Minipterional Craniotomy in Surgery for Anterior Circle of Willis Aneurysms

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One of the significant events in aneurysm surgery was promotion of a microneurosurgical technique by G. Yasargil. Despite its versatility, pterional craniotomy is associated with extensive osteotomy and a significant incision of the skin and temporal muscle, which may lead to the adverse cosmetic effects, risk of temporomandibular joint dysfunction, injury to the frontal branch of the facial nerve, and facial and scalp numbness. We present our experience with minipterional craniotomy in surgery for anterior circle of Willis aneurysms in 40 patients. There were no serious complications or deaths. Also, there were no intraoperative aneurysm ruptures. All patients experienced expected transient hypesthesia in the temporal region, which was not considered as a complication. In this case, hypesthesia was significantly milder compared to that in the classical pterional craniotomy. Patients assessed the postoperative cosmetic outcome as excellent.

Keywords: minipterional craniotomy, keyhole, minimally invasive surgery, aneurysms.

The traditional pterional approach in surgery of cerebral aneurysms was proposed by G. Yasargil. The approach includes an arcuate incision of the skin from the tragus to the midline along the hairline, followed by an extensive dissection of the temporal muscle and craniotomy of the frontotemporal region [1, 2].

This classical extensive approach is often associated with various postoperative complications, unsatisfactory cosmetic results, prolonged stay of patients in a hospital, and prolonged postoperative recovery at the outpatient stage, which entails great economic costs. Later, J. Hernesniemi et al. [3] modified pterional craniotomy (PC) and proposed a lateral supraorbital approach that differed (in the authors’ opinion) from PC by the subfrontal trajectory facilitating an approach to the parasellar space and causing less damage.

The modern concept of keyhole surgery involves reducing the aggressiveness of surgery by minimizing a surgical approach. Modified keyhole approaches were initially proposed in surgery of anterior circulation aneurysm and parasellar space-occupying lesions [4—23]. We have used a differentiated approach for surgical accesses and the concept of keyhole surgery for anterior circulation aneurysms and anterior and middle cranial fossa tumors since 2014.

In this work, we present the experience of using the minipterional craniotomy (MPC) in surgery of anterior circle of Willis aneurysms.

Material and methods

In the period between March 2014 and December 2015, 40 aneurysms were clipped using the minipterional craniotomy. The aneurysm location was as follows: 30 middle cerebral artery (MCA) aneurysms, 7 internal carotid artery (ICA) aneurysms in the area of the posterior communicating artery orifice, and 3 ophthalmic aneurysms. The male:female ratio was 1:2.5. The mean age of patients was 53.7 years. Thirty patients had unruptured aneurysms. Ten patients had subarachnoid hemorrhage (SAH): 7 of these were operated on in the acute period. The condition of these patients was assessed using the Hunt—Hess scale, and the amount of SAH was assessed using the Fisher scale. Four patients underwent surgery in the early period. Three patients underwent clipping in the long-term period. All patients had a Hunt—Hess grade of I or II and Fisher grade 1 or 2 SAH.

Preoperatively, all patients underwent two-dimensional and 3D-CT angiography. The surgical approach was chosen after a thorough evaluation of the anatomy of intracranial structures and aneurysms. All aneurysms clipped using MPC were of small or medium size, no more than 15 mm in diameter. In the case of complex large and giant aneurysms, the method of choice involved more extended approaches ranging from the classical pterional craniotomy to the orbitozygomatic approach and its different modifications. Also, we did not consider MPC as an acceptable technique in patients in a decompensated state (Hunt—Hess grade IV—V) as well as in the case of massive subarachnoid hemorrhages and large parenchymal hematomas accompanied by brain edema and intracranial hypertension. Along with clipping, most of the patients underwent extensive decompressive trepanation.

Surgical technique

Surgery is performed under general anesthesia, with the patient in a supine position with the head turned in the opposite direction at an angle of 30—60°, depending on the lesion location. The neck is maximally extended to provide gravitational retraction of the frontal lobe from the skull base and adequate venous drainage. A 4—5 cm arcuate incision of the skin and soft tissues is performed in the temporal region, starting from the...
zygomatic process, 1 cm anterior to the superficial temporal artery, and to the hairline or not reaching the superior temporal line (Fig. 1).

Next, the classical interfascial temporal muscle dissection is performed, with the frontal branch of the facial nerve being preserved. An incision of the temporal fascia is performed by monopolar coagulation with preservation of the myofascial cuff. After a subperiosteal dissection, the temporal muscle is expanded by a small retractor or reduced by hook tensioners. This enables full exposure of the pterion area. A burr hole is placed superior to the frontozygomatic suture. A craniotomy, 2—3 cm in size, includes the lateral sphenoid bone, a portion of the frontal bone below the superior temporal line, and a minimum portion of the temporal bone. Like in the classical PC, the sphenoid crest is resected until the meningo-orbital artery in the superior orbital fissure is visualized (Fig. 2).

The dura mater (DM) is opened by a semi-oval incision, with its base directed towards the pterion. The intradural stage of surgery is performed under a microscope (Fig. 3).

The subsequent technique depends on the aneurysm location. In the case of MCA aneurysms, the Sylvian fissure is dissected anteriorly to the superficial Sylvian veins that should be preserved from damage. The Sylvian fissure is sharply dissected. Usually, small bridging veins coming from the temporal lobe to the frontal lobe can be coagulated without consequences. Of great importance is a dissection in the subarachnoid space area to preserve the cortex and minimize its damage. However, this is not always possible in patients after massive subarachnoid hemorrhage accompanied by brain edema and obliteration of the Sylvian fissure. In the case of MCA M1 bifurcation aneurysms, the transsylvian approach, without dissection of the parasellar cisterns, may be sufficient. In this situation, identification of the M1 segment to provide proximal control is the priority, and then, the MCA branches (M2 segment) and aneurysms are identified. After dissection, the aneurysm is clipped with temporary clipping or without it. In the case of ICA aneurysms, the classical microsurgical technique with early brain relaxation by opening of the optic nerve and carotid artery cisterns is used. Further, a limited dissection of the medial Sylvian fissure is performed to provide moderate traction of the frontal lobe and visualization of the ICA bifurcation. The posterior communicating artery is visualized through the optic-carotid triangle. Arachnoid adhesions of the ICA are sharply dissected, and then the anterior choroid artery is identified. The microsurgical technique is dictated by the aneurysm location. In the case of carotid-ophthalmic aneurysms, intradural resection of the anterior clinoid process may be necessary to provide proximal control and visualization of the ophthalmic artery.

In the case of adequate brain relaxation after draining the cerebrospinal fluid from the subarachnoid cisterns and/or after pharmacological exposures, there is no need for significant retraction of the parenchyma. In the case of hemorrhage, the brain may be edematous. In these cases, the carotid cistern is first opened for adequate relaxation, which then enables more comfortable and less traumatic dissection of the Sylvian fissure. Early placement of a lumbar drain may be an alternative in SAH patients.

After clipping the aneurysm and verifying its complete exclusion (it is optimal to use intraoperative indocyanine green (ICG) angiography, followed by opening of the aneurysm), hemostasis is performed. The DM is tightly closed. A bone flap is fixed with craniofixes or miniplates. The temporal fascia/muscle, subcutaneous tissue, and skin are sutured in layers (Fig. 4). Given a small wound size, wound drainage is not performed, which is also an undoubted advantage of minimally invasive surgery.

Below, we provide an example of surgery in a female patient with a carotid-ophthalmic ICA aneurysm. The microsurgical stage of surgery was performed without retractors (Fig. 5).

**Results and discussion**

All aneurysms were completely excluded from the cerebral circulation, which was confirmed by...
intraoperative opening of aneurysms and subsequent monitoring using intraoperative indocyanine green angiography and control 3D-SCT angiography in the postoperative period. There were no serious complications or lethal cases in patients. Also, there were no intraoperative aneurysm ruptures. All patients experienced transient hypesthesia in the temporal region, which was expected and, therefore, was not regarded as a complication. It should be noted, that the hypesthesia area was significantly smaller when compared to the outcomes of classical pterional craniotomy.

**Fig. 2. Minimal pterional craniotomy.**
a — an intraoperative view: a skin-aponeurotic flap is moved anteriorly, and the temporal muscle is spread by a retractor; b — the size of a bone flap.

**Fig. 3. Stages of microsurgical treatment of a left MCA aneurysm.**
a — SCT-angiography: a saccular aneurysm of the left MCA M1 segment is seen; b — an intraoperative view after minipterional craniotomy and opening of the DM; the center of craniotomy is situated over the Sylvian fissure; c, d — stages of Sylvian fissure dissection; e — the saccular aneurysm of the MCA M1 segment; f — clipping of the aneurysm; g, h — intraoperative indocyanine green angiography: the aneurysm is excluded from blood flow, the MCA branches, not stenotic, are visualized; i — a view after clipping of the aneurysm and opening of the aneurysmal sac.
Patients assessed the postoperative cosmetic result as excellent. In 2 patients, a follow-up examination at up to 10 months revealed minimal dysfunction in the temporomandibular joint area and symptoms of temporal muscle atrophy in the craniotomy area.

The traditional approach in surgery for intracranial aneurysms of the anterior circulation is the pterional craniotomy proposed by M. Yasargil in 1975 [1, 2]. Pterional craniotomy is associated with a quite extensive osteotomy and a significant incision of the skin and temporal muscle, which may lead to the following side effects: temporal muscle atrophy, scar formation, facial asymmetry, risk of temporomandibular joint dysfunction, chewing pain, discomfort when wearing glasses, damage to the frontal branch of the facial nerve, scalp numbness, and scar alopecia. Exposure of the cortex at the intradural stage, more significant in size, may be accompanied by damage to the cortex due to the influence of the non-physiological environment, retractor trauma, etc [21—25].

The concept of keyhole is not new. Since its introduction by A. Perneczky et al. [10, 11, 21—25], considerable experience in surgery of aneurysms and intracranial tumors has been accumulated. Keyhole surgery is a modern concept that significantly reduces injury caused by surgery. The size of keyhole craniotomy is 2—3 cm, on average. However, this is not just a reduction in the trephination window size. Keyhole means the creation of an optimal surgical corridor in each particular case to access a certain lesion with minimal injury to both soft tissues, including the temporal muscle, and brain tissue. This goal is achieved through the use of small incisions of soft tissues, minimal DM opening, and exposure of the cortex with minimal retraction of the brain. This enables achieving the main goals of minimally invasive neurosurgery: minimization of surgical invasion, improvement of the cosmetic effect compared to that of classical surgery, shorter surgery time, reduction in blood loss, postoperative pain, and postoperative complications, and shorter total hospital stay, which reduces financial and economic costs for treatment of patients. It is also important to assess the outcomes of minimally invasive microsurgery of aneurysms in terms of patient satisfaction with surgery.

The keyhole approaches used for anterior circulation aneurysms are primarily supraorbital and minipterional ones. B. Chehrazi [6] was one of the first researchers who described a temporal transsylvian approach to aneurysms as an alternative to the classical pterional craniotomy, which was accompanied by a decrease in the trephination
Later, many authors [5—16] used the minimally invasive approach in aneurysm surgery, calling it a modified pterional craniotomy. E. Figueiredo et al. [10, 11] compared the minipterional approach and the pterional craniotomy in two groups of patients. Despite the similar treatment outcomes, the authors noted that the minipterional approach was associated with less damage to soft tissues and less craniotomy, which reduced the time of surgery and recovery period and improved cosmetic results. A necessary support in keyhole surgery of aneurysms is the use of an additional imaging technique, intraoperative indocyanine green fluorescence angiography [4, 26—28].

Keyhole surgery is based on a thorough preoperative assessment to determine the trephination window position depending on the pathological process and individual patho-anatomic picture. We associate the good results of surgical treatment in our group with careful preoperative selection of candidates for minimally invasive surgery and exclusion of patients being at the decompensated stage (Hunt—Hess grade IV—V). Patients with unruptured aneurysms are ideal candidates for keyhole surgery, except for patients with large and giant aneurysms. Among patients with the clinical presentation of SAH, the most favorable candidates for minimally invasive surgery are patients with Hunt—Hess grade I—II aneurysms. For subcompensated and decompensated patients, we consider the classical pterional approach with its modifications (orbitopterional or orbitozygomatic craniotomy) as the method of choice.

Fig. 5. Stages of microsurgical treatment of a carotid-ophthalmic ICA aneurysm.

a — SCT-angiography: a carotid-ophthalmic aneurysm on the right is visualized; b — an intraoperative image after minipterional craniotomy and opening of the DM; the Sylvian fissure is indicated by the arrow; c — intradural resection of the anterior clinoid process by a 2 mm diamond burr; d, e — stages of aneurysm isolation; f — aneurysm clipping; g — a view of the surgical wound at the end of surgery.
Conclusions
The minipерipheral craniotomy is the method of choice for most MCA and some ICA aneurysms. The main goal of keyhole surgery is not to reduce the trephination window but also to decrease traction brain injury. An important support in minimally invasive surgery of aneurysms is the use of ICG-angiography and endoscopic assistance, which greatly enhances visualization and control in a narrow deep wound.

There is no conflict of interest.

REFERENCES

Pterional craniotomy with transsylvian dissection provides a wide viewing angle for manipulations with intracranial structures and is used as a standard approach for clipping of anterior circulation and upper basilar artery aneurysms. A modification of the pterional craniotomy in terms of minimally invasive surgery, called minipterional craniotomy, is characterized by reduced iatrogenic trauma. High safety of surgery is achieved by reducing the length of a skin incision, length of temporal muscle dissection, size of a bone flap, and time spent on performing the approach and closing the wound.

Any desire to minimize a surgical approach to intracranial structures requires a comparative evaluation of the safety of the new technique, degree of its versatility (applicability), duration of surgery, cosmetic results, etc. In the presented work, R.S. Dzhindzhikhadze and co-authors analyze the experience of using minipterional craniotomy in treatment of 40 saccular aneurysms of the carotid territory, with 30 of them being middle cerebral artery aneurysms.

In the discussion of minimally invasive approaches in surgery of aneurysms, the authors refer to studies devoted to a supraciliary approach. The supraciliary approach is a variant of the supraorbital subfrontal approach and, being significantly different, provides significantly less freedom of surgical manipulations in the Sylvian fissure compared to the minipterional approach.

The indications for minimally invasive surgery, including minipterional craniotomy, in treatment of arterial aneurysms are determined not only by the aneurysm size but also by the aneurysm neck configuration. The use of a relatively narrow intracranial corridor reduces visualization and hampers arachnoid dissection of the vascular structures as well as limits the use of complex configuration clips and clip holders with large swing flexible heads.

The minipterional approach is most appropriate for clipping of middle cerebral artery and supraclinoid internal carotid artery aneurysms with a simple neck configuration directed perpendicular to the axis of a planned approach. Exposure of the Sylvian fissure within a relatively small trephination window enables its safe dissection in the lateromedial (distal-proximal) direction, which is usually sufficient for clipping of middle cerebral artery aneurysms. In my opinion, this approach can not be used for complex middle cerebral artery and anterior communicating artery aneurysms and, if necessary, for contralateral dissection in multiple aneurysms. All similar cases require extensive arachnoid dissection with retraction of the frontal lobe and the standard pterional craniotomy, the size of which enables insertion of instruments and clips into the depth of the wound at different angles.

The presented good results of minipterional craniotomy in surgical treatment of aneurysms of the carotid territory are associated with careful analysis of the relationship among the aneurysm location, the direction and shape of the aneurysm neck, the presence of hemorrhages and edema of brain tissue that have been considered by the authors at the preoperative planning stage. Experience of R.S. Dzhindzhikhadze and co-authors emphasizes the important point about the need for selecting not only a surgical approach but also its minimally invasive modification to ensure both the primary goal of surgical intervention (safe clipping of the aneurysm) and reduce the total injury rate and duration of surgery.

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