Manifestation of neuroimage results in CTA and DSCTA

We rapid injected water-soluble iodine contrast agent to all patients through the peripheral vein. The positive indications were judged when the contrast agent filled in the target vessels based on previously published criteria [10,11]. The positive indications of cerebrovascular malformation for CTA and DSCTA scans are defined as follow: IA typically manifests as a bulging or saccular dilation of the vessel wall, exhibiting either regular or irregular morphology through the CTA or DSCTA imaging scans in a 3-dimensional manner. The feature of carotid arteriovenous fistulas (CCF) shows a direct connection between the internal carotid artery or its branches and the cavernous sinus, forming abnormal arteriovenous fistulas. These fistulas typically exhibit prominent vascular dilation and abnormal blood flow, creating an aberrant channel between the normally separated arterial and venous systems. The feature of Moyamoya disease (MMD) exhibits stenosis or occlusion of the terminal internal carotid arteries. This stenosis results in the development of a characteristic collateral vasculature, known as moyamoya vessels, which appear as a dense network of tiny, tortuous blood vessels at the base of the brain.

2.4. DSA tests to confirm the cerebrovascular disorders

All patients received DSA tests to confirm the cerebrovascular disorders. The Briefly, we used a standard four-vessel study with a 3D rotational sequence for enhanced delineation of the cerebrovascular disorders. We could observe both characters and morphological features, including location, shape, and proximity to parent and branch vessels in DSA tests.

2.5. Statistical analysis

SPSS 19.0 software was applied for statistical analysis. All enumeration data were given as mean ± standard deviation (Mean ± SD) and analyzed by Student *t*-test. Binary data were analyzed by Chi-squared test. The *p* values reported in the study were based on a two-sided probability test with a significance level of $p < 0.05$.

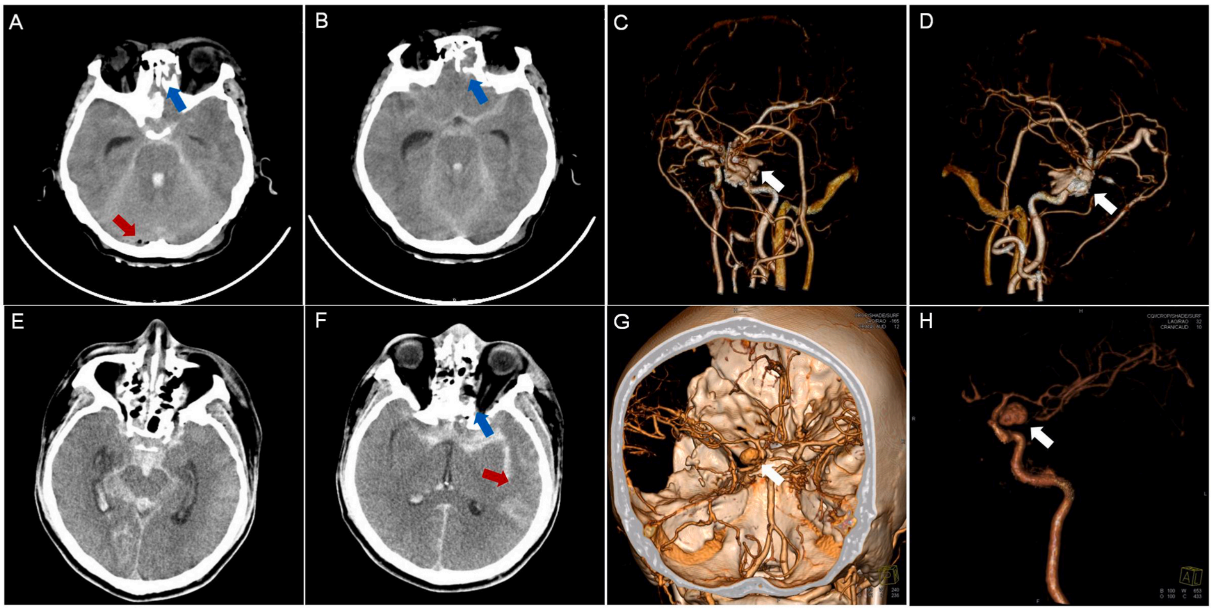

Fig. 1. Representative neuroimages of traumatic subarachnoid hemorrhage (tSAH) patients with dual-source computed tomography angiography (DSCTA) scans. Case 1: CT scan showed the extensive SAH in the cistern of skull base (A and B; red arrow: intracranial pneumatosis; blue arrow: multiple skull fractures). Volume rendering images indicated the pseudoaneurysm combining of carotid artery cavernous sinus fistula CCF (C and D; white arrow). Case 2: CT scan showed the extensive SAH in the skull base as well as the contusion and laceration of temporal lobe. (E and F; red arrow: cerebral contusion and laceration; blue arrow: multiple skull fractures). Volume rendering images indicated the IA in posterior communicating artery (G and H; white arrow).

3. Results

3.1. Positive results for the DSCTA

In DSCTA tests, we found that 9 out of 42 patients had positive indications for cerebrovascular disorders, with the positive rate of 21.4 %. Seven patients were diagnosed with IA. Among that, four aneurysms located in the posterior communicating artery (PCA), two aneurysms in anterior communication artery (ACA) and a aneurysm in paraclinoid of internal carotid artery (ICA). The consistent localization between the hemorrhage site and IA lesions were found in 6 patients. However, a patient had inconsistent localization between the hemorrhage site and the IA. Besides, a patient was diagnosed with pseudoaneurysm with carotid artery cavernous sinus fistula (CCF) and another patients was diagnosed with Moyamoya disease (MMD). Two representative neuroimages with DSCTA scans for the tSAH patients were illustrated in Fig. 1. In case 1, CT scan showed the extensive SAH in the cistern of skull base (Fig. 1A and B), and the volume rendering images indicated the pseudoaneurysm combining of carotid artery cavernous sinus fistula CCF (Fig. 1C and D). In case 2, CT scan showed the extensive SAH in the skull base as well as the contusion and laceration of temporal lobe (Fig. 1E and F) and volume rendering images indicated the IA in posterior communicating artery (Fig. 1G and H). Other information for the patients were summarized in Table 2.

3.2. Comparison of IA positive results between DSCTA and CTA tests

All patients received DSA tests to confirm the existence of cerebrovascular disorders. The results of DSA tests were consistent with that in DSCTA scans, indicating the 100 % accuracy for the diagnosis by DSCTA scan. In another group, 71 tSAH patients received CTA scans, and 19.7 % (14/71) patients showed positive indications for IA. However, the positive results by DSA tests were 22.5 % (16/71). We found that there were 2 inconsistent results between the CTA scans and DSA tests among tSAH patients, including an arteriovenous malformation and an arteriovenous fistula. The results inferred that the DSCTA might have a higher detection rate of cerebrovascular disorders in tSAH patients that using the traditional CTA screening.

3.3. Treatments and prognosis

All patients received standardized treatments. Among the 33 patients with negative result in DSCTA tests, 6 patients received craniotomy operation owing to the formation of delayed hematoma, and the rest of patients received conservative treatments. Consequently, 27 patients recovered and 6 patients had improvements. In another aspect, among the 9 tSAH patients with the DSCTA positive results, 7 patients received endovascular embolization treatments, a patients received conservative treatments and another patient received craniotomy clipping treatment. Eight patients had acceptable results in prognosis. However, a patients, who had comorbidity of the pseudoaneurysm combined with the CCF, died because of the re-hemorrhage (Table 2). In the cohort of patient receiving CTA scan, 51 out of 55 patients who had negative indications of cerebrovascular disorders had conservative treatment, and another 4 patients received craniotomy operation because of delayed hematoma. Additionally, among the 16 patients who had positive results with cerebrovascular disorders, 12 patients received endovascular embolization operations, 2 IA patients received conservative treatment, and another 2 IA patients received craniotomy clipping surgery. All patients had good recovery in this cohort.

Table 2
tSAH with positive results of DSCTA. PCoA: posterior communicating artery. ACoA: anterior communicating artery. ICA: internal carotid artery. CCF: carotid cavernous fistula. MMD: Moyamoya disease.

Case number	GCS	DSCTA indication	Accordance with tSAH distribution	Complication	Cause of trauma	Therapeutic method	Prognosis
1	13	PCoA	Yes	Skull fracture	Traffic accident	Embolization	Recovered
2	9	PCoA	Yes	Skull fracture and brain contusion	Traffic accident	Embolization	Recovered
3	10	ACoA	Yes	Brain contusion	Falling	Embolization	Improved
4	8	PCoA	Yes	Skull fracture, brain contusion and subdural hematoma	Clooision	craniotomy clipping	Improved
5	11	PCoA	No	Scalp hematoma	Traffic accident	Conservative treatment	Recovered
6	7	ACoA	Yes	Skull fracture	Clooision	Embolization	Improved
7	6	Paraclinoid of ICA	Yes	Skull fracture and brain contusion	Unknown reason	Conservative treatment	Improved
8	4	Pseudoaneurysm combined with CCF	Yes	Skull fracture and brain contusion	Traffic accident	Conservative treatment	Death
9	9	MMD	–	Brain contusion	Falling	Conservative treatment	Improved

4. Discussion

In this study, we compared diagnostic effects between CTA and DSCTA scans in the tSAH patients. The results showed that DSCTA scan had a similar diagnostic effect with CTA scan but a higher diagnostic accuracy, indicating that DSCTA scan can be used as a effective tool in screening out cerebrovascular disorders in tSAH patients.

Previous studies indicated that the hemorrhage in tSAH patient was mostly caused by the tearing of the bridging veins or the small vessels on the surface of cortex and was significantly correlated with subdural hematoma as well as cerebral contusion and laceration [12]. However, in a part of tSAH patients, the hemorrhage distributes at the cistern of skull base. The clinical presentation and morphological feature of this tSAH type are similar to that of aSAH patients, thus leading to the diagnostic challenges in the pathogenesis of hemorrhage [5]. Previous reports have demonstrated that the re-rupture rate of IA was as high as 15 %–20 % [13], and the mortality rate would be at 80 % [14]. Therefore, it is important to have an accurate diagnosis at the early stage to facilitate the identification of cerebrovascular disorder and consequently reduce the complication and mortality rate.

The indications of neuroimage tests play a pivotal role in clinical decision making. Although DSA examination is the gold standard for the identification of cerebrovascular disorders, it belongs to an invasive operation that usually induces additional and unessential damages to the tSAH patients without cerebrovascular disorder [15]. Therefore, CTA has been widely used as the first-line diagnostic modality in the screening of IA, especially at the emergency condition [5]. However, the traditional CTA has some shortages in the diagnosis of certain types of cerebrovascular disorder. Due to the influence of the bone structure of the cervical vertebra and skull, it is difficult to display the blood vessels near the bone structure, and the false-negative rate of vascular lesions in this area is relatively high. Furthermore, CTA has a relatively poor positive rate in identification of the malformations locating in microvascular branch and clumpy malformed vessels. In our study, we found that there were 2 inconsistent results between the CTA scan and DSA test among tSAH patients, including an arteriovenous malformation and an arteriovenous fistula. In comparison with IA identification, traditional CTA may have a relatively poor positive rate for these vessel malformations, especially when the size of the disorders is small.

In recent years, DSCTA technology has promoted the range of application due to the comparable sensitivity and specificity with DSA for the improved image quality, facilitating the judgment and the final clinical diagnosis [16]. As reported, the diagnostic rate for the IA which sized more than 3 mm by using DSCTA scan was almost the same as that using DSA test. Both sensitivity and specificity of DSCTA scan for diagnosis of the IA could reach 100 %. As for the IA sized less than 3 mm, sensitivity and specificity of DSCTA scan in diagnosis of IA could be as high as 80 % and 100 %, respectively [11]. Therefore, we infer that using DSCTA scan for screening out the potential IAs among tSAH patients was a considerable method and might be served as a priority in clinical practice.

In another aspect, we found the positive rate of IA in the tSAH patients of our study seemed higher than those in other studies. In clinical practice, a smeared borderline between the TBI-induced tSAH and the aSAH-induced TBI might potentially influence the IA rate among tSAH patients [17]. The rupture of IA induces disturbance of consciousness, and consequently leads to the incidence of TBI. On this occasion, disturbance of consciousness is sometimes difficult to be aware by the patient, even in the circumstance of witnesses. Therefore, we defined the inclusion criteria with the hemorrhage involving more than two cerebral cisterns. The relatively strict criteria could probably distinguish the potential IA-caused tSAH patients with those tSAH patients who were caused by the ruptures of small cerebral vessels or bridging veins. In a previous study, Cummings et al. [18] reported that the comorbidity rate of IA rupture with TBI made up 8 % in tSAH patients. However, in our study, the general positive rate in group of DSCTA scan was 21.4 % (9/42). Among that, the positive rate of IA was 16.7 % (7/42). We hypothesized that the relatively strict inclusion criteria increased the positive rate of cerebrovascular disorders.

Some limitations should be presented. First, the sample size is relatively small. Because a strict inclusion criteria was applied in this study which may increase the positive rate in identification of cerebrovascular disorders. However, a systemic analysis for the inclusion criteria should be performed to investigate the potential indicators of IA among tSAH patients. Secondly, in this retrospective and single-center study, some subjective factors which might influence the results can not be ignored. Because the technicians of CTA and DSCTA were not the same, and the diagnosis of certain types of cerebrovascular disorder might be ignored. Furthermore, each patient can not simultaneously receive both CTA and DSCTA tests owing to the financial prohibition, we can not compare the image quality for the same patients that may influence the diagnostic decisions. In consideration of such limitations, a large-cohort and multicenter study should be performed to lower the subjective bias and make the results convinced.

5. Conclusion

To conclude, we found DSCTA scan had a similar diagnostic effect with CTA scan in screening out cerebrovascular disorders in tSAH patients, but might have a higher diagnostic accuracy than CTA scan.

Data availability statement

The original data presented in the study are included in the article file, and other datasets generated and/or analyzed during the current study are available from the corresponding author on a reasonable request.

Funding statement

There was no external funding for this study.

Ethics approval

This study was approved by the Ethics Committee (No. PJ2023-14-35). Informed consents were obtained from participated patients or immediate relatives.

CRediT authorship contribution statement

Mingyue Bao: Writing – original draft, Data curation, Conceptualization. **Lei Ye:** Writing – review & editing. **Peng Gao:** Software, Resources. **Hongwei Cheng:** Project administration. **Xing Zhang:** Writing – review & editing, Validation, Conceptualization.

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.

Acknowledgement

None.

References

[1] J. C. Zacko, L. Haris, M. R. Bullock, Surgical management of traumatic brain injury. In: Richard Winn H, editor. Youmans Neurological Surgery. sixth ed. Ch. 335. Saunders; p. 3428.
[2] Y. He, L. Xu, B. Li, Z.n. Guo, Q. Hu, Z. Guo, J. Tang, Y. Chen, Y. Zhang, J. Tang, et al., Macrophage-inducible C-type lectin/spleen tyrosine kinase signaling pathway contributes to neuroinflammation after subarachnoid *Hemorrhage in rats. Stroke* 46 (2015) 2277–2286.
[3] F. Servadei, G.D. Murray, G.M. Teasdale, M. Dearden, F. Iannotti, F. Lapierre, A.J.R. Maas, A. Karimi, J. Ohman, L. Persson, et al., Traumatic subarachnoid hemorrhage: demographic and clinical study of 750 patients from the European brain injury consortium survey of head injuries, Neurosurgery 50 (2002) 261–269.
[4] R.M. deSouza, M. Shah, P. Koumellis, M. Foroughi, Subarachnoid haemorrhage secondary to traumatic intracranial aneurysm of the posterior cerebral circulation: case series and literature review, Acta Neurochir. 158 (2016) 1731–1740.
[5] A. Kayhan, O. Koc, S. Keskin, F. Keskin, The role of bone subtraction computed tomographic angiography in determining intracranial aneurysms in non-traumatic subarachnoid hemorrhage, Iran. J. Radiol. 11 (2014) e12670.
[6] J.S. Catapano, M.J. Lang, S.W. Koester, D.J. Wang, J.D. DiDomenico, V.L. Fredrickson, T.S. Cole, J. Lee, M.T. Lawton, A.F. Ducruet, et al., Digital subtraction cerebral angiography after negative computed tomography angiography findings in non-traumatic subarachnoid hemorrhage, J. Neurointerventional Surg. 12 (2020) 526–530.
[7] B. Long, A. Koyfman, M.S. Runyon, Subarachnoid hemorrhage: updates in diagnosis and management, Emerg. Med. Clin. 35 (2017) 803–824.
[8] M. Honda, S. Sase, K. Yokota, R. Ichibayashi, K. Yoshihara, Y. Sakata, H. Masuda, H. Uekusa, Y. Seiki, T. Kishi, Early cerebral circulatory disturbance in patients suffering subarachnoid hemorrhage prior to the delayed cerebral vasospasm stage: xenon computed tomography and perfusion computed tomography study, Neurol. Med.-Chir. 52 (2012) 488–494.
[9] J. Paul, R.W. Bauer, W. Maentele, T.J. Vogl, Image fusion in dual energy computed tomography for detection of various anatomic structures–effect on contrast enhancement, contrast-to-noise ratio, signal-to-noise ratio and image quality, Eur. J. Radiol. 80 (2011) 612–619.
[10] A.M. McKinney, C.S. Palmer, C.L. Truwit, A. Karagulle, M. Teksam, Detection of aneurysms by 64-section multidetector CT angiography in patients acutely suspected of having an intracranial aneurysm and comparison with digital subtraction and 3D rotational angiography, AJR Am. J. Roentgenol. 29 (2008) 594–602.
[11] L.J. Zhang, S.Y. Wu, J.B. Niu, Z.L. Zhang, H.Z. Wang, Y.E. Zhao, X. Chai, C.S. Zhou, G.M. Lu, Dual-energy CT angiography in the evaluation of intracranial aneurysms: image quality, radiation dose, and comparison with 3D rotational digital subtraction angiography, AJR Am. J. Roentgenol. 194 (2010) 23–30.
[12] D.A. Crooks, Pathogenesis and biomechanics of traumatic intracranial haemorrhages, Virchows Arch. A Pathol. Anat. Histopathol. 418 (1991) 479–483.
[13] H. Ohkuma, H. Tsurutani, S. Suzuki, Incidence and significance of early aneurysmal rebleeding before neurosurgical or neurological management, Stroke 32 (2001) 1176–1180.
[14] Q. Liu, P. Jiang, J. Wu, M. Li, B. Gao, Y. Zhang, B. Ning, Y. Cao, S. Wang, Intracranial aneurysm rupture score may correlate to the risk of rebleeding before treatment of ruptured intracranial aneurysms, Neurol. Sci. 40 (2019) 1683–1693.
[15] B. Ramgren, R. Siemund, O.G. Nilsson, P. Hoglund, E.M. Larsson, K. Abul-Kasim, I.M. Björkman-Burtscher, CT angiography in non-traumatic subarachnoid hemorrhage: the importance of arterial attenuation for the detection of intracranial aneurysms, Acta Radiol. 56 (2015) 1248–1255.
[16] G.Z. Chen, S. Luo, C.S. Zhou, L.J. Zhang, G.M. Lu, Digital subtraction CT angiography for the detection of posterior inferior cerebellar artery aneurysms: comparison with digital subtraction angiography, Eur. Radiol. 27 (2017) 3744–3751.
[17] A.A. Raslan, A.B. Abougamil, M. Okasha, M. Angelova-Chee, K. Ashkan, Diffuse traumatic subarachnoid hemorrhage mimicking aneurysmal bleeding secondary to ophthalmic artery avulsion: case report and review *of the literature. World neurosurg* 143 (2020) 513–517.
[18] T.J. Cummings, R.R. Johnson, F.G. Diaz, D.B. Michael, The relationship of blunt head trauma, subarachnoid hemorrhage, and rupture of pre-existing intracranial saccular aneurysms, Neurol. Res. 22 (2000) 165–170.