Acta Neurochir (2005) [Suppl] 94: 31–38

Printed in Austria

Subtemporal approach to basilar bifurcation aneurysms: advanced technique and clinical experience

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Summary

Objective. The surgical treatment of basilar bifurcation aneurysms is challenging, and many of these aneurysms are currently treated by endovascular means. However, the complete closure of the aneurysm by surgical clipping still remains the best and most permanent cure for the aneurysm. The "gold standard", subtemporal approach was established and introduced by Drake and it has been adapted by the senior author Hernesniemi. We describe our present modified technique of this approach based on clinical experience.

Methods. The subtemporal approach to basilar bifurcation aneurysms has been regularly used by the senior author Hernesniemi in recent 15 years in over 200 operations in Kuopio and Helsinki, Finland.

Results. This approach is suitable in most basilar bifurcation aneurysms except for those high above the posterior clinoid process. To avoid temporal lobe damage, cerebrospinal fluid drainage is necessary. Benefits of subtemporal approach are short operative and retraction times, and no need for skull base resection.

Conclusion. The subtemporal approach is simple and safe in experienced hands, and should be considered the standard method to approach most basilar bifurcation aneurysms.

Keywords: Approach; subtemporal; pterional; cerebral aneurysm; intracranial aneurysm; basilar bifurcation aneurysm; surgery.

Introduction

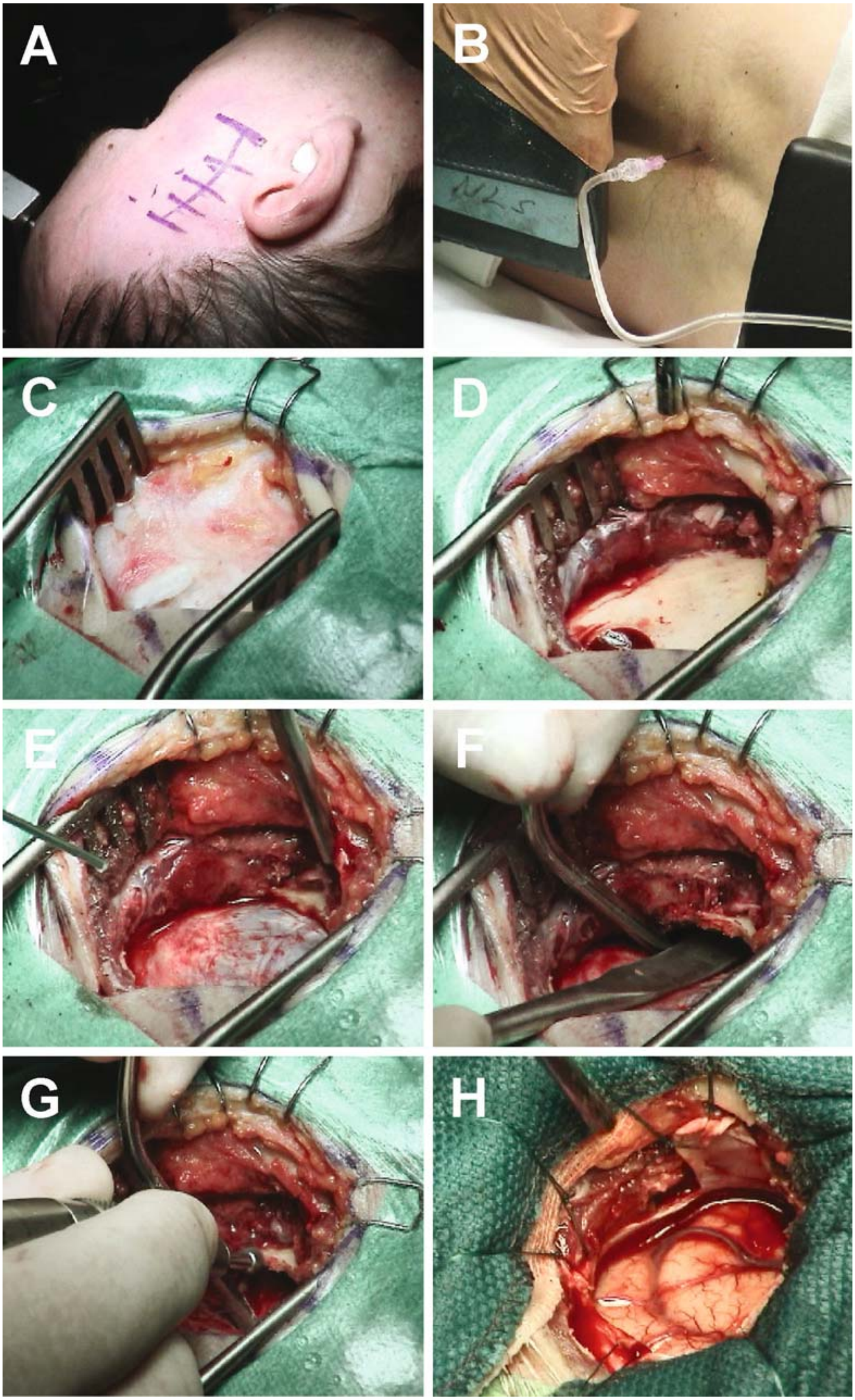
The surgical treatment of basilar bifurcation aneurysms (BBAs) remains one of the most difficult tasks in neurosurgery because of the anatomical and technical difficulties. Recently, many of these rare aneurysms located in a narrow space in front of the brain stem have been treated by endovascular procedures in many institutions. However, closure of the base of the aneurysm by clipping still remains the most effective cure for the aneurysm [12, 20]. Several surgical approaches, such as subtemporal approach, pterional approach, supraorbital approach, orbitozygomatic approach, transpetrosal approach and combined approaches are currently used for the treatment of BBAs [1–6, 8–11, 13–19]. The subtemporal approach is the oldest one, which was widely used by Drake and Peerless in more than 1000 patients [2–4]. The senior author Hernesniemi adopted the use the subtemporal approach in the 80's after studying chapters written by Drake and Peerless in different text books. This experience was later refined by coworking with these authors [4, 7]. We describe our recently modified operative technique of the subtemporal approach.

Operative procedure

Craniotomy, approach to tentorial edge and basilar bifurcation

The patient is positioned in the park bench position. A small subtemporal craniotomy through a linear incision is done. Ordinarily, the non-dominant, right side is used, unless the projection or complexity of the aneurysm, scarring from earlier operations, severe anatomical rotation of the basilar bifurcation, left oculomotor palsy, left sided blindness or right hemiparesis, makes an approach from the dominant side necessary.

The subtemporal approach can be converted into a pterional or posterior temporal bone flap, which, however, is rarely needed. The skin incision is at right angle to the zygoma about 1 cm in front of the ear and is carried down to the level of the zygomatic arch (Fig. 1A). Here, care must be taken not to injure the upper branch of the facial nerve, and it is advisable to retract the lower part of the incision downwards with a "fish hooks" (Fig. 1A, C). After incising the fascia and temporal muscle along its fibers to the arch, it is important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to detach the muscle with its fascia posteriorly from the temporal root of the zygoma (Fig. 1D). Anteriorly, both leaves of the temporal fascia are separated from the arch one centimeter's distance with blunt dissection, not to injure the nerve (Fig. 1D). This allows wider spreading of the temporal muscle with a curved retractor and fishhooks (Fig. 1D). A small bone flap sized 3×3 cm is done with one burr hole and craniotome taking care not to injure the dura which may be heavily attached to the skull at the most based part of the craniotomy (Fig. 1D, E). Resection of a part of the zygomatic arch can be done with a diamond drill, but is not often necessary or very helpful (Fig. 1F, G).

The trick of the proper use of the subtemporal approach lies in getting in quickly, without heavy compression of the temporal lobe, and with just enough space to reach the tentorial edge. Lumbar drainage installed by the neurosurgeon before surgery, is the key to successful surgery (Fig. 1B). Modern neuroanesthesia with Mannitol may be helpful to accelerate slack brain, but without CSF drainage we would not be recommend to start a subtemporal approach. In the presence of hydrocephalus a frontal ventricular drainage has been applied, and when widening the opening into a pterional approach lamina terminalis can also be opened.

With spinal drainage of 50–100 ml of CSF, the brain will be slack when the dura is opened, even in early surgery for ruptured aneurysms in good grade patients (Fig. 1B, H). After opening the dura in V-shaped form, base downwards, and after very careful fixation of the dura with stitches to the surrounding muscles or draping, the microscope should be brought into position (Fig. 1H). Fibrin glue has proved to be extremely useful in stopping possible epidural bleedings. Absolute hemostasis is done before proceeding deeper; otherwise blood may be poured on the operation field at the most critical moments of deep surgery. The retraction of the temporal lobe should be slowly increased. The brain is covered with oxidized cellulose and large wet cottonoids. The line of retraction goes first slightly downwards, then across the floor of the middle fossa and after that upwards to the tentorial edge. The course of creating the operative route is like taking the temporal lobe in your retracting hand and pulling upwards to see the tentorial edge. A broad Aesculap ^{o,R} retractor is used, very gently, and another may assist to hold the temporal pole anteriorly.

The angle of the subtemporal approach ordinarily is nearly perpendicular to the sagittal plane, but even through a small craniotomy the angle can be changed. An opposite P1 hidden behind a large sac with its perforators can usually be seen by angling the retractor forward a few degrees under the temporal pole, changing the angle of the operating microscope and then displacing the waist of the sac posteriorly. This maneuver is particularly appropriate when a larger bone flap has been used. Associated ipsilateral intact carotid aneurysms are easily exposed for clipping by moving the retractor tip forward a few centimeters under the temporal pole.

One or two temporal lobe bridging veins crossing to the floor of the middle fossa in the line of approach must be divided, but usually other veins on either side can be spared. The adjacent bridging veins are under stretch but they may be dissected a few millimeters from arachnoid to get more freedom for retraction. The junction of the vein of Labbé with the lateral sinus is further away posteriorly located and not in jeopardy in this approach. It is critical that this vein is not injured, to avoid major temporal lobe hemorrhagic infarction.

As the edge of the tentorium comes slowly into view, having the temporal lobe in your "hand", the uncus will leave its position inside the edge of the tentorium. The uncus is the landmark for this retraction, as its elevation by the retractor tip exposes the opening into the interpeduncular cistern. A medial temporal vein may be divided before the final retractor placement on the temporal lobe mesially at the base or under the tip of the uncus.

As the uncus is raised with the tip of the retractor, the third nerve is elevated with it, without placing disturbing angular tension on it. It is usually possible to work below the third nerve to clip the aneurysm except for the case of a higher basilar bifurcation or a giant

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Fig. 1. (A) Skin incision. The skin incision is at right angle to the zygoma about 1 cm in front of the ear and is carried to the level of the zygomatic arch. (B) Setting of lumbar spinal drainage. (C) Retraction. Care must be taken not to injure the upper branch of the facial nerve, and it is better to retract the lower part of the incision downwards with a fish hook. A curved retractor and fish hooks allow wider spreading of the temporal muscle. (D) Location of the burr hole. (E) Craniotomy. A small bone flap sized 3×3 cm is done with one burrhole. (F) Detaching the heavily attached dura at the lowest part of the craniotomy. (G) Removal of lowest part of the skull by drilling. (H) Dural opening. Dura was opened in a V-shaped form, base downwards, and fixed very carefully with stiches to the surrounding muscles or draping

sac, when it may be necessary to separate the third nerve from the uncus. The third nerve may be relaxed by dividing the arachnoid bands holding it. The third nerve tolerance to manipulation varies greatly: an oculomotor palsy may follow a most delicate dissection, and sometimes no palsy is seen even after a relatively strong, long lasting manipulation.

Even with the uncal retraction of the third nerve, the opening into the interpeduncular cistern is narrow. It can be widened significantly by the original simple maneuver of placing a suture in the edge of the tent just in front of, but free of, the insertion and intradural course of the fourth nerve. This suturing is awkward in the deep small gap, and it has been replaced by the use of a small Aesculap o, R clip reflecting the edge of the tentorium by about 1 cm towards the surgeon to the floor of the middle fossa. The bleeding is stopped by the use of fibrin glue. The fourth nerve is freed from its arachnoid adhesions, and can be tucked below a cottonoid under the tentorial edge for safety. If necessary, the tentorium is divided and fixed also with a small Aesculap clip(s) to get better access for temporary clipping of the basilar artery. In the case of a low lying basilar bifurcation, tentorium division remains absolutely necessary, and a more posterior approach with a larger flap is planned from the beginning of the operation.

All the arachnoid is widely opened beginning just above the fourth nerve and the superior cerebellar artery below the third nerve on the side of the midbrain, going forward anterior to the third nerve freeing also carotid and posterior communicating arteries. A small space exists between the peduncle and the dorsum sellae laterally. The brain stem can be compressed against the clivus, hiding the interpeduncular fossa. With careful preparation of the arachnoid and further removal of CSF, the peduncle is retracted with the dissecting instruments and cottonoids to see the basilar artery and the base of the aneurysm. The posterior clinoid is not removed as the working field in this position is lateral (posterior) to it.

Depending on the extent of the patient's hemorrhage and the interval between the bleeding and surgery, the interpeduncular fossa may be either filled with clear CSF, packed with fresh or disintegrating clot, or, occasionally in long delayed cases, obliterated with dense arachnoiditis. To avoid heavier retractor pressure in order to see the PCA above the third nerve, it is convenient to follow the superior cerebellar artery back under the third nerve to the BA, sucking away clot to expose its origin just below that of P1. The lower aspect of P1 will disappear underneath the third nerve. Even though still covered by a clot, the position of the lateral aspect of the neck and waist of the aneurysm is just medial to P1 and usually partially covered laterally and posteriorly by the P1 perforators. The PCoA should be carefully preserved in case some injury to P1 occurs or if it becomes necessary to include P1 in the clip. Furthermore, the PCoA gives rise to important diencephalic branches (anterior thalamoperforating arteries) the integrity of which may be compromised by its occlusion.

Intraoperative hypotension and temporary clipping

Tension in the aneurysm wall is related in an almost linear fashion to systemic blood pressure. Induced hypotension by various means has contributed to the safety of aneurysm surgery with minimal risk of ischemia. Systemic hypotension, down to mean arterial pressure (MAP) of 40–50 mmHg has been widely recognized to reduce the tension and fragility of the aneurysm wall. Recently, local or regional hypotension induced by temporary occlusion of the parent artery has replaced systemic hypotension.

Temporary clipping of BA, which requires most demanding, difficult dissection and a lot of work, has been recently replaced by balloon occlusion. P1 is always above the third nerve and the PCoA joins it; the SCA is always below. A segment of the BA below the SCA and free of perforators for 2 or 3 millimeters should be always exposed for placement of a temporary clip. Our experience indicates that nearly none of these aneurysms should be treated without the use of temporary occlusion of BA.

Temporary clipping is safe and useful when very low tension in the aneurysm is deemed essential for dissection, coagulation or clipping. For difficult aneurysms, especially large ones at the basilar bifurcation, and when one or both PCoAs are large, temporary trapping has been used by occluding one or both PCoAs during the BA occlusion. The opposite PCoA is usually seen unless the aneurysm fills the space. It is more convenient to leave the temporary basilar clip in place while removing and replacing the clip on a large PCoA to provide the intervals for reflow.

Dissection of the aneurysm base

There is a big difference if the BBA is projected forward (rare; may be attached to clivus when low),

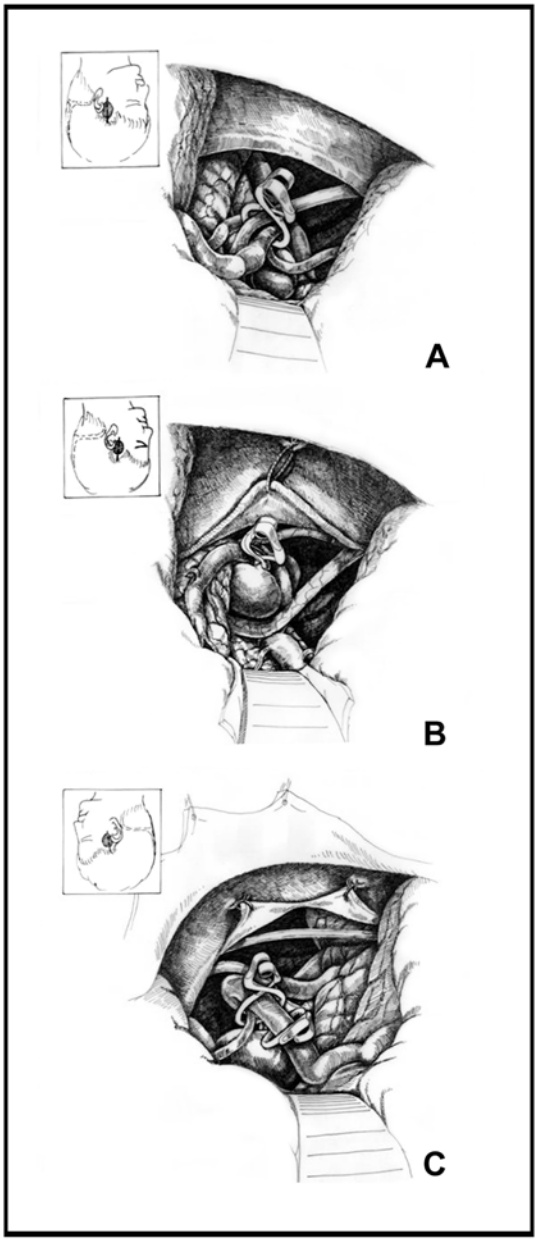

Fig. 2. (A) Schematic drawing shows the skin incision and a small left sided tic craniotomy, and the operative sketch after total occlusion of a basilar bifurcation aneurysm failed to be occluded by earlier coiling and pterional right sided approach. A short ring clip leaves P1–P2 and posterior communicating artery and third nerve inside the ring. (B) Schematic drawing shows the skin incision and small left sided tic craniotomy, and the operative sketch after total occlusion of a BA-SCA aneurysm with a curved microclip before opening and coagulating the aneurysm. The tenting suture has nowadays been replaced by a short straight microclip. (C) Schematic drawing shows the skin incision and small right sided tic craniotomy, and the operative sketch after total occlusion of a large basilar bifurcation aneurysm with two ring clips leaving P1–P2 and posterior communicating artery inside the rings. The tenting sutures have nowadays been replaced by short straight microclips

upwards (most common) or backwards (most difficult due to vicinity of the perforators). The front of the BA is cleared of clot gently upward across the ipsilateral P1 origin where the bulging of the anterior aspect of the neck of the aneurysm is first seen. If the clot can be sucked or teased away easily, the whole of the front of the neck and waist of the aneurysm can be exposed quickly. Occasionally, the clot is tough and adherent to a thin neck; then, only enough neck is cleared to accept the width of the clip blade. Depending on the bulge of the neck and the projection of the aneurysm, the opposite P1 can usually be seen by displacing the waist of the sac posteriorly with a dissector. This will confirm the angle the clip blades must take during application, and further, will often help to visualize the perforators arising from the opposite P1, as well as the opposite third nerve. Sometimes, it will be necessary to clear arachnoid with blunt or sharp dissection on the other side of the neck to see the opposite P1 origin clearly with its perforators.

The major difficulties with this aneurysm lie behind the sac. Rarely, it will stand free in the interpeduncular space; usually, it will be half buried in the interpeduncular fossa. Clearing the base of P1 behind will prepare the way for the important task of finding and separating the perforators. Gentle retraction of the crus is well tolerated and will expose the posterolateral aspect of the neck and waist of the sac, sucking or teasing away old clot if needed. Most of the perforators arise from P1 near its origin and course obliquely upward and backward on the side and back of the base and waist of the sac. They are often free or only lightly adherent to small sacs, but are usually adherent, sometimes densely, to large aneurysms. Not infrequently, one or more perforators arising from the upper BA course upward on the back of the neck. Getting behind the neck usually requires gentle retraction forward of the waist of the sac with the sucker tip, while using a small curved dissector to clear and separate any perforators clinging to the back of the neck. Usually, the perforators can be teased off, but occasionally one or more can be quite adherent to a thin-walled neck. More forceful dissection to free them is made less dangerous by temporary occlusion of BA. Ordinarily, the neck can be displaced forward far enough to see across the interpeduncular fossa to the opposite peduncle, the origin of the opposite P1 and the root of the opposite third nerve. Adherent perforators must be separated upward far enough so that the posterior clip blade can slip inside them without kinking or tearing their origin.

Clipping

The neck of an aneurysm is most completely obliterated when the clip blades fall across the neck in parallel with the parent bifurcation; then there is less risk of kinking P1, particularly with large necks. This ideal placement is more likely to occur with the subtemporal exposure, and is identical to the principles used to treat the much more common middle cerebral artery bifurcation aneurysms. Clips placed more perpendicular to this crotch often leave tags of neck in front and behind (“dog ears”), as the sides of the neck are approximated and the bifurcation crimped. “Dog ears” of residual neck can grow into new aneurysms in our “and others” experience.

The upward curve of P1 only stands free beside small aneurysms, but is usually adherent to larger sacs, often tightly. With the design of the fenestrated clip in 1969 by Drake, P1 can be left adherent to the sac, but open in the aperture while the blades fall across the neck of the aneurysm. Some perforators or the third nerve, too, may be included safely in the aperture. To obscure vision least during clip application, a very low profile clip applier should be used. The fenestrated ring beyond the applier tips tends to obscure vision in the narrow confines, especially behind the aneurysm. The clip blades must be no longer than the flattened, occluded neck or else the P1 origin(s) and its perforators may be stenosed or occluded. Exact measurement of the base in anterior-posterior projection of the aneurysm in CT angiography has proved very useful. A flattened neck is about 1.5 times the width of an open, circular neck (for example a 6 mm aneurysm base needs a clip with 9 mm blades for complete occlusion). Placing the clip too far out on the neck leave a part of the aneurysm base unsecured. The origin of the SCA may not be mistaken for P1, as inadvertent occlusion of the basilar bifurcation will occur. Not uncommonly a bit of the neck is left open in the aperture just medial to the P1 root. This is usually the cause of an aneurysm that still pulsates or bleeds on needling, although it must be certain that the clip tips cross to the far side of the neck. Repositioning of the clip a little higher or addition of a straight tandem clip may suffice to occlude the remaining neck. As the posterior blade is passed behind the neck, one must be certain that it is inside the perforators while using temporary basilar occlusion to soften a dangerously thin neck. As the blades are allowed to close and narrow the neck, the opposite P1 will come into view so that final alignment, flush with the neck at the upper origins of P1 on each side, can be made before final closure. The posterior blade must not be put too far across, for the root of the opposite third nerve courses up just behind the opposite P1 and can be brushed or actually injured by this blade. As for any aneurysm, immediate inspection is done in front of and behind the neck to determine whether each P1 is open and no perforators are caught or kinked by the blades. Rotating the clip handle forward usually exposes the posterior blade and looking just above the blade will determine whether or not any perforators emerge from underneath it. The clip must be removed and reapplied as many times as necessary for perfect placement. Not infrequently with the first placement, the blades will be too high or too low on the opposite side and it is sobering how often, when surely all the perforators have been seen and separated, one or more are still found caught under the blade.

If single fenestrated clip blades cannot be positioned perfectly without concern for the P1 origins or perforators, then shorter, fenestrated blades should be placed so as to occlude accurately the far two-thirds of the neck, leaving the near neck and P1 and perforators open in the fenestration. Usually then it is simple to separate this open but narrowed portion of the neck from P1 and the perforators, and occlude it by adding a tandem straight clip. This short clip may be applied in front of or behind P1 and the perforators while being certain that it crosses all the neck remaining open in the aperture of the first clip. Instead of using short blades for the tandem clip just to occlude the remaining neck in the fenestration, longer straight blades are used and worked across the whole of the neck, just beyond the fenestrated clip, which then can be removed. The straight clip blades then can be repositioned lower on the neck if necessary. This is of particular value if the fenestrated clip has slid down to obliterate the P1(s) or if the fenestrated blades cannot be positioned so as to occlude both sides of the neck. Provided they do not kink P1, straight blades are more satisfactory; there is no worry about any open near neck and without the obscuration of the fenestrated rings, the tips can be positioned very accurately on the far side of the neck. If the aneurysm base is thick, it may keep the blades of a long clip open on the far side to allow continued filling of the aneurysms. A tandem, fenestrated clip will close the far side of the neck. Because of the small gap and the clip handles, it may be difficult to needle and collapse the sac to prove completed clipping, but it should be done. When coming subtemporally, bipolar coagulation is occasionally useful to shrink and firm up bulbous or otherwise awkward necks of aneurysms, but the fear for occlusion of nearby or hidden perforators always remain. In clipping of SCA and proximal PCA aneurysms, the perforators are usually not of so much concern, but the height and direction of the aneurysm besides its size deserve careful preoperative planning.

Local papaverine is applied after clipping of the aneurysm. The wound is closed to the last stitch under microscope in several layers extremely carefully without leaving any drains.

Discussion

In 1958, the approaches to various segments of the basilar artery were worked out by Drake in the post-mortem room [2–4]. The anterior subtemporal approach across the floor of the middle fossa and tentorial edge into the mouth of the incisura in front of the midbrain seemed to provide the most direct and widest exposure of the interpeduncular region. Consequently, the subtemporal approach was used by Drake and Peerless in 1250 cases in their never-to-repeated series of 1767 patients with vertebrobasilar artery aneurysms (VBAAs) in 1959–1992. Eighty percent (80%) of the 1234 patients with basilar tip aneurysms were treated by subtemporal approach. The main reason for the use of frontotemporal approach for Drake and Peerless was the multiplicity with other aneurysms on the anterior circulation. Much of the merit of this approach is a matter of continued use and familiarity with the anatomy. There is an awkward far side of the operative field with its related difficulties by every approach [1–6, 8–11, 13–19]. The major difficulties with the basilar bifurcation aneurysm lie behind the sac. The advances of the subtemporal approach are that basilar tip aneurysms, especially their backside can be visualized simply and quickly regardless of their size, height, direction or multilocularity. The inner third of the tent can be divided for very low necks and placement of a temporary basilar artery clip, and there is no necessity to open the cavernous sinus, to remove the posterior clinoid or inner petrous apex. This approach has been used by the senior author also for posterior projecting ruptured carotid aneurysms. For associated middle cerebral, carotid bifurcation and anterior communicating aneurysms, the subtemporal exposure usually has been abandoned for the transsylvian approach. However, optic tract and trajectory above it are well seen during subtemporal approach, and it seems possible that at least some of the anterior communicating aneurysms could be clipped through this approach. On the other hand, the transmastoid-transpetrosal presigmoid approach, through a completely divided tentorium, has been used for difficult, large, low placed necks, as well for basilar trunk aneurysms.

In regard to temporary occlusion of basilar artery, the safe time for temporary basilar clipping in normothermia is unknown. Our experience indicates that three to four minute intervals are safe for any artery, and much dissection can be done in that time. The highly variable collateral circulation will be a major factor in the time element for each artery. Under barbiturates and Mannitol protection (1–2 gm/kg), up to ten minutes of single total occlusion times seems to be safe; between 10 to 15 minutes in small and large basilar bifurcation aneurysms the mortality and morbidity rised implying technically more difficult aneurysms.

Conclusion

The advantages of the subtemporal approach to the basilar tip aneurysms (especially their backside) are its simplicity and quickness regardless of the aneurysm size, height, direction or multilocularity. In addition, it is not necessary to open the cavernous sinus and remove the posterior clinoid or inner petrous apex. This classical approach is still most useful for the surgical treatment of basilar bifurcation aneurysms.

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