Results of Microsurgical Treatment of Large and Giant ICA Aneurysms Using the Retrograde Suction Decompression (RSD) Technique: Series of 92 Patients

Shalva S. Eliava, Yuri M. Filatov, Sergei B. Yakovlev, Oleg D. Shekhtman, Ali S. Kheireddin, Ilya A. Sazonov, Olga B. Sazonova, Dmitry N. Okishev

Key words
- Cerebral aneurysm
- Internal carotid artery
- Large and giant aneurysm
- Retrograde suction decompression

Abbreviations and Acronyms
ECA: External carotid artery
EEG: Electroencephalography
GOS: Glasgow outcome scale
ICA: Internal carotid artery
PcomA: Posterior communicating artery
RSD: Retrograde suction decompression

From the Burdenko Neurosurgical Institute, Russian Academy of Medical Sciences, Moscow, Russia

To whom correspondence should be addressed: Oleg D. Shekhtman, M.D., Ph.D.
[E-mail: oshekhtman@nsi.ru]

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■ BACKGROUND: **Microsurgical treatment of large and giant paraclinoid internal carotid artery (ICA) aneurysms often requires the use of the retrograde suction decompression (RSD) technique to facilitate clipping. Surgical results, functional outcomes at discharge, and technique limitations based on single institution series are presented.**

■ MATERIALS AND METHODS: **Between 1996 and 2009, eighty-three consecutive patients (19 to 68 years, mean 45.5 ± 9.9 years), predominantly women (69 women and 14 men) with large (23 patients, 27.7%) or giant (60 patients, 72.3%) paraclinoid aneurysms were surgically treated with the RSD technique performed by the neck route (62 patients, 74.4%) or later on, by endovascular means (21 patients, 25.3%). Patients were admitted after hemorrhage (48 patients, 57.9%), pseudotumor course (28 patients, 33.7%), mixed symptoms (5 patients, 6%), or asymptomatic (2 patients, 2.4%).**

■ RESULTS: **In most RSD surgeries (90.4%) aneurysms were successfully excluded: neck was clipped in 57 patients (68.7%) or clipping with ICA reconstruction was achieved in 18 patients (21.7%). In six patients aneurysms were wrapped with glue (7.2%), trapped in one patient (1.2%), and in one patient, ICA balloon deconstruction was performed (1.2%). Good or excellent results (Glasgow Outcome Scale scores 4-5) at discharge were achieved in 69 patients (83.1%), 11 patients (13.3%) remained severely disabled (Glasgow Outcome Scale 3), and 3 patients died (3.6%).**

■ CONCLUSIONS: **Surgical clipping with the RSD method remains a treatment of choice with acceptable outcomes for patients not amenable for endovascular treatment.**

INTRODUCTION

Giant aneurysms account for only 2% to 5% of all cerebral aneurysms, but large referral centers may encounter 25 to 35 such patients a year (7, 12, 23, 34). About 60% of giant aneurysms are partially thrombosed or have atherosclerotic walls that hinder their clipping (4, 29, 31). Yet the prognosis of giant aneurysms is poor without surgical treatment. Regardless of clinical presentation, 20% to 80% of these patients die within 2 to 5 years of diagnosis (17, 29).

Microsurgical treatment of large and giant paraclinoid internal carotid artery (ICA) aneurysms remains challenging even for experienced neurovascular surgeons. Anatomic constraints, size of the lesions, and limited proximal control make these vascular lesions risky to exclude from the circulation. Due to retrograde flow through the ophthalmic artery and cavernous branches, simple trapping is not sufficient to relax the aneurysm dome. In addition, the aneurysmal distension may force the clip off the neck occluding the ICA. The retrograde suction decompression (RSD) technique provides an adequate relaxation of the aneurysmal dome enabling the surgeon to fully dissect the ICA with branches, the aneurysm itself, and to clip it, often reconstructing the ICA lumen.

The RSD technique through the ICA exposed at the neck was first introduced by Batjer and Samson in 1990 (3). One year after, Scott et al. (26) has reported a successful endovascular RSD in a patient with an ophthalmic aneurysm.

Retrograde suction decompression with a direct or an endovascular route was introduced into practice at the Burdenko Neurosurgical Institute in 1996 and soon has became a standard treatment for patients not amenable for endovascular intervention. The goals of the current study were to critically analyze our experience with the RSD method and to define its place in modern vascular neurosurgery.

MATERIALS AND METHODS

Between 1996 and 2009, 83 patients with large (1.5–2.5 cm) or giant (>2.5 cm) in size paraclinoid aneurysms were treated with direct clipping using the RSD method. The patient population was predominantly women, 69 (83.1%) versus 14 men (16.9%),

Table 1. Characteristics of the Patients

Total number	83 patients
Sex (M:F)	14:69
Age, year (mean ± SD)	45.5 ± 9.9
Aneurysm (%)	
Giant (>2.5 cm)	60 (72.3%)
Large (1.5–2.5 cm)	23 (27.7%)
Manifestation	82 (100.0%)
Hemorrhage	48 (57.9%)
Pseudotumors	28 (33.7%)
Mixed	5 (6.0%)
Asymptomatic	2 (2.4%)

with a mean age of 45.5 ± 9.9 years (range 19 – 68 years).

Forty-eight patients (57.9%) presented with intracranial hemorrhages, 28 (33.7%) had a pseudotumor course, and 5 (6%) had mixed symptoms. In two patients (2.4%), the aneurysms were asymptomatic. Fourteen patients (16.8%) underwent surgery during the acute subarachnoid hemorrhage period (first 3 weeks), Hunt-Hess 1–3. Patient summary is presented in **Table 1**.

In relation to ICA lesions were distributed as follows: were distributed as follows: in 19 patients (23%) aneurysms were predominantly located anteriorly, in 10 (12%) posteriorly, in 7 (8.4 %) laterally, and in 44 patients (53%) medially. Three (3.6%) were true fusiform aneurysms presenting as ICA bulging with major branches originating from it.

Aneurysms were also classified according to the involved segment of the ICA. In presented series, 7 patients (8.4%) had lesions with extradural–intracranial neck or what we call a "borderline" aneurysms (or superior hypophyseal artery as classified by other investigators). The aneurysmal sac and distal rim of the neck are located intracranially, whereas the proximal rim lies extradurally starting proximal to the ophthalmic artery. In such patients, the aneurysm often spreads to the cavernous sinus stretching to the dural rings.

Fifty-five patients (62.3%) had paraclinoid (carotid–ophthalmic) aneurysms, which extended from the mouth of the ophthalmic artery to the posterior communicating artery (PcomA) distally. Eighteen patients (21.7%) had supraclinoid aneurysms, the neck of which extended from the PcomA distally. The classification of the aneurysm by location is summarized in **Tables 2** and **3**.

Table 2. Distribution of Aneurysms According to Internal Carotid Artery Wall

Location	N (%)
Anterior (superior)	19 (23.0%)
Posterior (inferior)	10 (12.0%)
Lateral	7 (8.4%)
Medial	44 (53.0%)
True fusiform	3 (3.6%)
Total	83 (100.0%)

All patients underwent preoperative and postoperative evaluation by a neurologist and an ophthalmologist. If needed, the opinions of other specialists were sought for somatic comorbidities before surgery. All patients underwent a diagnostic workup including digital subtraction angiography with three-dimensional reconstruction, magnetic resonance imaging, and computed tomography angiography. Special attention was paid to aneurysm anatomy, the ICA and its branches, cross-circulation supply and collaterals, aneurysm wall calcification. and degree of thrombosis. Patients with significant calcium deposits and mostly thrombosed aneurysms were excluded as these are not clippable lesions. Functional evaluation of collateral flow included electroencephalography (EEG) with the Matas test and later on, when it became available, transcranial Doppler ultrasonography with a balloon occlusion test or computed tomography perfusion studies. Patients assessed as having the "decompensated" type of collaterals were also disqualified from the study.

Table 3. Distribution of Aneurysm According to Internal Carotid Artery Segment

Location	N (%)
Borderline (extradural–intracranial)	7 (8.4%)
Carotid-ophthalmic (paraclinoid)	55 (66.3%)
Supraclinoid	18 (21.7%)
Fusiform	3 (3.6%)
Total	83 (100.0%)

Surgical Technique

The patient is positioned for a standard pterional craniotomy with the head rotated 30 degrees to the opposite side and slightly extended. The EEG scalp electrodes are placed. The frontotemporal and anterolateral cervical areas are prepared and draped as one field. Usually neck dissection and craniotomy are done simultaneously by two surgeons. The common carotid artery along with the internal and external carotids are isolated. Rubber tapes are placed around each of the arteries to ease further manipulations. Mannitol (0.5–1 mg/kg) is usually used to relax the brain.

Standard pterional craniotomy with resection of sphenoid ridge is performed. Dura opening is followed by dissection of basal cisterns and sylvian fissure. The electrocorticographic electrodes are placed at the cortex. Aneurysm anatomy and ICA branches are established and surrounding structures (e.g., chiasm, optic nerve, frontal lobe) are dissected. The site for the distal temporary clip is prepared. The anterior clinoid process and the optic roof are drilled out. The dissection is performed until the proximal aneurysmal neck, when possible, is exposed. As a rule, at this stage RSD or temporal neck ICA clamping becomes necessary.

The field is set for the RSD technique. First, the aneurysm is trapped by putting a temporal clip on the intracranial ICA distal to the aneurysm neck followed by clamping of common carotid and external carotid arteries. Blood is gently aspirated through the catheter introduced into the cervical ICA, resulting in aneurysm collapse and therefore enabling the surgeon to finalize its dissection and clipping it. The RSD may be performed in a staged manner when the aneurysm obliteration cannot be completed in one step. Aspirated blood is usually collected to blood bags and might be reinfused.

The endovascular RSD cranial stage is performed in the same fashion. The cervical ICA is reached with the transfemoral approach when the aneurysm is already exposed and aspiration is needed. The balloon is usually placed into the cervical ICA proximal to the ophthalmic artery. A double-lumen suction–aspiration catheter is used to deflate the aneurysm and to run a control angiography after clipping. Since the introduction of the "armed" double-lumen balloon catheters, which provide a very effective aspiration, endovascular RSD has became the preferred technique in our institution.

Flow control, in particular in small vessels like the anterior choroidal artery, is assessed with a microvascular Doppler or flowmeter. Control angiography is usually done as a final stage of the endovascular intervention. Wounds are closed with special care to hemostasis. The patient is then transferred to the intensive care unit for follow-up until the next day.

The ultimate goal of surgical intervention with RSD is to exclude the aneurysm and preserve the blood flow in the ICA and its branches as close to the initial state as possible. Very frequently giant and large paraclinoid ICA aneurysms have a broad neck and may present as large saccular lesions or fusiform, ectatic-like arterial sacs. In the former, the neck is usually easy to define and clipping is done with straight or angled clips, often inserted in a fence-like fashion. Ectatic aneurysms may often have a hardly defined neck, presenting as a large artery bulging on the side. Such aneurysms are clipped along the "presumed" neck across the body of the aneurysm with reconstruction of ICA lumen using tunnel or angled clips or its combination. Fusiform aneurysms incorporating major ICA branches pose the most difficulty and are rarely "clippable." In some instances they could be removed with a combination of different clips; the remainder are candidates for bypass surgery.

RESULTS

In most cases—57 patients (68.7%)—the RSD technique resulted in neck clipping or aneurysm clipping with ICA reconstruction (18 patients, 21.7%). Thus radical exclusion was achieved in 75 patients (90.4%).

In one patient (1.2%), an attempt to dissect the aneurysm sac failed because of its very large size and partial thrombosis. The surgery was ended with ICA balloon occlusion. The occlusion was monitored with EEG and electrocorticograph and tolerated well; the patient was discharged without deficit. In another patient (1.2%), a giant aneurysm appeared to be a fusiform ICA lesion, extending extradurally. The RSD effectively relaxed the dome but the proximal neck could not be found. Because the patient had a good collateral flow from PComA the aneurysm was trapped by putting the clips proximal to the PComA and ligating the ICA and ECA on the neck. The patient tolerated the procedure and was discharged with minor deficit (light aphasia).

In 6 patients (7.2%) the aneurysm could not be clipped and was wrapped with gauze and glued. Reasons for ineffective surgery were broad neck, rigid walls affected with atherosclerotic process, solid thrombosis, and extradural (cavernous) extension of the aneurysm sac. Frequently these factors were combined and were not adequately assessed before surgery.

Fifteen aneurysms (18.1%) ruptured intraoperatively during dissection or clipping. The RSD technique was able to manage the bleeding and the aneurysms were clipped in all patients. No statistical difference in relation to outcomes and neurological complications were found in the intraoperative rupture subgroup.

Functional outcome was assessed with the Glasgow outcome scale (GOS). Neurological examination at discharge included evaluation of visual, motor, and speech, and cranial nerves function. Of 83 patients treated, 36 (43.4%) made excellent recovery (GOS 5). Thirty-three (39.8%) had moderate disabilities (GOS 4) and 11 (13.3%) were severely disabled (GOS 3). No patients were vegetative (GOS 2). There were three lethal outcomes (3.6%). All three patients had giant and partially thrombosed aneurysms. In two patients the aneurysms were clipped successfully with ICA reconstruction. In one of them, soon after surgery as a result of clip migration the ICA flow was compromised causing severe cerebral ischemia. One patient died of a hemispheric ischemic stroke although flow in the ICA was adequate and confirmed with ultrasound study. One patient with a giant partially thrombosed aneurysm that was wrapped, died from repeated hemorrhages. The GOS outcomes of the series are presented in **Table 4**.

Table 4. GOS Outcomes of Surgical Treatment at Discharge

GOS	N (%)
5 (good recovery)	36 (43.4%)
4 (moderate disability)	33 (39.8%)
3 (severe disability)	11 (13.3%)
2 (vegetative state)	0
1 (death)	3 (3.6%)
Total	83 (100.0%)

GOS, Glasgow outcome score.

At discharge, visual status remained unchanged in 51 patients (63.8%) and had improved in 9 patients (11.2%). Fourteen patients (17.5%) had ipsilateral light perception only or amaurosis, 4 (5%) had hemianopia or quadrantanopsia, and 2 patients (2.5%) experienced a decrease in visual acuity. Six patients (7.5%) had cranial nerve III palsy and two patients (2.5%) had light facial nerve deficit. The motor function of 65 patients (81.2%) was unchanged, 4 (5%) had light, 4 (5%) moderate, and 5 patients (6.3%) deep hemiparesis; 2 patients (2.5%) were left hemiplegic. The neurological status of the patients is summarized in **Table 5**.

Table 5. Vision, Motor, and Cranial Nerve Deficit at Discharge

Total number (%)	80 patients
Vision	
Improved	9 (11.2%)
Light perception/amaurosis	14 (17.5%)
Hemianopia/quadrantanopsia	4 (5.0%)
Acuity decrease	2 (2.5%)
Motor function	
Light hemiparesis	4 (5.0%)
Moderate hemiparesis	4 (5.0%)
Severe hemiparesis	5 (6.3%)
Hemiplegic	2 (2.5%)
Cranial nerves	
III n. palsy	6 (7.5%)
VII n. palsy	2 (5.0%)

DISCUSSION

Despite modern technical achievements, giant paraclinoid ICA aneurysms, which often present as broad-neck dome-shaped vascular lesions that extend into the cavernous sinus, remain difficult lesions to treat surgically. Due to their large size, proximal location, frequent atherosclerotic wall changes, and partial thrombosis, surgery becomes a complicated intervention associated with a significant risk of neurological deficits (1, 7, 14, 15, 31).

Historically, the first attempts to treat giant paraclinoid aneurysms were deconstructive in nature (ICA ligation) and thus were associated with high rates of morbidity and mortality. In 1914, Matas (19) suggested the finger compression test of the ICA to evaluate patient's tolerance to permanent occlusion, a maneuver later named after him. In the 1970-1980s, ligation of the ICA was widely applied, and investigations were focused mainly on patient selection, indications, performance, and results (10, 14, 16, 20, 34). In 1974, Serbinenko and coworkers introduced further technical advances performing an endovascular ICA balloon occlusion, later combined with extracranial to intracranial bypasses pioneered by Yasargil and Donaghy in 1967 (27, 28, 33). Careful selection of patients based on the balloon occlusion test with EEG control and subsequent endovascular ICA deconstruction, combined with extracranial to intracranial bypass if needed, enabled numerous successful operations (8, 14, 15, 24, 28).

Direct puncture of the aneurysm followed by blood suction by way of a butterfly needle to deflate the aneurysm were first described by Flamm (9). This type of technique appeared to be cumbersome and prevented the surgeon from using both hands during dissection. Retrograde blood suction from the neck ICA greatly facilitated surgeries, effectively relaxing the aneursmal sac to perform delicate dissection and clipping. The RSD method is successful in doing what were previously considered inoperable lesions.

As the RSD technique gained popularity, there have been several variations on the classic procedure. Fan et al. (6) included aspiration through the ECA to minimize ICA dissection and the risk of embolization; Scott et al. (26) were the first to report a successful case of endovascular aspiration. At most hospitals endovascular RSD is now the primary option and includes double-lumen and single-lumen catheter techniques (1, 5, 21, 23, 30, 32). In 2006, Parkinson et al. (22) presented a case using RSD with a new concentric balloon containing a guide catheter, which offers the additional advantage of high-volume decompression and delivery of necessary endovascular devices to the location of the aneurysm.

In our institution a double-lumen balloon catheter (BALT, BALT Extrusion, Montmorency, France) is used for ICA occlusion proximal to the ophthalmic artery (7). The procedure of direct RSD is similar to the one described by Fan et al. (6). Surgery usually consists of 1–3 minutes of aspiration followed by 4–5 minutes of reperfusion. The direct aspiration technique carries risks of potential retinal ischemia due to ECA occlusion. Direct RSD could be hindered or carry the risk of thromboembolia in patients with advanced carotid disease, which made an ultrasound a mandatory preoperative exam. In 2009, Fulkerson et al. (11) reported no statistical difference in complications, visual defects, or death rates using the endovascular RSD technique in comparison to regular clipping in 118 patients with ophthalmic aneurysms.

Patient selection and careful preoperative planning are of extreme importance. In six patients (7.2%), the aneurysms were found unclippable at surgery and instead were wrapped with gauze and glued. The RSD technique provides two main benefits in surgery of paraclinoid aneurysms: proximal control of ICA flow and an opportunity to deflate the aneurysm safely to isolate and clip it. With the use of modern visualization techniques, for example, the aneurysm wall, the degree of thrombosing and its density, calcification of the neck, can be evaluated in advance to minimize failures at surgery. Fusiform aneurysms and those with extension into the cavernous ICA (borderline) pose significant difficulties in clipping. Although these types of aneurysms could be excluded in some instances, bypass surgery and modern endovascular techniques, the are of most benefit to such patients.

Vision preservation is of paramount importance during RSD surgery for ICA aneurysms. Twenty patients (25%) in our series experienced visual worsening at discharge. The major reason we believe was mechanical trauma and microcirculation disruption to the optic nerve and chiasm during dissection. It seems hardly avoidable as paraclinoid aneurysms frequently have adhesions to the optic nerve and roughly displace it. Another cause was the probable retinal ischemia during suction with the clamped ECA. Profound optic strut resection should be achieved in such cases to minimize nerve traction. Clips should be placed avoiding the distortion of the optic apparatus whenever possible. Nevertheless, as reported by Barami et al. (2) vision impairment with direct surgery for paraclinod aneurysms may comprise up to 20% at the 6-month follow-up. We estimate that the rate will eventually be less in our group as certain patients will improve with time.

It is worth mentioning that at present there is still no convincing data in favor of endovascular treatment in vision improvement, not with radical aneurysm exclusion. In fact, microsurgery carries an advantage of immediate optic nerve decompression, which is specifically effective in patients with acute hemorrhages. Vargas et al. (33) treated 19 patients with visual defects caused by giant aneurysms with balloons or coils; only 7 patients (36.8%) improved, although not completely, whereas 11 (57.8%) remained unchanged and 1 (5.2%) worsened. Heran et al. (13), in 16 patients with anterior optic pathway compression treated initially with coils at final follow-up achieved improvement in 50%, worsening in 25%, and no change in another 25% of patients. Staged treatment included repeat coil embolizations, ICA occlusion (7 patients), and microsurgery (3 patients), with an overall mortality of 12.5% (2 patients died from repeated hemorrhage). Aneurysm closure was incomplete in 50% cases. Malisch et al. (18) demonstrated a 33% recanalization rate in giant aneurysms; of 8 patients with impaired vision, only 4 (50%) improved at the 20.1-month follow-up.

Among most recent studies, van Rooji and Sluzewski (25) in 2006 reported a 64% reopening rate for previously coiled large and giant unruptured aneurysm. Regrowth of an aneurysm, coil compaction, and coil migration into a soft thrombosed intra-aneurysm were considered to be the reasons for fast recanalization. The risk of rupture after coiling remains unknown (12, 18).

At discharge from the institution good surgical results (GOS 4-5) were achieved in 69 patients (83.1%), fair (GOS 3) in 11 (13.3%), and no poor results (GOS 2) were registered. Mortality was 3.6% (3 patients). Overall, our surgical outcomes are on line with published series. In the recent analysis by Hauck et al. (12), of 62 patients with very large and giant anterior circulation aneurysms treated with clipping, 42 patients (68%) showed good results, 20 (32%) poor, and 9 (15%) died. In the series by Batjer et al. (4) in the subgroup of 89 patients with paraclinoid aneurysms, there were 22 patients with giant aneurysm, 13 (59%) of which had a good outcome, 5 (23%) fair , and 3 (14%) did poorly. One death occurred, comprising 5% mortality for this subgroup.

Serving as a federal referral center Burdenko's neurovascular service admits a high number of complex large and giant aneurysms annually and uses a multidiscipline approach in treatment. With further development of endovascular techniques, the direct microsurgical approach might become less popular. We, however, believe that the RSD method remains an effective treatment for dedicated neurovascular centers with acceptable outcomes.

CONCLUSIONS

Treatment of large and giant paraclinod aneurysms remain hazardous and are best performed in large centers specialized in neurovascular surgery. A multidisciplinary approach should be taken with attention to aneurysm anatomy, size, patient age, and comorbidities to offer the best treatment tactics. The RSD is the treatment of choice for patients not amenable for endovascular intervention. Our series demonstrates that good results could be achieved with these high-risk lesions with careful patient selection, preoperative planning, and anesthesia support.

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