Objective: Petrous internal carotid aneurysm (PA) concomitant with a mass lesion and cranial nerve palsy is relatively rare. Flow-diverter stent implantation is now widely used as an alternative treatment for PA. However, alternative treatments sometimes cannot be used because of tortuosity of the carotid artery, allergies to contrast material, and high costs. The outcomes of different treatment methods should therefore be assessed. Here, we review the available literature on treatments for PA.

Methods: In a search using the terms “aneurysm”, “carotid artery”, and “petrous” on PubMed, MEDLINE, and databases such as OvidSP, 221 articles were identified. We also performed a literature review and discuss and compare the causes, symptoms, treatment methods, and clinical outcomes of PA.

Results and Conclusions: Onset of secondary aneurysm was generally heralded by bleeding (p<0.001), while onset of primary aneurysm was heralded by cranial nerve deficit (p= 0.0014). Outcomes after treatment of 34 cranial nerve palsies in 25 patients are reported. (J Nippon Med Sch 2020; 87: 172–183)

Key words: cerebral aneurysm, hypoglossal nerve, internal carotid artery, systematic review, petrous

Introduction
Extracranial, non-traumatic, non-dissecting saccular internal carotid artery (IC) aneurysms are usually located in the lower cervical region; aneurysms in the petrous portion of the IC are rare. Extracranial IC dissection can cause hypoglossal nerve palsy, and concomitant incidence with IC dissection was reported in 5% of cases. However, no case of hypoglossal nerve palsy due to saccular aneurysm in the petrous IC has been reported. In the largest series, which included 100 cases of hypoglossal nerve palsy, nearly 50% of cases of hypoglossal nerve palsy were caused by tumors. Other causes include trauma, stroke, multiple sclerosis, surgery, Guillain-Barré neuropathy, and infection. Hypoglossal nerve palsy resulting from extracranial aneurysm is rare.

Petrous IC aneurysm (PA) is relatively rare, has a wide variety of causes, including infection, trauma, and pseudoaneurysm, and has been studied since 2004. In recent years, multiple treatments for PA, such as use of a flow diverter, have been reported; however, revascularization surgery remains an important strategy. PA is often difficult to treat intravascularly, particularly in patients with infectious diseases, rupture, and pseudoaneurysm. Furthermore, not all treatment strategies are available for all patients, as some patients are allergic to contrast agents or metals and some have renal dysfunction. Another reason for the unavailability of a treatment may be its high cost. Therefore, the outcomes of available treatment methods need to be compared.

Studies of the symptoms of unruptured PAs commonly report cranial nerve symptoms. Several studies have investigated the effects of treatment for cranial nerve symptoms of internal carotid artery-posterior communicating artery (ICPC) aneurysms and cavernous carotid aneurysms; however, few studies have examined the effects of treatment for cranial nerve symptoms of PAs. Unlike ICPC and cavernous carotid aneurysms, PAs are partially surrounded by bone structure; therefore, the effect of decompression on the cranial nerve may be a characteristic of this lesion site. Further-
more, because symptoms differ in relation to the cause of PA,

 even for aneurysms at the same location, we evalu-

 ated differences in symptoms between primary petrous
carotid aneurysms and traumatic, infectious, and iatro-
genic petrous aneurysms. For this purpose, we per-

formed a systemic review of available studies on PAs. We
also reviewed reports on PAs with different causes.

Systematic Review
To determine future treatment strategies for cranial nerve
palsy due to PAs, we conducted a literature review of
previously reported cases. We searched for all reported case studies and clinical research studies of
PAs that were published in English. PubMed, MEDLINE,
and other databases, such as OvidSP, were searched by
using keywords such as “petrous,” “aneurysm,” and “ca-
rotid artery.” The initial search was completed at the end
of July 2018 and yielded 221 articles; data for 107 pa-
tients (109 sides [2 cases of bilateral aneurysm]) from 79
studies were reviewed. The exclusion criteria were
(1) articles in a language other than English (n = 23); (2) review articles or clinical studies not related to
petrous carotid aneurysm (n = 115); and (3) clinical stud-
ies with no data on the effects of the case study (n = 13).

The included studies are summarized in Table 1. Nine
reports were added by requotation. Using these data, we
compared primary and secondary petrous carotid aneu-
rysms in relation to age, sex, side, and frequency of
bleeding (Table 2). The incidences of complications and
additional interventions in patients who underwent each
type of treatment were also analyzed. Those who under-
went additional treatment were regarded as having un-
dergone 2 treatments. Because of the low radiological di-
agnostic and prognostic accuracy, all cases reported be-
fore 1970 were excluded. Two authors (Y.M. and K.S.) as-

eressed and graded (modified Rankin scale score, 0-2 or

not) postoperative complications reported in each study.

Treatment methods were classified into 5 categories: (1)
surgical or interventional carotid artery occlusion or trap-
ping, without aneurysm embolization, (2) stenting, with
or without coiling, (3) revascularization surgery, (4) aneu-
rys embolization with a coil or balloon, and (5) conserva-
tive or no treatment. All variables were evaluated by
using JMP version 11.0.0 (SAS Institute Inc., Cary, NC,
USA). A P value of less than 0.05 (Pearson analysis) was
considered to indicate statistical significance.

All procedures performed involving human partici-
pants were in accordance with the ethical standards of
the institutional and/or national research committee and

with the 1964 Helsinki Declaration and its later amend-
ments, or with comparable ethical standards.

Results of Systematic Review
The results of the analysis are shown in Table
1. The characteristics of patients with pri-
mary and secondary (infectious, traumatic, radiation in-
duced, or iatrogenic) petrous carotid aneurysm are
shown in Table 2. The treatments selected are shown in
Table 3. The average age of the reported patients was
41.4 years (range, 5-81 years). Among the 94 patients for
which sex was reported, 54 were male and 40 were fe-
male (Table 2). Among the 95 patients for which the side
of the aneurysm was reported, the aneurysm was located
on the right side in 44 cases and on the left side in 51.

Thirty-nine patients developed 1 or more cranial nerve
deficits (Table 1, 4, 5). Only a few studies reported the
interval from symptom onset to treatment, so this vari-
able was excluded from the present study. The most
common sites of cranial nerve deficit were the eighth (n
= 15), sixth (n = 13), seventh (n = 10), and fifth cranial
nerves (n = 8) (Table 4). Thirty-five cranial nerve symp-
toms from 25 patients with a recorded post-treatment
course were examined (Table 4, 5). Cranial nerve symp-
toms did not change in 9 cranial nerves, improved in 19
cranial nerves, and resolved in 7 cranial nerves.

There were 39 cases of bleeding from life-threatening
otorrhagia or epistaxis (Table 1, 2). The cause was de-
scribed in 45 of the 109 cases: 16 involved infectious dis-
eases, including chronic otitis media, and 13 involved
cervical trauma. Radiation therapy was performed for a
cranio-cervical tumor in 10 patients, and the cause was
characterized as iatrogenic in 6 patients.

Statistical analysis revealed that onset of secondary
aneurysm was heralded by bleeding (p < 0.001) and that
onset of primary aneurysm was heralded by cranial nerve
injury (p = 0.0014) (Table 2). Factors associated with
outcomes of treatment for injured cranial nerves were ex-
amined. The number of cases was insufficient to assess
statistically the effect of individual treatments on each
cranial nerve (Table 5). We also compared the incidences
of complications and additional interventions, by treat-
mament type, and studied 78 treatments performed for 75
cases and 10 patients undergoing conservative treatment
(Table 6). Of the reported patients, 93.2% (82/88) were
free of complications. There was no significant difference
in the incidence of any complication. Four cases of rebleeding after treatment were reported, and additional
treatment was required in 3 of these 4 cases.
| Author & Year | Age | Sex | Side | Size (mm) | CN symptoms | Other symptoms | Treatment | CN post treatment | Post treatment ischemia | Cause |
|--------------|-----|-----|------|-----------|-------------|---------------|-----------|------------------|----------------------|-------|
| Barrett et al., 1960 | 26 | M | L | NA | none | otalgia | CCA ligation | NA | none | infection |
| Guirguis et al., 1961 | 19 | M | L | giant | 6,7,8,9 | headache | ligation | NA | Dead | |
| Hirandani et al., 1962 | 40 | M | R | 40 | none | otalgia | none | NA | none | |
| Wemple et al., 1966 | 18 | M | L | large | 6,8 | Horner | IC ligation | diplopia | improved | none |
| Allen et al., 1967 | 43 | F | R | NA | 8 | none | conservative | NA | NA | iatrogenic |
| Busby et al., 1968 | 29 | M | R | NA | 6,7,8 | epistaxis | ECA ligation | NA | none | trauma |
| Steffen et al., 1968 | 47 | F | L | NA | none | tinnitus | NA | NA | none | |
| Conley et al., 1969 | 7 | F | L | NA | NA | direct removal | NA | none | none | |
| Stallings et al., 1969 | 9 | F | R | 3 | NA | purulent otorrhea | NA | NA | NA | |
| Anderson-1 et al., 1972 | 19 | F | L | 20 | none | otorrhagia | trap (ligation and clip) | NA | none | |
| Anderson-2 et al., 1972 | 59 | F | R | 30 | none | tinnitus, otorrhagia | trap (clip and clip) | NA | none | |
| Teal-1 et al., 1973 | 36 | M | L | NA | none | none | conservative | NA | NA | trauma |
| Teal-2 et al., 1973 | 36 | M | L | NA | none | headache | conservative | NA | NA | trauma |
| Morantz et al., 1976 | 34 | F | R | NA | none | hyperacusis, tinnitus | IC ligation | NA | none | |
| Holtzman et al., 1979 | 35 | M | L | 5 | none | otorrhagia | IC ligation | end to end anastomosis | NA | infection |
| Glassock et al., 1983 | 9 | M | L | 18 | NA | otalgia | NA | none | iatrogenic |
| Lynch et al., 1983 | 28 | F | L | 50 | 8 | ear pain | ligation | no change | none | |
| Kelly-1 et al., 1985 | 61 | F | R | NA | 7 | none | conservative | NA | NA | |
| Kelly-2 et al., 1985 | 63 | M | L | NA | 6 | none | NA | NA | |
| DelBalso et al., 1986 | 50 | F | L | large | none | transient ischemic attack | NA | NA | none | |
| McGrail et al., 1986 | 44 | M | L | 25 | 5,6 | none | IC trap with balloon & STA-MCA | improve (months) | none | infection |
| Willinsky et al., 1987 | 35 | F | L | 5 | none | epistaxes, ear pain | AN balloon emboli | NA | none | |
| Gibson et al., 1989 | 56 | M | L | 60 | 5 | temporal pain | conservative | mild facial palsy | NA | |
| Frank et al., 1989 | 18 | F | R | large | 8 | bruit | conservative | NA | none | neurofibromatosis |
| Halbach-1 et al., 1990 | 19 | M | L | NA | 5,7 | bruit | IC ligation | 5 resolved, 7 persistent resolved | amauropenia fugax | none |
| Halbach-2 et al., 1990 | 7 | M | L | NA | 8 | headache, amaurosis fugax | ICO with balloon | amauropenia fugax | none | |
| Halbach-3 et al., 1990 | 14 | F | R | NA | 8 | headache, tinnitus, vertigo | IC trap with balloon | resolved | none | |
| Halbach-4 et al., 1990 | 31 | F | L | NA | 8 | none | IC trap with balloon | resolved | none | |
| Halbach-5 et al., 1990 | 62 | F | L | NA | 5 | none | AN balloon emboli | resolved | none | |
| Halbach-6 et al., 1990 | 60 | F | L | NA | none | headache | ICO with balloon | NA | none | |
| Halbach-7 et al., 1990 | 19 | M | R | NA | 3 | none | ICO with balloon | resolved | none | |
| Costantino et al., 1991 | 37 | F | R | NA | none | epistaxis, otorrhagia | ICO with balloon & coil | NA | none | |
| Tokimura et al., 1992 | 64 | F | R | large | none | none | end to end anastomosis | NA | none | |
| Umez et al., 1993 | 21 | M | L | 20 | 7,8 | otalgia | PAO with balloon → trap & STA-MCA | NA | none | |
Table 1  Patient characteristics of reported petrous carotid aneurysm

| Author & Year               | Age | Sex | Side | Size (mm) | CN symptoms       | Other symptoms      | Treatment                          | CN post treatment | Post treatment ischemia | Cause     |
|-----------------------------|-----|-----|------|-----------|-------------------|---------------------|------------------------------------|-------------------|--------------------------|-----------|
| Papazian-1 et al., 1993     | 18  | F   | NA   | NA        | none              | none                | NA                                 | none              | NA                       | infection |
| Papazian-2 et al., 1993     | 49  | M   | NA   | NA        | none              | headache            | NA                                 | none              | NA                       |           |
| Papazian-3 et al., 1993     | 52  | F   | NA   | 3.5       | none              | headache            | NA                                 | none              | NA                       |           |
| Cross et al., 1995          | 31  | M   | L    | giant     | none              | epistaxis           | IC trap with balloon            | NA                | none                     | infection |
| Patrick-1 et al., 1996      | 70  | M   | L    | giant     | none              | none                | conservative treatment          | NA                | none                     |           |
| Patrick-2 et al., 1996      | 43  | F   | L    | giant     | 7                 | none                | ICO with balloon with EC-IC bypass | 7 persist         | none                     |           |
| Love et al., 1996           | 50  | M   | L    | NA        | 7.8               | tinnitus            | ICO with balloon                | 7 persist, 8 lessened | none                     |           |
| Goodman et al., 1996        | 22  | M   | R    | large     | 8                 | Horner              | ICO with balloon                | 8 improved        | none                     |           |
| Coley et al., 1998          | 15  | M   | L    | giant     | 8                 | headache, Horner    | ICO with balloon                | NA                | none                     |           |
| Zander et al., 1998         | 45  | M   | R    | 5         | none              | headache, Horner    | conservative treatment          | improve           | none                     |           |
| Lempert et al., 1998        | 36  | M   | L    | 8         | 5                 | NA                  | coiling                          | NA                | none                     | trauma    |
| Tanaka et al., 1998         | 37  | F   | R    | 30        | 12                | headache            | ICO with balloon & coil          | NA                | none                     | infection |
| Date et al., 1999           | 46  | F   | L    | 40        | 3,4,5,6           | none                | ICO with balloon                | improve           | none                     |           |
| Reece et al., 1999          | 21  | M   | L    | large     | 8                 | otalgia, tinnitus   | ICO with balloon persist        | NA                | none                     |           |
| Forshaw et al., 2000        | 20  | M   | L    | 30        | none              | otorthagia          | ICO with balloon resection & SV graft | NA                | none                     |           |
| Couldwell et al., 2001      | 47  | M   | L    | giant     | 6                 | headache            | ICO with balloon                | NA                | none                     |           |
| Scavée et al., 2001         | 53  | M   | R    | 13        | NA                | dizziness, neck pain | covered stent                   | NA                | none                     | trauma    |
| Cheng-1 et al., 2001        | 54  | M   | R    | NA        | none              | epistaxis           | ICO with coil                    | NA                | none                     | radiation |
| Cheng-2 et al., 2001        | 35  | M   | R    | small     | none              | otalgia             | ICO with coil                    | NA                | none                     | radiation |
| Vasama et al., 2001         | 5   | NA  | R    | NA        | none              | epistaxis           | ICO with balloon                | NA                | none                     | trauma    |
| Alexander et al., 2002      | 42  | F   | R    | 6         | none              | otalgia             | covered stent                   | NA                | none                     | iatrogenic|
| Depauw et al., 2003         | 29  | M   | L    | giant     | none              | cerebral ischemia   | ICO with balloon                | no ischemia       | none                     |           |
| Auyeung-1 et al., 2003      | 52  | F   | R    | small     | NA                | none                | epistaxis                        | covered stent     | none                     | radiation |
| Auyeung-2 et al., 2003      | 52  | M   | L    | large     | none              | epistaxis           | covered stent                   | NA                | none                     | radiation |
| Saatci-1 et al., 2004       | 48  | F   | R    | 31        | none              | headache            | covered stent                   | NC                | NC                       | trauma    |
| Saatci-2 et al., 2004       | 25  | M   | L    | 7         | none              | none                | covered stent                   | NC                | NC                       | trauma    |
| Saatci-3 et al., 2004       | 18  | M   | L    | 14        | none              | none                | covered stent                   | NC                | NC                       | trauma    |
| Saatci-4 et al., 2004       | 22  | M   | R    | 9         | none              | none                | covered stent                   | NC                | NC                       | trauma    |
| Saatci-5 et al., 2004       | 36  | F   | L    | 28        | none              | headache            | covered stent                   | NA                | NC                       | trauma    |
| Horowitz et al., 2005       | 24  | F   | R    | 4         | none              | epistaxis           | stent coil                       | NA                | none                     | pseu-doAN |
| Cohen et al., 2007          | 54  | F   | R    | large     | 8                 | tinnitus, headache  | covered stent                   | NA                | CNVI palsy                | fibromasculardysplasia |
| Singh et al., 2008          | 30  | M   | L    | 46        | none              | epistaxis, headaches | ligation                        | persist           | none                     |           |
| Schmerber et al., 2008      | 67  | M   | R    | NC        | none              | otalgia, epistaxis   | ICO with balloon                | NA                | none                     | iatrogenic|
Table 1  Patient characteristics of reported petrous carotid aneurysm

| Author & Year          | Age | Sex | Side | Size (mm) | CN symp-toms | Other symptoms | Treatment | CN post treatment | Post treatment ischemia | Cause                           |
|------------------------|-----|-----|------|-----------|--------------|----------------|-----------|------------------|--------------------------|--------------------------------|
| Ferroli et al., 2009   | 66  | F   | R    | giant     | 6            | headache       | RA graft & IC ligation | persist           | none                      | none                           |
| Saylam et al., 2009    | 28  | F   | L    | small     | none         | none           | PAO with Balloon coil & ligation trap & SV graft | NA               | none                      | iatrogenic infection          |
| Oyama et al., 2010     | 60  | M   | R    | small     | none         | otalgia        | NA                    | NA               | none                      | NA                            |
| Palacios et al., 2010  | 27  | M   | R    | NC        | 5,0          | tinnitus       | NA                    | NA               | NA                        | NA                            |
| Sun et al., 2010       | 6   | M   | L    | 30        | none         | headache, Horner | conservative        | NA               | NA                        | NA                            |
| Rose et al., 2010      | 33  | M   | R    | NA        | 6            | none           | conservative        | NA               | NA                        | NA                            |
| Endo et al., 2011      | 62  | F   | L    | small     | NA           | epistaxis, head-aches, SAH Horner | IC trapping with coil & STA-MCA coil | NA               | none                      | iatrogenic infection          |
| Mangat et al., 2011    | 15  | M   | R    | large     | 6            | none           | PED                  | improve (5M)      | NA                        | NA                            |
| Lerat-1 et al., 2011   | 64  | F   | L    | 19        | 7            | none           | PED                  | improved          | none                      | pseudo-AN                    |
| Lerat-2 et al., 2011   | 64  | F   | (bilateral) | 15        | none         | none           | PED                  | NA               | none                      | NA                            |
| Kim et al., 2012       | 54  | F   | R    | 14        | none         | pulsatile tinnitus. | AN coil             | tinnitus improve | none                      | none                           |
| Rathore et al., 2012   | 30  | NA  | R    | NA        | 3            | NA             | IC ligation          | NA               | none                      | radiation infection          |
| Bien et al., 2013      | 63  | M   | R    | large     | none         | bloody otorrhea. | ICO with coil       | NA               | NA                        | NA                            |
| Chen et al., 2013      | 23  | F   | L    | 24        | none         | none           | PAO with coil        | NA               | none                      | NA                            |
| Hamamoto et al., 2013  | 77  | F   | R    | large     | 7            | none           | coil                 | NA               | none                      | NA                            |
| Kadkhodayan et al., 2013| 50  | F   | L    | small     | none         | otalgia        | PED (rebleed additional coil) | NA               | NA                        | NA                            |
| Shon et al., 2013      | 79  | M   | L    | 10        | none         | otalgia, cerebral embolism | conservative       | NA               | NA                        | NA                            |
| Kalani et al., 2014    | 51  | M   | L    | NA        | NA           | NA             | ICO with clip & STA-MCA bypass | NA               | none                      | NA                            |
| Moon et al., 2014      | 64  | M   | L    | 16        | 2,5,6        | none           | PED with coil       | improve           | none                      | infection                     |
| Mascitelli et al., 2014| 64  | M   | L    | 17        | none         | otalgia        | PED with coil → (rebleed) covered stent | NA               | none                      | NA                            |
| Tsang-1 et al., 2015   | 40s | NA  | R    | 1.2       | NA           | epistaxis      | PED                  | NA               | none                      | radiation infection          |
| Tsang-2 et al., 2015   | 50s | NA  | R    | 2.2       | NA           | epistaxis      | PED                  | NA               | Multiple CI                | NA                            |
| Tsang-3 et al., 2015   | 60s | NA  | R    | 1.8       | NA           | epistaxis      | PED with coil       | NA               | none                      | radiation infection          |
| Tsang-4 et al., 2015   | 60s | NA  | L    | 14        | NA           | epistaxis      | PED with coil       | NA               | none                      | radiation infection          |
| Tsang-5 et al., 2015   | 60s | NA  | R    | 3.3       | NA           | epistaxis      | PED                  | NA               | delayed ICO (10M)          | NA                            |
| Baker et al., 2015     | 81  | M   | L    | 31        | none         | otalgia, trismus. CI | ICO with clip & bypass stent coil | NA               | NA                        | NA                            |
| Lee et al., 2015       | 18  | M   | L    | 15        | none         | headache, nausea, tinnitus | stent coil          | NA               | none                      | neurofibromatosis             |
| Mukher et al., 2016    | 64  | M   | R    | NA        | none         | occipital infarction | SV bypass end to end | NA               | temporal facial palsy      | none                          |
| Han et al., 2016       | 21  | M   | R    | 15        | 7            | meningitis     | covered stent       | NA               | infection                  | none                          |
Petrous Carotid Aneurysm

| Author & Year | Age | Sex | Side | Size (mm) | CN symptoms | Other symptoms | Treatment | CN post treatment | Post treatment ischemia | Cause |
|---------------|-----|-----|------|-----------|-------------|---------------|-----------|-------------------|------------------------|-------|
| Akhtar et al., 2017 | 13  | M   | R    | NA        | none        | otorrhagia    | IC ligation & STA-MCA bypass | NA                  | none                  | trauma    |
| Gross-1 et al., 2017 | NA  | NA  | NA   | 17        | none        | tinnitus      | Neuroform | tinnitus cone     | none                   |       |
| Gross-2 et al., 2017 | NA  | NA  | NA   | 10        | none        | none          | Enterprise coil | NA                  | none                   |       |
| Gross-3 et al., 2017 | NA  | NA  | NA   | 17        | 5,6         | none          | PED with coil | NA                  | improve                | none |
| Gross-4 et al., 2017 | NA  | NA  | NA   | 12        | none        | none          | PED with coil | NA                  | NA                     | none |
| Gross-5 et al., 2017 | NA  | NA  | NA   | 6         | 6           | none          | PED with coil | NA                  | NA                     | none |
| Gross-6 et al., 2017 | NA  | NA  | NA   | 10        | none        | none          | Balloon coil  | NA                  | NA                     | none |
| Németh-1 rt et al., 2017 | 68  | F   | R    | NA        | none        | otalgia right | flow diverter | NA                  | NA                     | infection |
| Németh-2 lt et al., 2017 | 68  | F   | L    | NA        | none        | otalgia left  | flow diverter | NA                  | NA                     | infection |
| Hassania-1 et al., 2018 | 75  | M   | L    | large     | NA          | otalgia, dysphonia, Horner | ICO with coil | NA                  | none                   | infection |
| Hassania-2 et al., 2018 | 60  | M   | R    | NA        | 9,10,12     | dysphonia, dysphagia | coil trap | NA                  | none                   | infection |
| Yu LB et al., 2018 | 58  | M   | R    | giant     | none        | otorrhagia    | coil → bypass & coil removal | NA                  | NA                     | none |
| Murai Y et al., 2018 | 64  | F   | L    | 28        | 11,12       | none          | IC ligation & RA graft | improve             | none                   |       |

AN, aneurysm; CCA, common carotid artery; CI, cerebral ischemia; CN, cranial nerve; EC, external carotid artery; F, female; IC, internal carotid artery; ICO, internal carotid artery occlusion; M, male; MCA, middle cerebral artery; NA, not applicable or no data; PAO, parent artery occlusion; RA, radial artery; SAH, subarachnoid hemorrhage; STA, superficial temporal artery; SV, saphenous vein

| Table 2 | Clinical characteristics of reported petrous carotid aneurysm |
|---------|-------------------------------------------------------------|
| All     | Primary | Secondary | P Value |
|----------|----------|-----------|---------|
| 107 cases 109 side | 64       | 45        | 0.231   |
| male:female 54:40 | 30:26    | 24:14     | 0.128   |
| Side (rt:lt) 44:51 | 21:32    | 23:19     | 0.291   |
| Age 41.37± 19.77 | 39.41± 19.74 | 44.02 ± 19.73 | 0.0001 |
| Hemorrhagic onset 11/56 (19.6%) | 28/44 (63.6%) | 0.089 |
| mean size (mm) of aneurysm 21.7±15.0 | 13.8±10.4 | 0.0014 |
| Size (mm) range of aneurysm 3-60 | 1.2-31 | 64 | 45 | Infection | 16 |
| Cranial Nerve symptom 32/60 (53.3%) | 7/35 (20%) | 10 | Radiation | 13 |
| Etiology     | 64       | 45        | Iatrogen | 6 |

Variables showing significant difference by Pearson’s analysis (p<0.05) are indicated by boldface.

Data are expressed as mean±SD

Discussion

Treatment Strategies and Results of Literature Review

It was difficult, even in this systematic review, to examine the effects of different treatments for cranial nerves. Treatment outcomes for the cranial nerve were reported in only 25 cases, and only a few studies examined treatment with a flow-diverter stent. The number of studies of flow diverters is
likely to increase, and this may aid in determining the
treatment effects of flow diverters and parent artery occlusion and entrapment.

In this review, 36 patients were treated with interventional or surgical parent-vessel occlusion only, without bypass (Table 3). Surgical revascularization was used in only 14 patients. Among these, only 6 cranial nerve injuries in 5 patients were reported. Of these, 4 cranial nerve injuries improved and 2 cranial nerve injuries were unchanged. Some patients with hemorrhagic PA required re-treatment. Mascitelli et al described a patient requiring an additional covered stenting because of rebleeding after aneurysm coiling, and Umezu et al reported a patient with rebleeding after treatment with balloon parent artery occlusion who needed additional trapping and STA-MCA anastomosis. Recently, Kadkhodayan et al reported a patient who required additional interventional coil trapping of the IC artery because of rebleeding 12 days after placement of a pipeline embolization device.

In addition, Yu et al reported a case in which the coil protruded into the external auditory canal after coiling; surgical extraction of the coil was required. These complications are characteristic of this type of lesion, as the coil is transported outside the body. These characteristics are not seen in the treatment of intracranial cerebral aneurysm. Therefore, treatment selection must consider

### Table 3 Treatment selection of reported patients

| Treatment                                | Total |
|------------------------------------------|-------|
| Conservative or NA                       | 19    |
| ICO without bypass                       | 36    |
| Interventional PAO                       | 16    |
| Surgical ligation                        | 10    |
| Interventional trapping                  | 8     |
| Surgical trapping                        | 2     |
| AN embolization (coil or balloon)        | 8     |
| Stent/flow diverter                      | 29    |
| Revascularization surgery                | 14    |
| STA-MCA bypass                           | 5     |
| Anastomosis                              | 2     |
| Radial artery graft                      | 3     |
| Saphenous vein graft                     | 3     |
| EC-IC bypass                             | 1     |
| Other                                    | 2     |

AN, aneurysm; EC, external carotid artery; IC, internal carotid artery; ICO, internal carotid artery occlusion; MCA, middle cerebral artery; NA, not applicable or no data; PAO, parent artery occlusion; STA, superficial temporal artery

### Table 4 Case number of cranial nerve disturbance and outcome

| Cranial Nerve | Unknown | Unchanged | Improved | Resolved | Total |
|---------------|---------|-----------|----------|----------|-------|
| II            | 0       | 0         | 1        | 0        | 1     |
| III           | 1       | 0         | 1        | 1        | 3     |
| IV            | 0       | 0         | 1        | 0        | 1     |
| V             | 1       | 1         | 4        | 2        | 8     |
| VI            | 4       | 1         | 7        | 1        | 13    |
| VII           | 6       | 3         | 1        | 0        | 10    |
| VIII          | 6       | 3         | 3        | 3        | 15    |
| IX            | 2       | 0         | 0        | 0        | 2     |
| X             | 1       | 0         | 0        | 0        | 1     |
| XI            | 0       | 1         | 0        | 0        | 1     |
| XII           | 1       | 0         | 1        | 0        | 2     |
Table 5 Rates of recovery after the treatment of cranial nerve injuries according to the factors studied

| Predictor                          | Rate of recovery |
|------------------------------------|------------------|
| All (n)                            | 26/34 (76.5%)    |
| **Age**                            |                  |
| <20                                | 5/8 (62.5%)      |
| 21<                               | 2/3 (66.7%)      |
| 41>                               | 15/19 (78.9%)    |
| **Sex**                            |                  |
| male                               | 11/15 (73.3%)    |
| female                             | 6/9 (66.7%)      |
| **Size (mm)**                      |                  |
| 12>                               | 1/1 (100%)       |
| 12<                               | 9/12 (75%)       |
| 25<                               | 9/13 (69.2%)     |
| **Treatment**                      |                  |
| IC ligation or interventional occlusion | 12/17 (70.5%) |
| Flow-diverter or stent w/wo coil   | 7/7 (100%)       |
| revascularization surgery          | 4/6 (66.7%)      |
| aneurysm embolization              | 2/2 (100%)       |
| conservative or no treatment       | 1/2 (50%)        |

Rate of injured cranial nerve recovery = number of recovered cranial nerves/total number of injured cranial nerves × 100%

Table 6 Treatment results and complications

| Selected Treatment                                      | ratio of mRS 0-2 | Details of complications                                      |
|----------------------------------------------------------|------------------|--------------------------------------------------------------|
| parent artery occlusion or trapping                      | 28/29 (96.6%)    | ischemia                                                      |
| (surgical and interventional)                            |                  | rebleeding (additional trapping and bypass)                  |
| flow diverter or stent w/wo coil                         | 23/26 (88.5%)    | ischemia                                                      |
| revascularization surgery                                | 14/14 (100%)     | ischemia                                                      |
| aneurysm embolization                                    | 8/9 (88.9%)      | ischemia                                                      |
| (coil or balloon)                                        |                  | rebleeding (additional IC coil occlusion)                     |
| conservative or no treatment                             | 9/10 (90%)       | extraction of protruded coil                                  |
| Total                                                    | 82/88 (93.2%)    | rebleeding (additional covered stent)                        |

features not found in intracranial cerebral aneurysm, especially in patients with sudden onset of epistaxis or otorrhagia.

Future studies are likely to report treatment outcomes for flow diverters. However, flow diverters cannot be used for all patients, including those with tortuous carotid arteries, allergies to contrast agent, and difficulties in angiographic access. In addition, flow diverters are not available in all countries because of their high cost. When considering treatment strategies from a global perspective, revascularization procedures and parent-vessel occlusion are important for treating patients with hemorrhagic PAs requiring emergency surgery who cannot undergo a balloon occlusion test.

Cranial Nerve Symptoms

The mechanism underlying cranial nerve palsy is aneurysm expansion, which causes mechanical compression of adjacent structures, in particular the hypoglossal and glossopharyngeal nerves, and subsequently results in nerve palsy\(^8\). The hypoglossal nerve emerges from the
anterior condylar canal in the skull base and passes downward between the IC and jugular vein. The glossopharyngeal nerve leaves the skull through the jugular foramen and again passes downward between the IC and internal jugular vein.

With regard to endovascular options, we considered a covered stent with coil embolization or a flow-diverter stent for patients with unruptured aneurysms. Endovascular stents are effective, but coil embolization may also be needed\textsuperscript{13,14,47}. Additionally, as this portion was circumscribed by the cranial bone, coil embolization may have worsened aneurysm compression and nerve palsy\textsuperscript{21,22}. A flow-diverter stent is a good option and was reported\textsuperscript{13,14,47} to be effective for extracranial IC aneurysm. However, placement of the stent in this portion is technically difficult and is associated with high risk because the petrous segment is located near the curved portion of the IC. Additionally, as the aneurysm is circumscribed by the petrous bone, recovery of cranial nerve palsy is uncertain. Moon et al\textsuperscript{19} reported that pipeline embolization improved cranial neuropathy of the second, third, fifth, and sixth nerves, but there are no reports of extracranial aneurysm with lower cranial nerve palsy.

In open surgery for lower cervical extracranial saccular aneurysm, aneurysmectomy with direct end-to-end anastomosis or an interposition graft is recommended\textsuperscript{60,65}. However, the aneurysm was located from the petrous portion to the higher cervical portion; thus, a direct surgical approach would have been difficult because of the anatomical characteristics\textsuperscript{60,65}. Proximal ligation of the IC is an effective treatment for unruptured cervical IC aneurysm, although direct clipping may be difficult\textsuperscript{65}. We safely performed treatment with proximal ligation and a radial artery graft for unruptured intracranial IC aneurysm in the cavernous portion\textsuperscript{23}. Proximal ligation and EC-IC bypass changes blood flow, and flow alteration promotes aneurysm thrombosis. Thus, EC-IC bypass and proximal ligation might be more effective than endovascular treatment for PA. Recovery of lower cranial nerve palsy due to aneurysmal compression is not well understood. However, in patients with oculomotor nerve palsy and posterior communicating artery aneurysm, clipping tends to result in faster, more complete recovery than coiling, and duration of recovery ranges from 0 to 250 days postoperatively\textsuperscript{21}.

**Limitations**

A limitation of our literature review is the lack of statistical power to examine the effects of particular treatments. Although all patients had petrous IC artery aneurysm, the causes and incidence rates of hemorrhage were different. Furthermore, progress and changes in endovascular treatment devices during the past decade affected the results. Therefore, we were unable to develop a general treatment strategy.

**Conclusions**

Treatment of extracranial saccular aneurysm with cranial nerve palsy remains controversial, and the proper treatment must be chosen for each aneurysm. EC-IC bypass and proximal ligation is an effective alternative to endovascular surgery for treatment of petrous carotid aneurysm with cranial nerve palsy. Further studies of patients with aneurysm and cranial nerve palsy are needed.

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**References**

1. Rosset E, Albertini JN, Magnan PE, et al. Surgical treatment of extracranial internal carotid artery aneurysms. J Vasc Surg. 2000;31(4):713–23.
2. Okunomiy T, Kageyama T, Suemaga T. Teaching NeuroImages: Isolated hypoglossal nerve palsy due to internal carotid artery dissection. Neurology. 2012;79(4):e37.
3. Riancho J, Infante J, Mateo JJ, et al. Unilateral isolated hypoglossal nerve palsy associated with internal carotid artery dissection. J Neurol Neurosurg Psychiatry. 2013;84(6):706.
4. Wessels T, Sparing R, Neuschafer-Rube C, Klötzsche C. Vocal cord palsy resulting from spontaneous carotid dissection. Laryngoscope. 2003;113(3):537–40.
5. Keane JR. Twelfth-nerve palsy. Analysis of 100 cases. Arch Neurol. 1996;53(6):561–6.
6. Hassannia F, Carr SD, Yu E, Rutka JA. Internal carotid artery aneurysm in skull base osteomyelitis: does the pattern of cranial nerve involvement matter? J Laryngol Otol. 2018;132(10):929–31.
7. Tanaka H, Patel U, Shrier DA, Coniglio JU. Pseudoaneurysm of the petrous internal carotid artery after skull base infection and prevertebral abscess drainage. AJNR Am J Neuroradiol. 1998;19(3):502–4.
8. Liu JK, Gottfried ON, Amin A, Couldwell WT. Aneurysms of the petrous internal carotid artery: anatomy, origins, and treatment. Neurosurg Focus. 2004;17(5):E13.
9. Németh T, Szákás L, Bella Z, et al. The treatment of pseudoaneurysms with flow diverters after malignant otitis externa. Interv Neuroradiol. 2017;23(6):609–13.
10. Akhtar MU, Akram M, Ahmed TM, Bhatti AM. Superficial temporal artery - middle cerebral artery bypass for internal carotid artery petrous aneurysm: A case report. J Pak Med Assoc. 2017;67(1):128–30.
11. Saatci I, Cekirge HS, Ozturk MH, et al. Treatment of internal carotid artery aneurysms with a covered stent: experience in 24 patients with mid-term follow-up results. AJNR Am J Neuroradiol. 2004;25(10):1742–9.
12. Lerat J, Orsel S, Mounayer C, et al. Peripheral facial pa-
ralysis and bilateral carotid pseudoaneurysms of petrous localization: A case report. Skull Base Rep. 2011;1(02):133–8.

13. Gross BA, Moon K, Ducruet AF, Albuquerque FC. A rare but morbid neurosurgical target: petrous aneurysms and their endovascular management in the stent/flow diverter era. J Neurointerv Surg. 2017;9(4):381–3.

14. Tsang AC, Leung K, Lee R, et al. Primary endovascular treatment of post-irradiated carotid pseudoaneurysm at the skull base with the Pipeline embolization device. J Neurointerv Surg. 2015;7(8):603–7.

15. Yu LB, Zhang D, Yang SH, Zhao JZ. Surgical management of giant intrapetrous internal carotid aneurysm presenting with coil exposure after endovascular treatment. Neurosurg Rev. 2018;41(3):891–4.

16. Baker A, Rizz H, Carroll W, Lambert P. Cervical internal carotid artery pseudoaneurysm complicating malignant otitis externa: first case report. Laryngoscope. 2015;125(3):733–5.

17. Mascitelli JR, De Leacy RA, Oermann EK, et al. Cervical-petrous internal carotid artery pseudoaneurysm presenting with otorrhagia treated with endovascular techniques. BMJ Case Rep. 2014;2014(30):1bcr2014011286.

18. Tsang ACO, Nicholson P, Pereira VM. Nickel-related adverse reactions in the treatment of cerebral aneurysms: A narrative review. World Neurosurg. 2018;115:147–53.

19. Moon K, Albuquerque FC, Ducruet AF, et al. Resolution of cranial neuropathies following treatment of intracranial aneurysms with the Pipeline embolization device. J Neurosurg. 2014;121(5):1085–92.

20. Hamamoto Filho PT, Machado VC, Macedo-de-Freitas CC. A giant aneurysm from the petrous carotid presenting with isolated peripheral facial palsy. Rev Assoc Med Bras. 2013;59(6):531–3.

21. McCracken DJ, Lovasik RP, McCracken CE, et al. Resolution of oculomotor nerve palsy secondary to posterior communicating artery aneurysms: comparison of clipping and coiling. Neurosurgery. 2015;77(6):931–9.

22. Hall S, Sadek AR, Dando A, et al. The resolution of oculomotor nerve palsy caused by unruptured posterior communicating artery aneurysms: A cohort study and narrative review. World Neurosurg. 2017;107:581–7.

23. Matano F, Murai Y, Mizunari T, et al. Recovery of visual and ophthalmologic symptoms after treating large or giant internal carotid artery aneurysm by high-flow bypass with cervical ligation. World Neurosurg. 2017;98(2):182–8.

24. Mangat SS, Nayak H, Chandra A. Horner’s syndrome and sixth nerve paresis secondary to a petrous internal carotid artery aneurysm. Semin Ophthalmol. 2011;26(1):23–4.

25. Date I, Sugiu K, Ohmoto T. A giant thrombosed aneurysm of the petrosus carotid artery presenting with cavernous sinus syndrome: case report. Skull Base Surg. 1999;9(1):65–70.

26. Welleweerd JC, Nelissen BGL, Koole D, et al. Histological analysis of extracranial carotid artery aneurysms. PloS One. 2015;10(1):e0117915.

27. Barrett JH, Lawrence VL. Aneurysm of the internal carotid artery as a complication of mastoidectomy. Arch Ottolaryngol. 1960;72:366–8.

28. Guirguis S, Tardos FW. An internal carotid aneurysm in the petrous temporal bone. J Neurol Neurosurg Psychiatry. 1961;24:84–5.

29. Hiranandani LH, Chandra O, Malpani NK, Ahuja KK. An internal carotid aneurysm in the petrous temporal bone. J Laryngol Otol. 1962;76:703–6.

30. Wemple JB, Smith GW. Extracranial carotid aneurysm. Report of four cases. J Neurosurg. 1966;24(3):667–71.

31. Allen GW. Angiography in otolaryngology. Laryngoscope. 1967;77(11):1909–61.

32. Busby DR, Slemmons DH, Miller TF. Fatal epistaxis via carotid aneurysm and eustachian tube. Arch Ottolaryngol. 1968;87(3):295–8.

33. Steffen TN. Vascular anomalies of the middle ear. Laryngoscope. 1968;78(2):171–97.

34. Conley J, Hildyard V. Aneurysm of the internal carotid artery presenting in the middle ear. Arch Ottolaryngol. 1969;90(1):35–8.

35. Stallings JO, McCabe BF. Congenital middle ear aneurysm of internal carotid. Arch Ottolaryngol. 1969;90(1):39–43.

36. Anderson RD, Liebeskind A, Schechtm M, Zingesser LH. Aneurysms of the internal carotid artery in the carotid canal of the petrous temporal bone. Radiology. 1972;102(3):639–42.

37. Teal JS, Bergeron RT, Rumbaugh CL, Segall HD. Aneurysms of the petrous and cavernous portions of the internal carotid artery associated with nonpenetrating head trauma. J Neurosurg. 1973;38(5):568–74.

38. Morantz RA, Kirchner FR, Kishore P. Aneurysms of the petrous portion of the internal carotid artery. Surg Neurol. 1976;6(6):313–8.

39. Holtzman RNN, Parisier SC. Acute spontaneous otorragha resulting from a ruptured petrous carotid aneurysm. J Neurosurg. 1979;51(2):258–61.

40. Glassock ME, Smith PG, Bond AG, et al. Management of aneurysms of the petrous portion of the internal carotid artery by resection and primary anastomosis. Laryngoscope. 1983;93(11 Pt 1):1445–53.

41. Lynch JC, Amaral MA, Pareira A. Giant aneurysm of the petrous portion of the carotid artery. J Neurology Neurosurg Psychiatry. 1983;46(7):685–7.

42. Kelly WM, Harsh GR. CT of petrous carotid aneurysms. AJNR Am J Neuroradiol. 1985;6(5):830–2.

43. DelBalso AM, Bowers JE. Aneurysm of intrapetrous carotid artery: CT and angiographic findings. J Comput Assist Tomogr. 1986;10(4):702–3.

44. McGrail KM, Heros RC, Debrun G, Beyerl BD. Aneurysms of the ICA petrous segment treated by balloon entrapment after EC-IC bypass. J Neurosurg. 1986;65(2):249–52.

45. Willinsky R, Lasjaunias P, Pruvost P, Boucherat M. Petrous internal carotid aneurysm causing epistaxis: balloon embolization with preservation of the parent vessel. Neuroradiology. 1987;29(6):570–2.

46. Gibson RD, Cowan IA. Giant aneurysm of the petrous carotid artery presenting with facial numbness. Neuroradiology. 1989;31(5):440–1.

47. Frank E, Brown BM, Wilson DF. Asymptomatic fusiform aneurysm of the petrous carotid artery in a patient with von Recklinghausen’s neurofibromatosis. Surg Neurol. 1989;32(1):75–8.

48. Halbach VV, Higashida RT, Hieshma GB, et al. Aneurysms of the petrous portion of the internal carotid artery: results of treatment with endovascular or surgical occlusion. AJNR Am J Neuroradiol. 1990;11(2):253–7.

49. Costantino PD, Russell E, Reisch D, et al. Ruptured petrous carotid aneurysm presenting with otorrhagia and epistaxis. A J Otol. 1991;12(5):378–83.

50. Tokimura H, Todoroki K, Asakura T, et al. Coexistence of extracranial internal carotid artery aneurysm and multiple intracranial aneurysms: case report. Neurol Med Chir (Tokyo). 1995;35(7):347–50.
51. Umezu H, Seki Y, Aiba T, Kumakawa K. Aneurysm arising from the petrous portion of the internal carotid artery: case report. Radiat Med. 1993;11(6):251-5.

52. Papazian M, Paparella M, Hames E, Frisk J. Aneurysms of the temporal bone. Ear Nose Throat J. 1993;72(7):474-84.

53. Cross DT, Moran CJ, Brown AP, et al. Endovascular treatment of epistaxis in a patient with tuberculosis and a giant petrous carotid pseudoaneurysm. AJNR Am J Neuroradiol. 1995;16(5):1084-6.

54. Patrick JT. Magnetic resonance imaging of petrous carotid aneurysms. J Neuroradiol. 1996;6(3):177-9.

55. Love MH, Bell KE. Case report: giant aneurysm of the intrapetrous carotid artery presenting as a cerebellopontine angle mass. Clin Radiol. 1996;51(8):587-8.

56. Coley SC, Clifton A, Britton J. Giant aneurysm of the petrous internal carotid artery: diagnosis and treatment. J Laryngol Otol. 1998;112(2):196-8.

57. Zander DR, Just N, Schipper HM. Aneurysm of the intrapetrous carotid artery presenting as isolated Horner’s syndrome: case report. Can Assoc Radiol Journal. 1998;49(1):46-8.

58. Lempert TE, Halbach VV, Higashida RT, et al. Endovascular treatment of pseudoaneurysms with electrolytically detachable coils. AJNR Am J Neuroradiol. 1998;19(5):907-11.

59. Reece PH, Higgins N, Hardy DG, Moffat DA. An aneurysm of the petrous internal carotid artery. J Laryngol Otol. 1999;113(5):55-7.

60. Forshaw MA, Higgins N, Hardy DG, Moffat DA. Rupture of an internal carotid artery aneurysm in the petrous temporal bone. Br J Neurosurg. 2000;14(5):479-82.

61. Gouldwell WT, Zuberb J, Onios E, et al. Giant petrous carotid aneurysm treated by submandibular carotid: saphenous vein bypass. J Neurosurg. 2001;94(5):806-10.

62. Scavée V, De Wispelaere JF, Mormont E, et al. Pseudoaneurysm of the internal carotid artery: treatment with a covered stent. Cardiovasc Intervent Radiol. 2001;24(4):283-5.

63. Cheng KM, Chan CM, Cheung YL, et al. Endovascular treatment of radiation-induced petrous internal carotid artery aneurysm presenting with acute haemorrhage. A report of two cases. Acta Neurochirurg (Wien). 2001;143(4):351-6.

64. Vasama JP, Ramsay H, Markkola A. Petrous internal carotid artery pseudoaneurysm due to gunshot injury. Ann Otol Rhinol Laryngol. 2001;110(5):491-3.

65. Alexander MJ, Smith TP, Tucci DL. Treatment of an iatrogenic petrous carotid artery pseudoaneurysm with a Symbiot covered stent: technical case report. Neurosurgery. 2002;50(3):658-62.

66. Depauw P, Defreyne L, Dewaele F, Caemaert J. Endovascular treatment of a giant petrous internal carotid artery aneurysm. Minim Invasive Neurosurg. 2003;46(4):250-3.

67. Auyeung KM, Lui WM, Chow LCK, Chan FL. Massive epistaxis related to petrous carotid artery pseudoaneurysm after radiation therapy: emergency treatment with covered stent in two cases. AJNR Am J Neuroradiol. 2003;24(7):1449-52.

68. Horowitz M, Levy E, Hathaway B, et al. Endovascular treatment of a petrous internal carotid artery aneurysm with hemotympanum and epistaxis using a coronary stent and detachable platinum coils: report of a case. Arch Otol Head Neck Surg. 2005;131(1):61-3.

69. Cohen JE, Grigoriadis S, Gomori JM. Petrous carotid artery pseudoaneurysm in bilateral carotid fibromuscular dysplasia: treatment by means of self-expanding covered stent. Surg Neurol. 2007;68(2):216-20.

70. Singh H, Thomas J, Hoe WLE, Sethi DS. Giant petrous carotid aneurysm: persistent epistaxis despite internal carotid artery ligation. J Laryngol Otol. 2008;122(08):e18.

71. Schmerber S, Vasdev A, Chahine K, et al. Internal carotid false aneurysm after thromcoagulation of the gasserian ganglion. Otol Neurotol. 2008;29(5):673-5.

72. Ferroli P, Bisleri G, Nakaji P, et al. Endoscopic radial artery harvesting for U-Clip EC-IC bypass in the treatment of a giant petrous internal carotid artery aneurysm: Technical case report. Minim Invasive Neurosurg. 2009;52(04):186-9.

73. Saylam G, Tulgar M, Saatsi I, Korkmaz H. Iatrogenic carotid artery pseudoaneurysm presenting with conductive hearing loss. Am J Otolaryngol. 2009;30(2):141-4.

74. Oyama H, Hattori K, Tanahashi S, et al. Ruptured pseudoaneurysm of the petrous internal carotid artery caused by chronic otitis media. Neurol Med Chir (Tokyo). 2010;50(7):578-80.

75. Palacios E, Gómez J, Alvernia JE, Jacob C. Aneurysm of the petrous portion of the internal carotid artery at the foramen lacerum: anatomic, imaging, and otologic findings. Ear Nose Throat J. 2010;89(7):303-5.

76. Sun T, Zhao J. Multiple saccular aneurysms of the extracranial and intracranial internal carotid artery associated with convexusiobias and arachnoid cyst in a 6-year-old boy: a case report. Childs Nerv Syst. 2010;26(11):113-6.

77. Rose J, Jacob P, Jacob T. Horner syndrome and VI nerve paresis as a diagnostic clue to a hidden lesion. Natl Med J India. 2010;23(6):344-5.

78. Endo H, Fujimura M, Inoue T, et al. Simultaneous occurrence of subarachnoid hemorrhage and epistaxis due to ruptured petrous internal carotid artery aneurysm: association with transsphenoidal surgery and radiation therapy: case report. Neurol Med Chir (Tokyo). 2011;51(3):226-9.

79. Kim DK, Shin YS, Lee JH, Park SN. Pulsatile tinnitus as the sole manifestation of an internal carotid artery aneurysm successfully treated by coil embolization. Clin Exp Otorhinolaryngol. 2012;5(3):170.

80. Rathore YS, Chandra PS, Kumar R, et al. Monitored gradual occlusion of the internal carotid artery followed by ligation for giant internal carotid artery aneurysms. Neurol India. 2012;60(2):174.

81. Bien AG, Cress MC, Nguyen SB, et al. Endovascular treatment of a temporal bone pseudoaneurysm presenting as bloody otorrhea. J Neurol Surg Rep. 2013;74(2):88-91.

82. Chen JB, Sun H, Zhou LX, et al. Successful endovascular treatment of carotid aneurysms in a patient with vascular Ehlers-Danlos syndrome. J Neurol Surg A Cent Eur Neurosurg. 2013;74(5):01:e85-8.

83. Kadkhodayan Y, Shetty VS, Blackburn SL, et al. Pipeline embolization device and subsequent vessel sacrifice for treatment of a bleeding carotid pseudoaneurysm at the skull base: a case report. J Neurointerv Surg. 2013;5(5):e31.

84. Shon AS, Berenson CS. Pseudomonas aeruginosa intrapetrous internal carotid artery mycotic aneurysm—a complication of mastoiditis: first reported case. BMJ Case Rep. 2013;2013(jul08 2):bcr2013200005.

85. Kalani MYS, Ramey W, Albuquerque FC, et al. Revascularization and aneurysm surgery. Neurosurgery. 2014;74(5):482-98.
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86. Lee SH, Jang JH, Kim KH, Kim YZ. Stent-assisted coil embolization of petrous ICA in a teenager with neurofibromatosis. J Cerebrovasc Endovasc Neurosurg. 2015;17(3):252–6.

87. Han MS, Jung SH, Kim TS, Joo SP. Reconstructive endovascular treatment of an intracranial infectious aneurysm in bacterial meningitis: A case report and review of literature. World Neurosurg. 2016;90:700.e1–5.

88. Goodman TR, Renowden S, Byrne JV. Case report: petrous internal carotid artery aneurysm: an unusual cause of eustachian tube dysfunction. Clin Radiol. 1996;51(9):658–60.

89. Mukherjee P, Huilgol R, Graham A, Fagan P. Open and endovascular repair of aneurysms affecting the distal extracranial internal carotid artery: case series. J Laryngol Otol. 2016;130(54):529–34.

90. Wilding LJ, Howlett DC, Anderson HJ, et al. Extracranial internal carotid artery aneurysm presenting as symptomatic hypoglossal and glossopharyngeal nerve paralysis. J Laryngol Otol. 2004;118(2):150–2.

91. Kaczynski J, Wilczynska M, Blaszczynski M, Fligelstone L. Extracranial saccular atherosclerotic aneurysm of the internal carotid artery (ICA) treated by an oblique end-to-end primary anastomosis. BMJ Case Rep. 2013;2013(jan08 1):bcr2012007705.

92. Malikov S, Thomassin JM, Magnan PE, et al. Open surgical reconstruction of the internal carotid artery aneurysm at the base of the skull. J Vasc Surg. 2010;51(2):323–9.

93. McCollum CH, Wheeler WG, Noon GP, DeBakey ME. Aneurysms of the extracranial carotid artery. Twenty-one years’ experience. Am J Surg. 1979;137(2):196–200.

94. Elhammady MS, Wolfe SQ, Farhat H, et al. Carotid artery sacrifice for unclippable and uncoilable aneurysms: endovascular occlusion vs common carotid artery ligation. Neurosurgery. 2010;67(5):1431–7.

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