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Clinical classification and individualized design for the treatment of basicranial artery injuries

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Abstract

This study aims to explore the principles of clinical classification and individualized treatment of basicranial artery injuries based on its anatomical correlation.

The data of 172 patients with various types of basicranial artery injuries were retrospectively analyzed. Among these patients, 128 patients were male and 44 patients were female, and the average age of these patients was 28.3 years old. All patients underwent computed tomography, some patients underwent computed tomography angiography or magnetic resonance angiography, and all the diagnoses were confirmed by digital subtraction angiography (DSA). According to anatomical correlation, the injuries were classified into 5 types: vascular wall injury (type I), intradural injury (type II), epidural injury (type III), sinus injury (type IV), and skull base bone injury (type V). Individualized treatment was adopted based on the different types and characteristics of injuries.

The percentages of basicranial artery injuries were as follows: type I, 4.6%; type II, 5.8%; type III, 3.5%; type IV, 77.9%; and type V, 8.1%. All 172 patients underwent DSA to demonstrate the classification. The lesion elimination rate revealed by DSA was 99.4% immediately after the operation, 98.3% at 1 week after the operation, and 98.8% at 3 months after the operation. The follow-up after 6 months revealed that the percentage of patients in whom clinical symptoms or signs completely disappeared was 97.7%, the percentage of patients with limited eye movement or visual impairment was 1.2%, and the percentage of patients with mild limb dysfunction was 0.6%.

Basicranial artery injuries can be classified into 5 types. Individualized design of embolization therapy based on different characteristics might be applicable for basicranial artery injuries treatment.

Abbreviations: BOT = balloon occlusion test, CCF = carotid cavernous fistulae, CT = computed tomography, CTA = computed tomography angiography, DSA = digital subtraction angiography, MRA = magnetic resonance angiography.

Keywords: artery injuries, basicranial artery, embolization therapy

1. Introduction

In recent years, with the extensive application of vehicles in human's life, the incidence of basicranial artery injury has largely increased.[1,2] Since computed tomography (CT) had been widely used in clinical practice, the experience in diagnosing and treating basicranial artery injury has become abundant, which improve the results. However, somewhat clinical misdiagnosis or delayed diagnosis occurred during the first reception in hospitals. Probably because the symptoms of basicranial artery injuries caused by trauma are diverse, causing the insidious signs and not easy to find. For example, the most of the manifestations are ocular symptoms including pulsating exophthalmos, conjunctival, congestion, edema, and periorbital vascular murmur. Patients usually visited the ophthalmologic department first.[3–5] If surgeons in ophthalmology, rhinology, or plastic were inadequate experience, diagnosis and proper treatment would often be delayed. Even identified this situation, on the other hand, the strategy for the next surgical repair remains challenging due to the complexity of intracranial arteries and dissections. Facing different situations of basicranial artery injury, improper surgical approach or technique would cut down the benefit of patients. In order to better diagnose or make strategy for personalized treatment, a new classification of basicranial artery injury and its strategy were concluded from our experience (Table 1). One hundred seventy two patients with basicranial artery injuries were treated with individualized treatment by interventional embolization, and the experience and effect of the diagnosis and treatment were relatively ideal. The details are reported, as follows.

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2. Materials and methods

(1) Clinical data: From March 1999 to February 2018, 172 patients with various types of basicranial artery injury, who were admitted in our hospital, were enrolled into the present study. Among these patients, 128 patients were male and 44 patients were female, and the average age of these patients was 28.3 years old. All patients had a history of head and neck trauma or sport

Table 1

The classification of basicranial artery injuries and related treatment.

Classification	Injured regions	Treatments
Type I	Vascular wall injury	Using single or multiple stents
Type II	Intradural injury	Using a dense mesh stent or multiple stents
Type III	Epidural injury	Gel embolization or hematoma clearance
Type IV	Sinus injury	Using a balloon, coil, gel, or covered stent
Type V	Skull base bone injury	Gel or coil embolization

injury, and the time of injury was 1–8 weeks after the trauma. Among these patients, 18 patients had disturbance of consciousness, 3 patients had limb dysfunction, 79 patients had congestion of the bulbar conjunctiva with pulsating exophthalmos, 58 patients had intracranial vascular murmurs, 10 patients had epistaxis, and 4 patients had dizziness. All patients underwent CT, some of the patients underwent computed tomography angiography (CTA) or magnetic resonance angiography (MRA), and the diagnoses of all these patients were confirmed by digital subtraction angiography (DSA). Among patients with basicranial artery injuries, 150 patients (87.2%) had injuries at the internal carotid artery, 10 patients (5.8%) had injuries at the internal maxillary artery, 8 patients (4.6%) had injuries at the middle meningeal artery, and 4 patients (2.3%) had injuries at the cone artery. Consents for the examinations or treatment had been provided to the patients or their families. This study was conducted in accordance with the declaration of Helsinki and approved by the local Ethics Committee.

To sum up, patients with a history of head and neck trauma who were diagnosed as basicranial artery injury after CT, MRI, and DSA were involved in our research.

(2) Angiography: Under local anesthesia, the patient underwent puncture through the femoral artery approach. Then, a 6F sheath was placed, and angiography of the whole brain was performed using a 5F contrast tube. Under general conditions, angiography of the 6 vessels, bilateral internal carotid arteries, bilateral external carotid arteries and bilateral vertebral arteries should be performed to determine the defects or targets (dissection, pseudoaneurysm, or fistula) of the damaged vessels. After the targets were determined, some of the patients with carotid cavernous fistulae (CCF) were subjected to a cross-circulation compensatory test or postoperative Mata's test. Intravascular embolization was immediately undergone if possible.

(3) Clinical classification: According to the anatomical correlation between the basicranial arteries and dura mater of the skull base bone, the injuries were classified into 5 types: vascular wall injuries (type I), the injuries are mainly located in the walls of the internal carotid artery or vertebral artery, which are mainly intimal injury, and often manifest as dissecting aneurysm; intradural injuries (type II), the injuries are mainly located in the cranial cavity in the dura mater, and are damage to the whole wall, which often manifest as subarachnoid hemorrhage or pseudoaneurysm; epidural injuries (type III), the injuries are mainly located in the lacunae between the dura mater and cranium, and are damage to the whole wall, which often manifest as epidural hematoma or pseudoaneurysm; sinus injuries (type IV), the injuries are mainly located in the cavernous sinus of the carotid artery, which are mainly damage to the whole wall, and often manifests as CCF; skull base bone injuries (type V), the injuries are mainly located in the lacunae in or out of the skull base bone, and are damage to the whole wall, which are often characterized by intractable nosebleed or pseudoaneurysm.

(4) Therapeutic methods: After the targets of basicranial artery injuries were determined by angiography, patients were treated under a heparinization state (unfractionated heparin at 60 U/kg), a 6F or 8F sheath was selected and placed into the femoral artery, and the corresponding model of guiding tube was placed at the level of the second cervical pyramid. An 8F guiding tube was selected for patients who used a balloon, while a 6F guiding tube was selected for the remaining patients. Patients with type I injury could achieve the goal of treatment by using a single stent or multiple stents to cover the lesion; patients with type II injury were treated with coil embolization or stent-aided coil embolization; patients with type III injury were treated with gel embolism or evacuation of hematoma after gel embolism; patients with type IV injury were treated with balloon, coil, gel, or covered stent; and patients with type V injury were treated with gel or coil embolization. Under the situation that traditional balloon therapy could not completely terminate the shunt, some of the patients underwent a balloon occlusion test at the affected side of the carotid artery. If the patient had good compensation and tolerance, occlusion of the internal carotid artery could be performed. Since the fistula in some patients was too small (trachoma-like fistula), the best treatment was to cover the lesion using a covered stent.

(5) Postoperative measures: Patients with type I injury were treated with single or multiple covered stents, and received anticoagulant therapy; patients with type II injury were treated with coil embolization or stent-aided coil embolization, and the latter required anticoagulant therapy; patients with type III injury were treated with gel embolism or hematoma clearance after gel embolism, and did not require anticoagulant therapy; patients with type IV injury were treated with intravascular intervention with balloon, coil, gel, or covered stent, and the latter required anticoagulant therapy; and patients with type V injury were treated with gel or coil embolization, and did not require anticoagulant therapy. Generally, patients underwent anticoagulant treatment for 3 to 6 months.

(6) Follow-up: CT or X-ray follow-up was performed 1 week after the treatment, and a follow-up was performed by telephone call or outpatient review after 3 months. Patient with symptoms must be reexamined by DSA. Furthermore, after 6 months, patients with symptoms must be reexamined by DSA. Moreover, intravascular interventional therapy was performed again, when necessary.

(7) Data collection and statistical analysis

The following data were collected for each patient; age, gender, symptoms at presentation, CT or DSA result, follow-up results. Only descriptive statistics are reported and proportions are presented with their percentages.

3. Results

(1) Classification of basicranial artery injuries: Among these 172 patients, 8 patients (4.6%) had vascular wall injury (type I), 10 patients (5.8%) had intradural injury (type II), six patients (3.5%) had epidural injury (type III), 134 patients (77.9%) had sinus injury (type IV), and 14 patients (8.1%) had skull base bone injury (type V).

(2) Diagnostic results: CT results of these 172 patients revealed that 6 patients (3.5%) had subarachnoid hemorrhage, 12 patients (7%) had epidural hematoma, 13 patients (7.6%) had bleeding of

the dished sinus or ethmoidal sinus, 139 patients (80.8%) had high-density shadow of the parasellar tissues, and 2 patients (1.2%) had no abnormality. Furthermore, among these 172 patients, 32 patients were examined by CTA, and the results revealed that 26 patients (81.3%) had CCF, while 29 patients were examined by MRA, and the results revealed that 25 patients (86.2%) had CCF. Among the 172 patients who underwent DSA, all 172 patients had positive results (Figs. 1–4). Among these patients, 8 patients (4.6%) had carotid artery or cone artery dissection (type I), 10 patients (5.8%) had carotid artery or cone artery pseudoaneurysm (type II), 6 patients (3.5%) had middle meningeal artery pseudoaneurysm (type III) (CT revealed that most patients had epidural hematoma), 134 patients (77.9%) had CCF (type IV), and 14 patients (8.1%) had internal maxillary artery or carotid artery pseudoaneurysms (type V).

(3) Therapeutic imaging results (Figs. 1–4): The DSA imaging results revealed that the lesion elimination rate was 99.4% after the operation, (1 patient had a small residual tumor of the neck), 98.3% at 1 week after the operation (169/172; 3 patients [1.7%] who received balloon embolization recurred), and 98.8% at 3 months after the operation (2 patients [1.2%] who received simple coil embolization recurred).

(4) Follow-up at 6 months after the operation: The results revealed the complete disappearance of main complaint symptoms or signs in 97.7% patients (168/172), limited eye movement or visual impairment in 2 patients (1.2%), and mild limb dysfunction in 1 patient (0.6%, limited movement of only 1 side of the upper limb).

(5) Adverse events: Among all patients, no complications were found, such as thrombosis, air embolism, or bleeding, no aggravation of the nervous system was observed, and no death occurred. Three patients who received balloon embolization recurred after 1 week, and completely recovered after undergoing the treatment again, while 2 patients with simple coil embolization recurred after 3 months, and completely recovered after undergoing the treatment again.

4. Discussion

Basicranial artery injury is a special type of injury in craniocerebral trauma, and few dissertations on this injury have been conducted.[6] From the clinical perspective, this kind of injury is deeply occulted, when condition were seriously injured the prognosis might not be optimistic.[6] Although CCF and pseudoaneurysm can be completely cured through certain treatments in clinic,[7] there still are a few patients who experienced delayed diagnosis and treatment, and rare patients with intractable nosebleed, which were life-threatening conditions.[8–10] Therefore, further clinical studies and experience on these kind of injury are particularly important. Some studies have concluded that in the anatomical correlation, basicranial arteries are closely correlated to the skull base bone and dura mater. Once the skull base bone is damaged or fractured, it would be inevitable for the peripheral nerves and blood vessels in the skull base bone to be damaged. To some extent, peripheral nerve injury is not fatal. Furthermore, vascular injury can affect the blood supply of the brain, and excessive bleeding can endanger the life of the patient. Therefore, according to the anatomical adjacent correlation to the skull base bone and dura mater, skull base vascular injury can be divided into 5 types: vascular wall injury (type I), intradural injury (type II), epidural injury (type III), sinus injury (type IV), and skull base bone injury (type V). These 5 types of classification of injury have a certain guiding value for clinical diagnosis and treatment and can be identified by DSA which is convenient and quick.

Ordinary CT scans can only detect subarachnoid hemorrhage, intracranial hematoma, and some skull base fractures. However, it cannot determine the target of the vascular damage. Furthermore, it can only diagnose type II and III and partial type IV cases qualitatively, and it cannot perform a localization diagnosis or accurate diagnosis. CTA or MRA can reveal the 3-dimensional structure of blood vessels, but these modalities are inaccurate for determining the peak time or postprocessing technology. Hence, an accurate diagnosis could not be drawn. Therefore, basicranial artery injuries should be early diagnosed and treated. In this process, DSA is applicable, because it can help draw a localization diagnosis, accurately determine the target of the basicranial artery injury (Figs. 1–4), and guide the classification. The results of the present study revealed that all patients were positive in the DSA examination. Among these patients, 8 patients (4.6%) had carotid artery or cone artery dissection (type I, Fig. 1A), 10 patients (5.8%) had internal carotid artery or cone artery pseudoaneurysm (type II, Fig. 2A), 6 patients (3.5%) had middle meningeal artery pseudoaneurysm (type III), 134 patients (77.9%) had CCF (type IV, Fig. 3A), and 14 patients (8.1%) had internal maxillary artery or internal carotid artery pseudoaneurysms (type V, Fig. 4A). In addition, DSA can reveal the specific site, shape, size, and hemodynamic parameters of various types of basicranial artery injuries, which has important reference value for different treatment plans.

The present study revealed that patients with type I injury can achieve the goal of treatment by using single or multiple stents to cover the injury site (Fig. 1B). For the selection of the stent for placement and the support or proper size, Solitaire AB (ev3), Enterprise (Godman), Neuroform (Boston Scientific/Target Therapeutics, Freemont, CA), Leo (BALT EXTRUSION), LVIS (MicroVention), and other stents can to be selected. Furthermore, type II injury can also be covered with a dense metal stent or multiple stents (Fig. 2B) to avoid recurrence induced by simple coil embolization or stent-aided coil embolization.[11,12] In the present study, 1 patient recurred at 1 week after the coil embolization, and recovered after the complementation of covered stent embolization. Patients with type III injury were treated with gel embolization or hematoma evacuation was performed after gel embolization, and such patients are associated with hemorrhage or pseudoaneurysms of the middle meningeal artery. Patients with type IV injury were treated with intravascular intervention using a balloon, coil, gel, or covered stent (Fig. 3B).[13–15] The traditional balloon technique had a good effect. However, few patients are often prone to relapse after a week due to changes in their position, turning over, coughing, out-of-bed activity, and so on.[16] Although a gel and coil cannot relatively and easily induce recurrence, these would inevitably induce chemical stimulation and mass effects. Therefore, application of a covered stent has been recently widely reported. However, it has not been widely applied, because it is sometimes difficult to position it in place.[17–19] Gel or coil embolization is the most effective treatment for patients with type V (Fig. 4B). However, such patients can easily be misdiagnosed, resulting in repeated intractable nosebleed, shock, and even death. These kinds of patients should be subjected to multidisciplinary diagnosis and treatment. According to the clinical classification of basicranial artery injuries, CCF (type IV) accounts for 77.9%, in which the affected side of the internal carotid artery should be treated with balloon occlusion test when traditional balloon therapy cannot completely terminate the

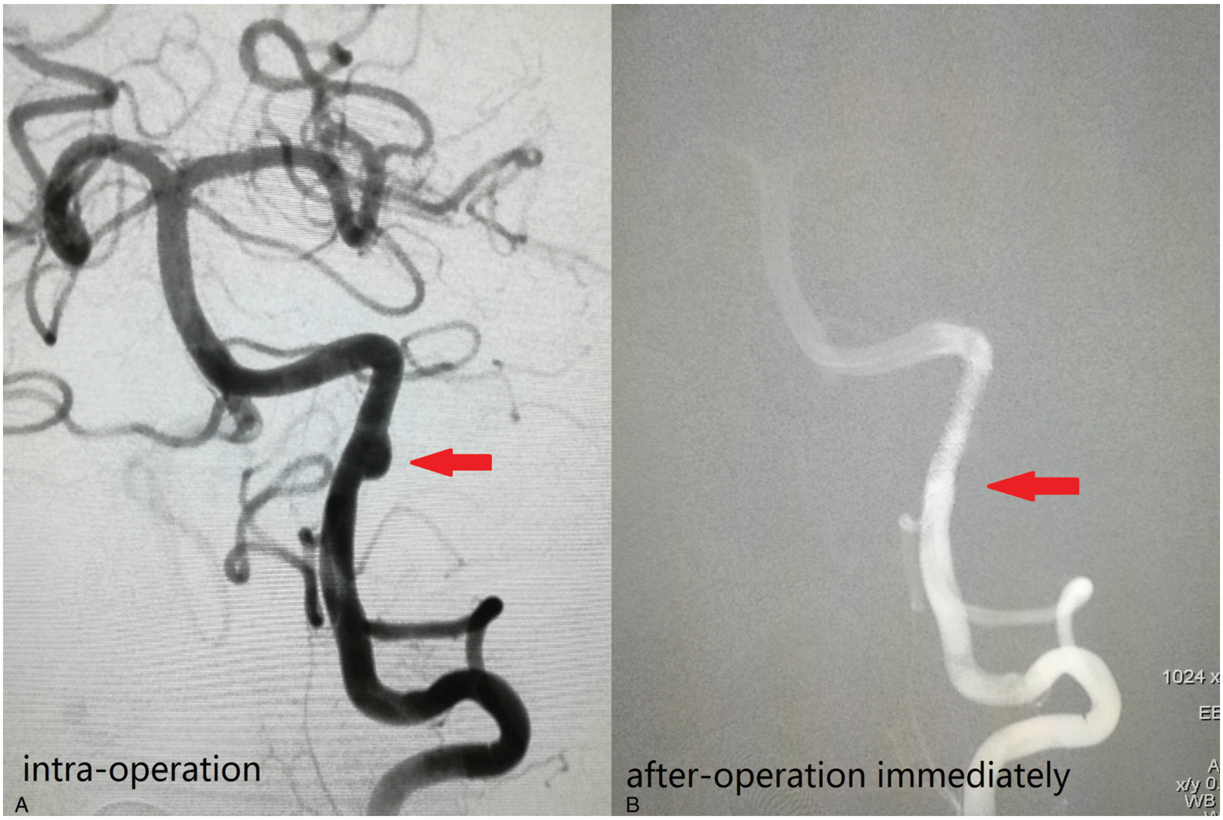

Figure 1. Vascular wall injury (type I). (A) Vertebral artery dissection. (B) The lesion disappeared after double covered stents were placed.

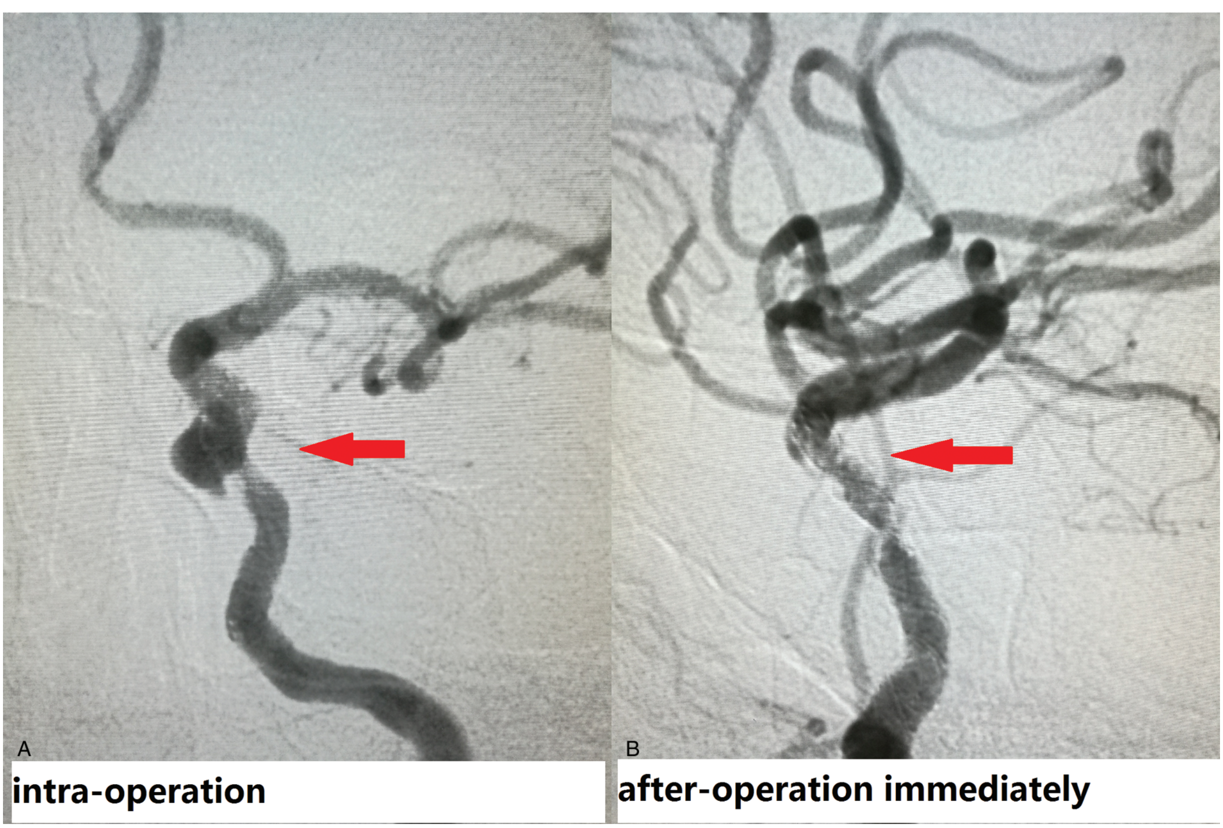

Figure 2. Intradural injury (type II). (A) Carotid artery pseudoaneurysm. (B) The lesion disappeared after being covered double stents.

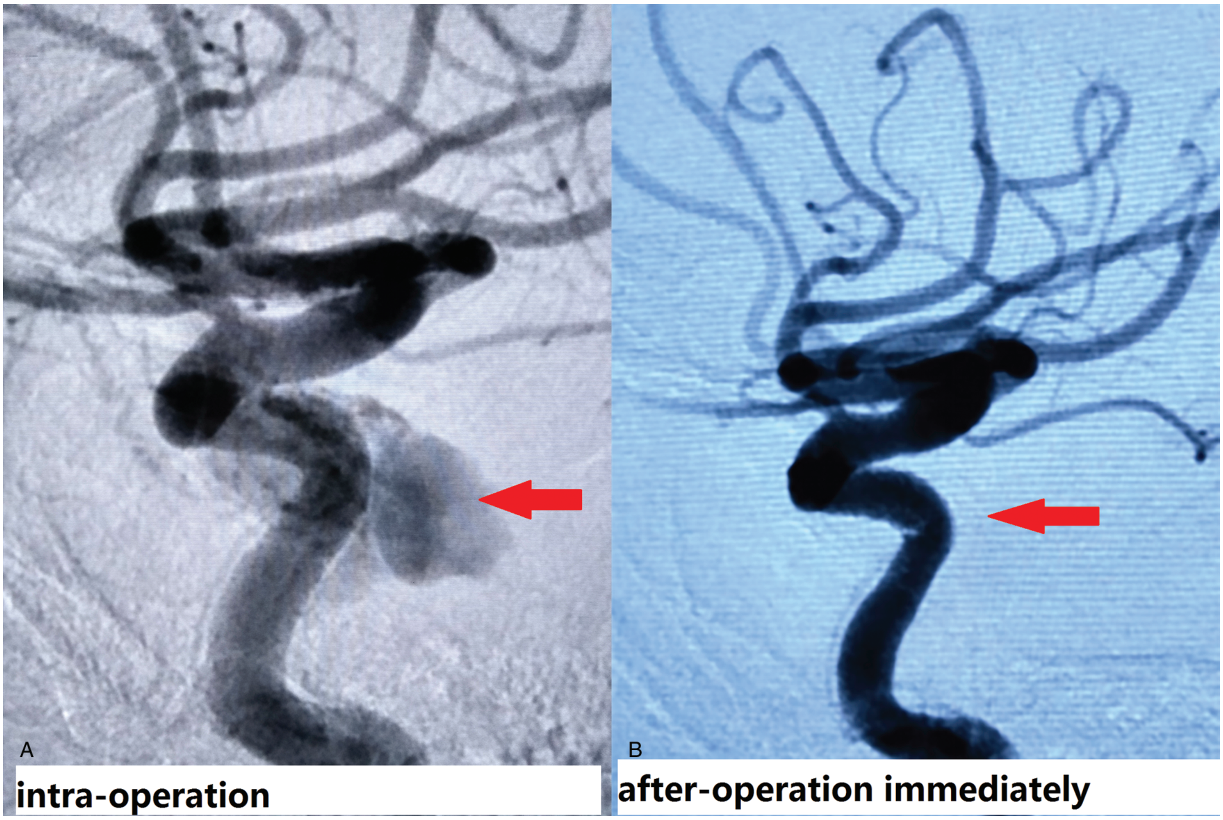

Figure 3. Sinus injury (type IV). (A) Carotid cavernous fistulae (CCF). (B) The trachoma-like fistula disappeared after being covered a stent.

shunt. If the patient has good compensation and tolerance, occlusion of the internal carotid artery can be performed. In the present study, this type of injury accounted for only 1.5%, which is lower than that reported in the literature. This mainly benefits from the improvement of embolization materials and technology level, which retains the patency rate of the internal carotid artery up to 98.5%. For patients with very small fistulas (trachoma-like fistula), a covered stent can be applied as one of the treatments

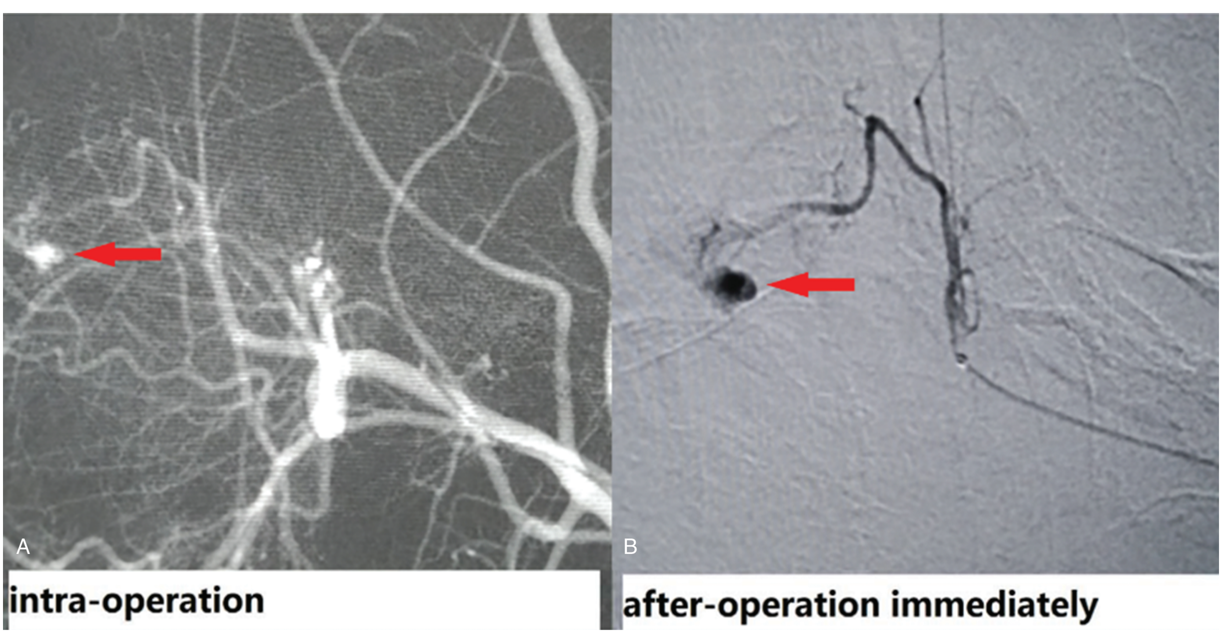

Figure 4. Skull base bone injury (type V). (A) Injury of the branches of the internal maxillary artery. (B) Insertion of a microcatheter into the vessels of the offending lesion (pseudoaneurysm).

(Fig. 3B). Compared with bare metal stent, covered stents have more advantage in the directly blocking the shunt without the mass effect caused by embolization therapy, since in-stent restenosis induced by endometrium hyperplasia is mild. However, if the target blood vessels are greatly tortuous, the application of a covered stent is limited due to its inability of compliance and trafficability.[20] Although certain studies have reported that patients with type IV injury were treated using the intravenous approach, filling the cavernous sinus not only requires a large number of coils, but may also lead to the exacerbation of ocular paralysis. Hence, the transcatheter arterial approach is still recommended due to various advantages. Indeed, when the stent cannot reach the required site through the transcatheter arterial approach, the intravenous approach would be an alternative choice.[21]

In summary, according to the clinical classification of basicranial artery injuries, the flexible application of various embolization techniques and individualized design options can provide a safe and effective treatment for patients with basicranial artery injury. This study is a retrospective study of a series of cases. According to different injury mechanism, the diverse type of skull base artery injury is objective. From these 172 patients we first concluded the types and each incidence rate. But this report is just a retrospective analysis. Based on facts, our data showed different types of incidences and incidences of associated symptoms. Whether this new classification is practical or applicable still need be demonstrated in more clinical data.

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