ISSN: 0975 -8542

Journal of Global Pharma Technology

Available Online at: www.jgpt.co.in

RESEARCH ARTICLE

Diagnosis and Management of Interventional Endovascular Carotid-cavernous Fistula: a Retrospective Study

Luh Putu Lina Kamelia[1]*, Ashari Bahar[2], Gede Wirata[3]

[1]Department of Neurology, Faculty of Medicine, Ganesha University, Buleleng General Hospital, Singaraja, Bali, Indonesia.

[2]Department of Neurology, Faculty of Medicine, Hasanuddin University, Dr. Wahidin Sudirohusodo Hospital, Makassar, Indonesia.

[3]Department of Anatomy, Faculty of Medicine, Universitas Udayana, Indonesia.

Abstract

Carotid-cavernous fistula (CCF) is a consequence of incremental intracavernous pressure. The direction of drainage is usually multidirectional. Initial DSA (digital subtraction angiography) solves in obtaining its information along with advanced technology nowadays. Aim: The study aims to analyze clinical characteristics, cerebral angiographic features, and management of endovascular embolization of CCF. Methods: The study is a retrospective analysis of each patient diagnosed with CCF. They were treated with endovascular embolization from January 2019 to April 2010 at the Brain Center Dr. Wahidin Sudirohusodo (DWS) General Hospital Makassar. We performed DSA on all patients before the endovascular procedure with catheterized access through the right femoral artery. Result: Angiograms of all patients showed typical CCF lesions, 8 patients then received endovascular management by coiling method, 2 were treated with a detachable balloon, while 1 received an Onyx injection. All patients experienced gradual improvement for orbital symptoms. Conclusion: Endovascular embolization-followed cerebral DSA is a useful diagnostic and therapeutic management to improve patients' clinical symptoms with CCF.

Keywords: *Carotid-cavernous fistula, Digital subtraction angiography, Embolization, Balloon, Onyx.*

Introduction

CCF is an abnormal communication between the cavernous sinus and the carotid artery system. This connection can be a direct connection between the cavernous sinus (CS) and the cavernous segment of the internal carotid artery (ICA), with the meningeal branches of ICA, external carotid artery (ECA), or even both [1-5]. Table 1 shows several classifications of CCF. Barrow *et al.* [6] proposed an anatomical classification of CCF into four types based on arterial supply. Type A is a direct connection between the ICA and the CS, usually with a high flow. Indirect fistulas are dural fistulas fed by the meningeal branches of ICA, ECA, or both. Type B fistula has dural branches of ICA that correspond to the CS and relatively rare. Type C fistula is entirely supplied by the ECA, while type D represents both ICA and ECA branches. Bilateral CCF cases only occur in about 12%-15% and are usually indirect [2, 3, 6].

Table 1: Several types of classification of CCF

Type	Classification
Hemodynamic	High vs. low flow
Etiological	Spontaneous vs. traumatic
Anatomical	Direct vs. indirect
Angioarchitecture (Barrow's type)	A,B,C,D
Tomsick's type	Unilateral (D1) vs bilateral (D)

Head trauma is the most common cause of CCF. As reported by various studies, 0.2% of craniocerebral trauma, 4% of cranial base fracture, and 0.2-0.3% of craniomaxillofacial [2, 5, 7]. Fistulas allow arterial blood to flow directly into the CS, causing venous hypertension. The clinical presentation of CCF is a consequence of incremental pressure of intracavernous pressure. The direction of drainage is usually multidirectional [3, 8]. CCF's clinical symptoms are related to size, location, fistula formation duration, adequacy, and route of venous drainage and arterial or venous collaterals. Classic manifestations for direct, high flow CCF are the Dandy's Triad, namely proptosis, bruits, and chemosis.

The common symptoms are proptosis (90%), chemosis (90%), diplopia (50%), visual disturbances (50%) [3, 9-11]. The gold standard for the definitive diagnosis of CCF is DSA. Initial DSA used to obtain information on the size and location of the fistula, direct or indirect lesions, the presence of steal phenomena, assessment of global circulation and collateral flow, identifying high-risk signs (e.g., cortical venous drainage, pseudoaneurysms, varix CS, arterial dissection), venous drainage patterns, determination of therapeutic routes, identification of dangerous collateral pathways [3, 12].

Recent endovascular technology provides different optional management according to CCF angioarchitecture, operator, or institutional preferences. A transarterial or transvenous approach can accomplish it. If the lesion is irreparable, sacrificing the involved ICA may be the only option [3, 5, 9, 12, 13].Regarding the background, the study optimally provides an overview of CCF's clinical characteristics, diagnosis, and interventional endovascular management.

Methods

The study implemented retrospective analysis of all CCF's participants. Secondary data had been collected at the Brain Center DWS General Hospital retrospectively from January 2019 till May 2020 (ethical clearance number 2080/UN14.2.2.VII.14/LT/2020). Data involved age, sex, clinical manifestations, radiological features, treatment, and clinical outcomes after procedure.

Some trained officers performed head non-contrast computed tomography scan (NCCT) and CT angiography (CTA) in all patients prior to DSA. Data also included their routine blood tests, LFT, RFT, coagulation test, chest X-ray, and electrocardiography (ECG). Some patients had received symptomatic medication. Pubic hair was shaved to keep the inguinal area aseptic. All patients received selective cerebral DSA under local anesthesia except one pediatric undergoing general anesthesia. The heparin dose in the procedure is 2500 IU (0.5 ml) dissolved in 500 ml of saline. We conducted a puncture with Seldinger needle 18G on the right femoral artery, then attaching a 6F size of the sheath, Conveyor 6F, Terumo wire 0.035.

Endovascular Therapy

Embolization was performed under general anesthesia via a transarterial approach. A 6F guide catheter was placed on the ICA on the side of CCF. Merely in patient number 8, a micro catheter was placed on the contralateral ICA because of no appropriate access through the common carotid artery on the fistula side due to ligation previously.

We used micro wire 0.014 inches 300 cm. After entering the CCF's distal end, it was removed. Angiography is executed to confirm the position of CCF. The platinum coils were laid on the fistula until it was closed completely. Several sizes of Axium 3D and Helix coils were chosen to suit the size of the fistula.

A multi-angle angiography was executed to confirm complete closure, reassess other blood vessels flow into the fistula, and new collaterals formation after embolization. One pediatric patient underwent Onyx injection, an *ethylene-vinyl alcohol copolymer* (EVOH) by ev3, Irvine, CA, USA. He received Onyx injection selectively and gradually to each feeder of CCF blood vessels, then angiography continued shortly afterward.

Two patients received detachable balloon embolization (Goldbal 2). Using the 0.035 260cm Terumo wire extension, the operator conducted the JR 3.5 5F guide catheter's replacement with Fargo Maxx 6F. On the catheter's direction, Goldbal 2 attached to the fistula, then relatively executing angiography to confirm the balloon's position.

An angiogram showed Goldbal 2 closing the fistula, and intracranial blood flow was well visible. The MBDTE catheter was initially removed, followed by immediate angiography to ensure sufficient intra- and extracranial blood flow.

Table 2: Distribution of demographic characteristics, clinical symptoms, type of CCF, and method of embolization

Characteristics	Amount (percentage)
Gender	
Male	10 (90.9%)
Female	1 (9.09%)
Age	
Children (<10 years)	1 (9.09%)
Young adults	9 (81.8%)
Elderly (> 50 years)	1 (9.09%)
History of head trauma	
Yes	10 (90.9%)
No	1 (9.09%)
Clinical symptoms	
Orbital symptoms	
- proptosis	11 (100%)
- chemosis	11 (100%)
- subconjunctival hemorrhage	11 (100%)
- orbital bruit	11 (100%)
- orbital pain	4 (36.3%)
Cavernous symptom	
- diplopia (ophthalmoplegia)	11 (100%)
Ocular symptoms	
- total blindness (vision 0)	6 (54.5%)
- decreased vision	5 (45.4%)
Cortical symptoms	
- headache	11 (100%)
- epistaxis	1 (10%)

Post-Treatment Monitoring

All patients could tolerate the entire procedure. After the sheath removal, we could felt the peripheral vessel's pulse naturally. The monitoring of hematoma on the puncture site is a must. First 6-8 hours after the procedure, patients should sleep on his back, right leg straight without much movement.

Figure 1: Angiogram of CCF Barrow type A from lateral and frontal views. S (A); dilated right superior ophthalmic vein (B), right IPS (C), right superior petrosal sinus (SPS) (D), and cortical veins (E)

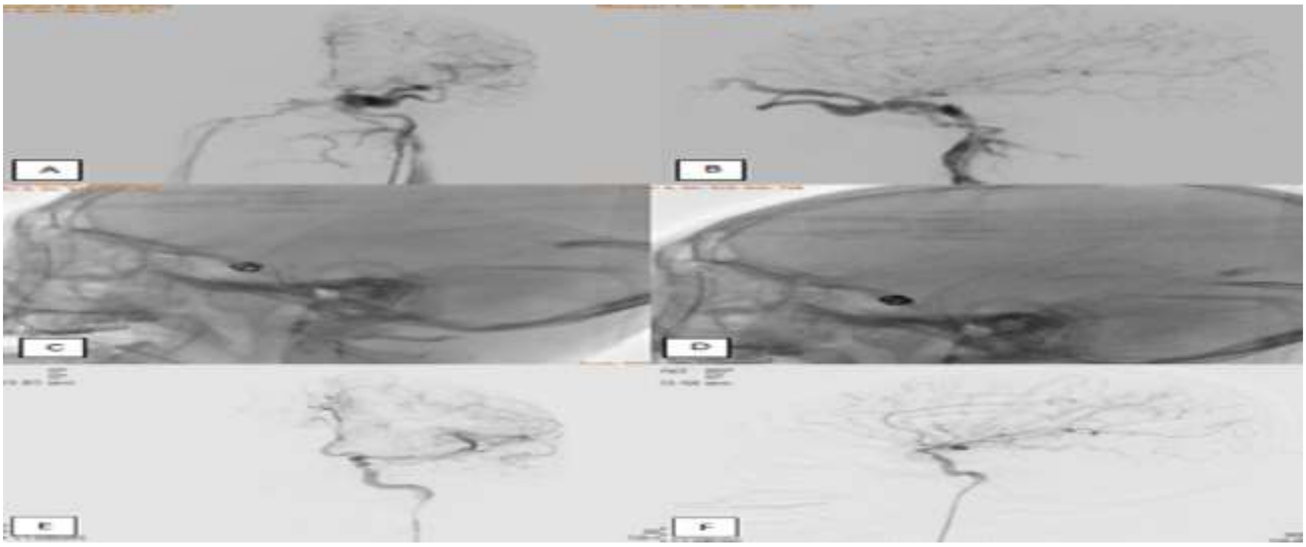

Figure 2: Coiling procedure of CCF type A patient. Labels A and B are the angiograms before coiling, delivering left CCF; Labels C and D denoted a coil attached to a fistula; the fistula was no longer visible in E and F labels

Results

The timing of diagnosis for traumatic CCF in this study varied from 1-6 months after head injury. The total number of patients in this study was 11, consisting of 10 men (90.9%) and one woman (9.09%), as described in Table 2. Most of the patients had a history of head trauma (90.9%). Orbital clinical symptoms were present in all patients, whereas orbital pain experienced by 36.3% of patients. One patient had posterior epistaxis (9.09%). As shown in Table 3, ten adult patients had traumatic, direct type (Barrow type A) CCF (also shown in Figure 1). One pediatric patient had spontaneous, indirect type (Barrow type C) CCF. Two patients (18.2 %) had cortical venous reflux. Most CCF was at the right side (54.5%); however, none had bilateral CCF. The embolization route picked by the operator was transarterial (100%). Coiling was the most embolization method applied by operators (63.6%). Imaging of the NCCT scan and CTA showed eyeball protrusion, venous dilation, especially the ophthalmic veins (Table 4).

Figure 3: Angiogram of the patient by the ballooning method. The red circle represents direct CCF after the detachable balloon on the fistula; the resolution appears immediately

Discussion

Naturally, the CS receives drainage from the superior-inferior ophthalmic vein, superior sphenoparietal sinus, Sylvian vein, and cortical veins. The CS flows posteriorly through IPS and SPS to the jugular bulb, inferiorly through the pterygoid plexus through the emissary's veins and contralateral CS [2, 8, 14, 15].In this study, most of the CCF sufferers were male with direct traumatic CCF (90.9%). It was consistent with the data presented by Halbach *et al.* [18] that traumatic CCF was dominant (57%) experienced by young adult males. Men tend to experience head injuries frequently caused by motorized accidents [16].

Based on population data from the Central Bureau of Statistics, referring to the latest census for the young population in South Sulawesi, the prevalence of CCF cases in this area was 0.26 per 100,000 adult populations [19].

Table 3: Distribution of CCF characteristics

Characteristics	Percentage
Type	
Traumatic, direct, Barrow type A	10 (90.9%)
Spontaneous, indirect, Barrow type C	1 (9.09%)
Cortical Venous Reflux	2 (18.2%)
Embolization method	
Coiling	7 (63.6%)
Detachable balloon	2 (18.2%)
Onyx injection	1 (9.09%)
Combination of coiling and Onyx	1 (9.09%)
Embolization route	
Trans arterial	11 (100%)
Trans venous	0 (0%)
Closure	
Complete	7 (63.3%)
Incomplete	4 (36.3%)
Side	
Right	5 (45.4%)
Left	6 (54.5%)
Embolization frequency	

once	9 (81.8%)
> 1	2 (18.2%)

The most common cause of CCF was injury (70%-90%), especially cranial base fracture, causing tears in ICA's cavernous segment. A cranial base fracture involving the sphenoid bone is a reminder to look for CCF possibility [1, 20]. One pediatric patient in the study had indirect and spontaneous CCF experienced from birth. It is a rare phenomenon in the pediatric population. However, some of CCF did develop spontaneously at birth [12, 16, 17].Clinical signs and symptoms obtained from patients in this study, namely (i) orbital symptoms such as proptosis, chemosis, conjunctival injection, increased intraocular pressure, ocular bruits, and orbital pain; (ii) ocular symptoms, for example, visual disturbances due to venous hypoxia hypertension causing corneal edema, macular edema or optic neuropathy; (iii) diplopia due to cranial nerve lesions or ischemia of extraocular muscles including cavernous symptoms. The patient's symptoms match the signs and symptoms of CCF with anterior vein drainage. CCF's clinical signs and symptoms usually occur acutely in direct fistulas but appear slowly in indirect CCF [10, 16].

Table 4: DSA imaging characteristics of CCF

Patient number	Fistulas side on ICA	Venous drainage
1	The left C5 segment, direct, type A	Left ophthalmic vein, left facial vein
2	The right C5 segment, direct, type A	Right ophthalmic vein, right facial vein
3	The left C4 segment to left CS, direct, type A	Left ophthalmic vein
4	The left C5 segment to left CS, direct, type A	Left ophthalmic vein
5	The right C5 segment to the right CS, direct, type A	Right ophthalmic vein, reflux flow to cortical veins
6	Fistula originating from the right middle meningeal artery (MMA) and artery of *foramen rotundum* to the right CS, indirect, type C	Left ophthalmic vein causes reflux to the cortical veins of left hemisphere.
7	The left C5 segment to the left CS, direct, type A	Left ophthalmic vein
8	The right C5 segment to the right CS, direct, type A	Left ophthalmic vein
9	The left C4-5 segment to the left CS, direct, type A	Left ophthalmic vein causes reflux to the cortical veins of the left hemisphere.
10	The right C4-5 segments to the right CS, direct, type A	Dilated right ophthalmic vein, and right inferior petrosal sinus (IPS).
11	The left C5 segment to the left CS, direct, type A	Dilatation and reflux of flow of the left superior ophthalmic vein and left facial vein

Table 5: Angiogram characteristics after embolization and clinical symptoms

Patient	Type of embolization	Post embolization angiogram	Clinical symptoms
1	*Coiling*	Closed fistula, no reflux flow to the left ophthalmic and facial veins	Reduced proptosis and chemosis in 3 months later
2	*Coiling*	Closed fistula, no reflux to the right ophthalmic vein	Ptosis disappears, chemosis shrinks 1 month later, Orbital pain is absent immediately
3	*Coiling*	Closed fistula, no reflux of flow to the left ophthalmic vein	Reduced proptosis and chemosis in 3 days after the procedure
4	*Detachable balloon* : Goldbal 2	Closed fistula, the intra- and extracranial blood flow appeared normal.	proptosis and chemosis disappeared 1 month after the procedure
5	*Coiling*	Closed fistula	-
6	*Onyx injection*	The fistula is not completely closed. The dilatation of the superior ophthalmic vein is reduced. There is collateral from the right posterior superior alveolar artery to the right superior ophthalmic vein	Reduced temporary headache post-procedure, and right orbital pain after the procedure
7	*Coiling*	Closed fistula	Chemosis reduced within a month
8	*Coiling f*ollowed by occlusion of the RCCA with Onyx until the flow through the narrow gap in the area is no longer visible.	No visible flow into the fistula from the distal segment of the right ICA	-
9	*Coiling* (4th embolization)	Fistula partially closed, reflux flow to the left ophthalmic vein and left facial vein began to decrease	Proptosis remain
10	*Coiling* (second embolization)	Closed fistula	Orbital pain disappeared immediately after the procedure
11	*Detachable balloon* :	The flow through the fistula is reduced. The	No epistaxis

	Goldbal 2	intracranial blood flow begins to improve	

If the fistula enters a stenotic vein or transverse sinus atresia, the blood flow will reflux from the transverse sinus to the cortical veins leading to venous hypertension. It has a potency to cause disaster (infarction or bleeding). Fistulas that drain to the transverse sinuses can lead to cerebral pseudotumor. If the petrosal sinus is atresia, the blood will reflux into the cortical veins or the orbital veins, even into both.

Cortical reflux causes intracranial hemorrhage, cerebral infarction, seizures, and even cervical myelopathy [3, 9]. All patients in this study experience ophthalmic venous reflux symptoms. Many differential diagnoses include superior orbital fissure syndrome, orbital apex syndrome, retrobulbar hematoma, cavernous sinus thrombosis [17].

Endovascular Management

The goal of endovascular management of CCF is to maintain maximum carotid artery flow with complete fistula closure. Difficulty accessing catheterization to the CCF site, relatively long treatment time, and the risk of perforation of the vessel wall during the procedure makes it challenging [21, 22].

The endovascular procedure in this study went well without any significant complications. There are several treatment options for CCF, including immediate surgery, by occlusion of the lesion ipsilateral carotid artery. However, sacrificing ICA carries a high risk of recurrence, a greater risk of vision loss (in patients who are not yet blind), and stroke risk [17].

The transarterial approach is based on ease of access and the underlying pathology (most cases are direct CCF). In comparison, the transvenous method is preferable to indirect CCF management. However, if the artery is narrow, winding (tortuous), transvenous is a more effective way [3, 9].

Reported complications founded 2%-5% of cases from endovascular procedures, included ischemic stroke, brain hemorrhage, decreased vision, diabetes insipidus, retroperitoneal hematoma, and femoral vein thrombosis [2]. The endovascular management of this study, both direct and indirect CCF, applied the transarterial approach.

Embolization with coil

Coiling was the most often method used in this study (72, 7%). It was intricate according to operator preference, material availability, and the architectural angle of the CCF. The detachable coil was a reliable and well-controlled deployment. The advantages of the coil, when compared to balloons, were the ease of access and availability of various sizes of embolization kits. Potential disadvantages included gradual and slower fistula occlusion and the risk of incomplete fistula occlusion.

Complications of transarterial coiling included the presence of thromboembolism, a prominent coil mass, and dissection of ICA. The coil was suitable for use as a cover for small fistulas measuring approximately 2-3 mm, multiple fistulae, and direct CCF [3]. Likewise, the participants had a single, small-sized CCF lesion, except in case number 9 required only one procedure using 3 coils.

Embolization with a Detachable Balloon

Detachable balloon still represents an important therapeutic method because of its effectiveness, safety, ease of procedure, and relatively low cost.

Disadvantages of detachable balloons are the recurrence rate, the emergence of thromboembolic complications, and incomplete orifice occlusion that cause a pseudoaneurysm formation-the further interval between trauma and intervention procedures, the lower the stability of the balloon.

The results were due to the enlarging size of the cavernous sinus. Balloons can decrease blood flow patterns in the cavernous sinuses. The failure rate for selective occlusion of the fistula with a balloon is about 10%.

Micro catheter navigation to reach the fistula can be a limiting factor in this option, mainly if it is located in the C4 segment because of the sharp entry angle in that segment [7, 13, 23].In this study, two cases successfully using detachable balloons.

Embolization with Onyx

Onyx is a non-adhesive liquid embolization agent suspended in dimethyl sulfoxide

(DMSO) to increase radiopacity. Arat *et al.* [24] used Onyx for the first time to embolize type D CCF transvenously without complications. Suzuki *et al.*[25] and also other reports of 6 cases of indirect CCF occluded by a combination of Onyx and coil.

There were no significant complications except headache, cranial nerves lesion that occurred temporarily after the procedure. In this study, operators used Onyx in pediatric patients, indirect CCF, and Barrow type D. Transarterial injection was performed selectively and gradually on the right MMA and the right artery of rotundum foramen. Although complete obliteration has not yet occurred, reflux flow to the right superior ophthalmic vein diminishes immediately after embolization.

No complications occurred after the procedure. In this case, coil placement was complicated by a complex angioarchitecture, the presence of septation (blockage), and the tiny size of the cavernous sinuses. The unique property of Onyx was its ability to gradually penetrated and travelled on the small artery branches, which in turned allows the fistula to close. The injection may be interrupted several times during the procedure to see the embolization pattern and identify dangerous anastomoses. Onyx did not stick to the vessel wall so that the degree of reflux of blood flow was tolerable during embolization without fear of catheter retention [9, 24, 26].

Although the effectiveness of Onyx is excellent, it should not be arbitrary without knowing its dangers. There are several complications in this procedure, such as cranial nerve neuropathy, cerebral sinus thrombosis, and cerebral edema. The angiotoxic effect of DMSO can be considered to explain this event [24, 27]. The CCF embolization procedure's success is characterized by the immediate resolution of symptoms (markedly proptosis, chemosis, bruits, ophthalmoplegia).

In some cases, it could achieve complete resolution within 4 months post-procedure (80%). It depends on the severity of the lesion and the duration of CCF. This study achieved the resolution of orbital symptoms in a few days to 4 months post-procedure [28]. The limitation of the study was hard to obtain follow-up data after discharged patients made it loss-to-follow-up.

Conclusion

Traumatic, direct CCF is the most common form of CCF and requires appropriate diagnostic and therapeutic management. Cerebral DSA is the gold standard diagnostic method for confirming a CCF and its characteristics. The role of endovascular embolization as the management of CCF therapy is useful because it provides a satisfactory clinical symptom improvement outcome with a low likelihood of complications.

Author Contributions

All authors state that they meet the current ICMJE criteria for authorship. Conceptualization, A.B.; Methodology, A.B., and L.P.L.K.; Writing-Original Draft, L.P.L.K., and G.W.; Writing-Review & Editing, G.W.; Supervision and Resources, A.B.; Formal Analysis, L.P.L.K.

References

1. Chaudhry IA, Elkhamry SM, Al-Rahed W, Bosley TM (2009) Carotid Cavernous Fistula: Ophthalmological Implications. Middle East African Journal of Ophthalmology. Middle East African Journal of Ophthalmology, 16: (2).
2. Ellish JA, Goldstein H, Connolly Jr S, MD, Meyers PM (2012) Carotid-cavernous Fistulas. In: Neurosurg Focus. New York: Departments of Neurological Surgery and Radiology, Columbia University Medical Center, New York.
3. Korkmazer B, Kocak B, Tureci E, Islak C, Kocer N, Kizilkilic O (2013) Endovascular Treatment Of Carotid Cavernous Sinus Fistula: A Systematic Review. World J. Radiol., 5: 143-55.
4. Du B, Zhang M, Wang Y, Li Q, Chen F (2016) A Retrospective Analysis of 38 Carotid Cavernous Fistula Patients Treated with Ballon-Assisted Endovascular Fistula, Embolization through Simultaneous Transarterian and Transvenous Approaches. Int. J. Clin Exp. Med., 9 (10): 19399-19407.

5. Ertl L, Bruckmann H, Patzig M, Fesl G (2019) Endovascular Therapy Of Direct Dural Carotid Cavernous Fistulas - A Therapy Assessment Study Including Long-Term Follow-Up Patient Interviews.
6. Barrow DL, Spector RH, Braun IF, Landman JA, Tindall SC, Tindall GT (1985) Classification and treatment of spontaneous carotid-cavernous sinus fistulas. J. Neurosurgery, 62: 248-56.
7. Xu XQ, Liu S, Su QQ, Zhao LB, Xia JG, Zhou CG, Zhou WZ, Shi HB (2013) Follow Up Of 58 Traumatic Carotid Cavernous Fistulas After Endovascular Detachable Balloon Embolization At A Single Center. J. Clin Neurol., 83-90.
8. Aralasmak A, Karaali K, Cevikol C, Senol U, Sindel T, Toprak H, Ozdemir H, Alkan A (2014) Venomous Drainage Patterns in Carotid Cavernous Fistulas. ISRN Radiology Hindawi Publishing Corporation.
9. Barry RC, Wilkinson M, Ahmed RM, Lim CS, Parker GD, McCluskey PJ, Halmagyi GM (2011) Interventional Treatment of Carotid Cavernous Fistula. Journal of Clinical Neuroscience, 18: 1072-1079.
10. Henderson AD, Miller NR (2018) Carotid-Cavernous Fistula: Current Concepts in Aetiology, Investigation, and Management. Eye, 32: 164-172.
11. Alam MS, Jain M, Mukherjee B, Sharma T, Halbe S, Jaisankar D, Raman R (2019) Visual Impairment in High Flow and Low Flow Carotid Cavernous Fistula. Sci. Rep., 9: 12872.
12. Benndorf G (2010) Dural Cavernous Sinus Fistulas Diagnosis and Endovascular Therapy. Germany: Springer.
13. Guiar GB, Jory M, Silva JM, Conti ML, Vega JC (2016) Advances in The Endovascular Treatment of Direct carotid-cavernous Fistulas. Rev. Assoc. Med. Bras., 62 (1): 78-84.
14. Zhang P, Xi H, Li W (2015) The Clinical Anatomy of Cavernous Sinus. Forensic Medicine and Anatomy Research, 3: 66-75.
15. Mitsuhashi Y, Hayasaki K, Kawakami T, Nagata T, Kaneshiro Y, Ohata K (2016) Dural Venous System in the Cavernous Sinus: A Literature Review and Embryological, Functional, and Endovascular Clinical Considerations. Neurol Med. Chir., 56: 326-339.
16. Miller NR (2012) Dural Carotid-Cavernous Fistulas: Epidemiology, Clinical Presentation, and Management. Neurosurg Clin N Am., 23: 179-192.
17. Fattahi T, T BM, S JW, B S (2003) Traumatic Carotid-Cavernous Fistula: Pathophysiology and Treatment. J. Craniofac Surg., 14: 2.
18. Halbach VV, Hiesimma GB, Higashida RT, Reicher, M (1987) Carotid Cavernous Fistulae: Indications for Urgent Treatment. AJNR, 8: 627-632.
19. Sensus Penduduk (2020) Jakarta (INA): Badan Pusat Statistik; 2020. [cited August 24th, 2020] Available at https://www.bps.go.id [Indonesian]
20. Le TH, Gean AD (2006) Imaging of Head Trauma. Seminars in Roentgenology, 04 (03): 177-189.
21. Young B, Ali AFM (2013) Endovascular Treatment of Traumatic Carotid Cavernous Fistula with Trapping Technique. Med. J. Indones., 22 (3): 178-182.
22. Castro-Afonso LH, Trivelato FP, Rezende MT, Ulho AC, Nakiri GS, Monsignore LM, Abud DG (2019) The Routes for Embolization of dural Carotid Cavernous Fistulas when The Endovascular Approach is Indicated as a First-Line Strategy. Interventional Neuroradiology, 0 (00): 1-5.
23. Li-Zhao C, Min-hui X, Dong-Hong Y, Yong-wen Z, Yun-dong Z (2010) Retrospective Study On The Endovascular Embolization For Traumatic Carotid Cavernous Fistula. Chinese Journal of Traumatology, 13 (1): 20-24.
24. Elhammady MS, Wolfe SQ, Farhat M, Moftakahar R, Aziz-Sultan MA (2010) Onyx Embolization of Carotid-Cavernous Fistulas. J. Neurosurg., 112: 589-594.
25. Suzuki S, Lee DW, Jahan R, Duckwiler GR, Viñuela F (2006) Transvenous Treatment of Spontaneous Dural Carotid-Cavernous Fistulas Using a Combination of Detachable Coils and Onyx. American Journal of Neuroradiology, 27(6): 1346.
26. Gandhi D, Ansari SA, Cornblath WT (2009) Successful Transarterial Embolization of a Barrow Type D Dural Carotid-Cavernous Fistula with Ethylene

Vinyl Alcohol Copolymer (Onyx). J. Neuro-Ophthalmol., 29 (1): 9-12.

27. Baccin CE, Campos CM, Abicalaf R, Kanashiro LH, Bolcato MR, Lima SS, Piske RL (2005) Traumatic Carotid-Cavernous Fistula: Endovascular Treatment with Onyx and Coils. Interventional Neuroradiology, 11: 363-367.

28. Wirata G, Karmaya INM, Muliarta IM (2019) Long-term visual deprivation inhibit the visual lobe neocortex cytoarchitecture increment in 42 days male rats (Rattus norvegicus): a stereological study. Indonesian Journal of Biomedical Science, 13(1):48-52. doi:10.15562/ijbs.v13i1.183