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Case Report

Keyhole clipping of a low-lying basilar apex aneurysm without posterior clinoidectomy utilizing endoscopic indocyanine green video angiography

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ABSTRACT

Background: Basilar apex (BX) aneurysms are surgically challenging due to their anatomic location, need to traverse neurovascular structures, and proximity to multiple perforator arteries. Surgical approaches often require extensive bone resection and neurovascular manipulation. Visualization of low-lying BX aneurysms is typically obscured by the posterior clinoid and upper clivus and poses a unique challenge. Subtemporal or anterolateral approaches with a posterior clinoidectomy are often required to achieve adequate exposure, though these maneuvers can add invasiveness, risk, and morbidity to the procedure. Endoscopes and, more recently, fluoroscopic angiography capable endoscopes offer the possibility of providing improved visualization with less exposure allowing for minimally invasive clipping.

Case Description: We present the case of a 42-year-old female with incidentally found 5 mm middle cerebral artery and 5 mm BX aneurysms. She underwent a minimally invasive supraorbital keyhole craniotomy for the clipping of both aneurysms. While the posterior clinoid obstructed the necessary visualization for the BX aneurysm, use of endoscopy and endoscopic fluoroscopic angiography allowed for safe and successful clipping without the need for a posterior clinoidectomy.

Conclusion: This represents the first reported case of a BX aneurysm clipping through a minimally invasive keyhole craniotomy using endoscopic indocyanine green video angiography. Use of endoscopic indocyanine green angiography, combined with keyhole endoscopic approaches, allows for safe minimally invasive clipping of challenging posterior circulation aneurysms.

Keywords: Basilar apex aneurysm, Endoscopic indocyanine green, Endoscopic surgery, Keyhole craniotomy, Minimally invasive aneurysm clipping

BACKGROUND

Basilar apex (BX) aneurysms are anatomically situated in one of the most challenging areas for a neurosurgeon to access. While the array of endovascular tools used to treat various aneurysms and the proportion of aneurysms treated through such procedures increases, there continues to be a certain subset of patients with BX aneurysms who could benefit from clipping.[18,19] In these patients, it is critical to reduce morbidity while maintaining or improving on the established success of traditional surgical clipping. Intraoperative fluoroscopic indocyanine green video angiography (ICG-VA) is a well described and widely used method to evaluate the vasculature and aneurysm before and after clip placement. Its use, however, has traditionally been limited to a microscope ICG-VA (mICG-VA) which requires surgical exposure of the field of interest to accommodate the view from a microscope. Recent advances in endoscopic technology have allowed for the use of intraoperative ICG-VA with an endoscope ICG-VA (eICG-VA). Thus far, the application of eICG-VA in neurovascular surgery has been limited to an adjunctive role, providing a final-look confirmatory view to ensure clip placement is satisfactory. As a result, the full potential of the technology has not yet been explored, particularly its role in reducing the invasiveness of surgical clipping. We describe and review the technical nuances of the first reported case of a BX aneurysm clipping through a minimally invasive keyhole craniotomy using eICG-VA which obviated the need for a posterior clinoidectomy.

CASE REPORT

A 42-year-old female presenting with headaches was found to have a 5 mm laterally projecting right middle cerebral artery (MCA) bifurcation aneurysm and a 5 mm BX aneurysm [Figure 1]. Given the patient's young age, surgical treatment was offered as an alternative to endovascular treatment. After discussion of the risks and benefits, the patient opted for a minimally invasive supraorbital keyhole craniotomy for clipping of both aneurysms.

Preoperative computed tomography angiography (CTA) evaluation of the patient's aneurysms revealed aneurysms amenable for surgical clipping through a supraorbital keyhole approach (SOKA). The MCA bifurcation aneurysm was noted to be at the level of the lesser wing of the sphenoid bone and evaluation of the anatomical accessibility of the BX aneurysm was determined using the orbital roof-dorsum estimation line as previously described.[31] Briefly, the elevation of the orbital roof off the anterior skull base is determined in the coronal plane which is then translated on to the midsagittal plane; this point is then extended to the top of the posterior clinoid and continuing until it reaches the basilar artery (BA) determining the most superior exposure of the BA. Utilizing this line, it was estimated that the superior most exposure through the SOKA would be the neck of the aneurysm with further inferior exposure afforded by the superior extent of the craniotomy off the roof of the orbit [Figure 2].

Operation

The patient was positioned supine and the head was placed in three-point fixation. A right-sided approximately 5 cm eyebrow incision was made extending from the supraorbital notch to just lateral to the superior temporal line [Video 1]. A 2 cm × 1 cm craniotomy was made above the orbital rim. A curvilinear dural incision was made and the frontal lobe gently dissected off the anterior skull base without the use of fixed retractors. The opticocarotid cistern was opened to release cerebrospinal fluid (CSF) and facilitate brain relaxation. The Sylvian fissure was then dissected to expose the MCA bifurcation aneurysm. A right-angled clip was applied and placement was confirmed with mICG-VA using a 0.5 mg/kg bolus of ICG [Figure 3]. Attention was then turned to the BX aneurysm. Arachnoid dissection around the optic nerve was performed to allow unencumbered access into the opticocarotid and carotidoculomotor triangles. Through the carotidoculomotor triangle, Liliequist's membrane was opened until the aneurysm dome was identified. The aneurysm dome and neck were visible; however, the more proximal BA and perforator origins were obscured by the posterior clinoid. A 0 degree, 4 mm outer diameter, ICG capable endoscope (Storz; Tuttlingen, Germany) was introduced through the opticocarotid window (OCW) allowing complete visualization of the more proximal BA and

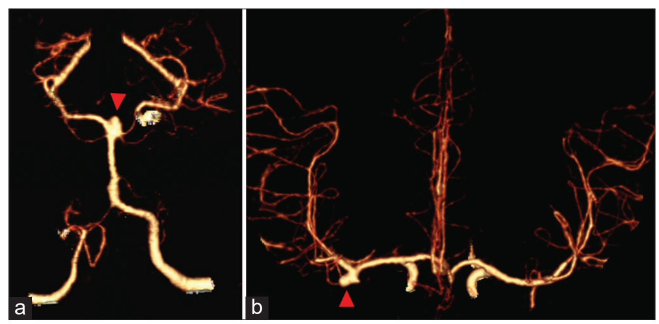

Figure 1: Three-dimensional reconstruction of a computed tomography angiogram. (a) Posterior circulation demonstrating basilar apex aneurysm (arrowhead) (b) anterior circulation demonstrating right middle cerebral artery aneurysm (arrowhead).

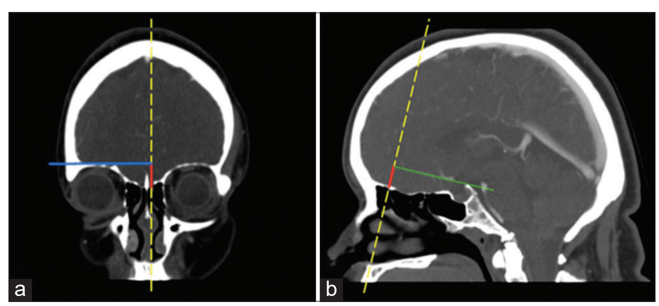

Figure 2: Orbital roof-dorsum estimation line. (a) Orbital height (red line) as measured by the line extending from the anterior skull base along the sagittal scout line (yellow line) to the intersection with the horizontal orthogonal line (blue solid) from the roof of the orbit to the sagittal scout line (b) orbital height line as determined on coronal section translated onto the coronal scout line in the sagittal plane with the orbital roof-dorsum estimation line (green line) extending from the superior point to the top of the posterior clinoid process. In this patient, this line estimates that the most conservative proximal exposure from a supraorbital approach is the neck of the aneurysm.

perforator origins. Another bolus of ICG was administered and the aneurysm was inspected with eICG-VA. A posterior clinoidectomy was considered but ultimately deemed unnecessary given the improved visualization. Adenosine was available, if necessary, for intraoperative rupture. After careful dissection of the perforators off the aneurysm neck, a straight blade aneurysm clip was placed under a microscopic view. Postclipping inspection of the aneurysm utilizing eICG-VA demonstrated good exclusion of the aneurysm with no neck remnant and intact parent and perforator vessels [Figure 4].

Postoperative course

Postoperative CTA confirmed adequate placement of clips with no residual [Figure 5]. Patient recovered well and was discharged on a postoperative day 2 with no short- or long-term complications or neurologic deficits at 3-month follow-up.

CONCLUSION

Aneurysms of the BX represent some of the most challenging aneurysms for the neurosurgeon. They are situated deep within the intracranial space and bound by neurovascular structures and critical perforators. While there has been a shift toward treating a majority of these aneurysms through endovascular techniques, there remains a subset of patients for whom surgical clipping continues to be the ideal treatment including those with wide-necked or small aneurysms, those who have failed endovascular treatment, and younger patients where a more definitive upfront treatment is desired.[18,19] As such, the continued development and tailoring of traditional surgical clipping techniques to minimize the invasiveness and morbidity and maximize optimal outcomes continues to be of interest.

Critical to the success of any aneurysm surgery is the ability to completely include the aneurysm neck with the surgical

Figure 3: (a) Surgical exposure and treatment of the middle cerebral artery aneurysm (b) aneurysm clip placement (c) microscopic indocyanine green angiography demonstrating aneurysm occlusion and vessel patency. MCA: Middle cerebral artery, *: Aneurysm.

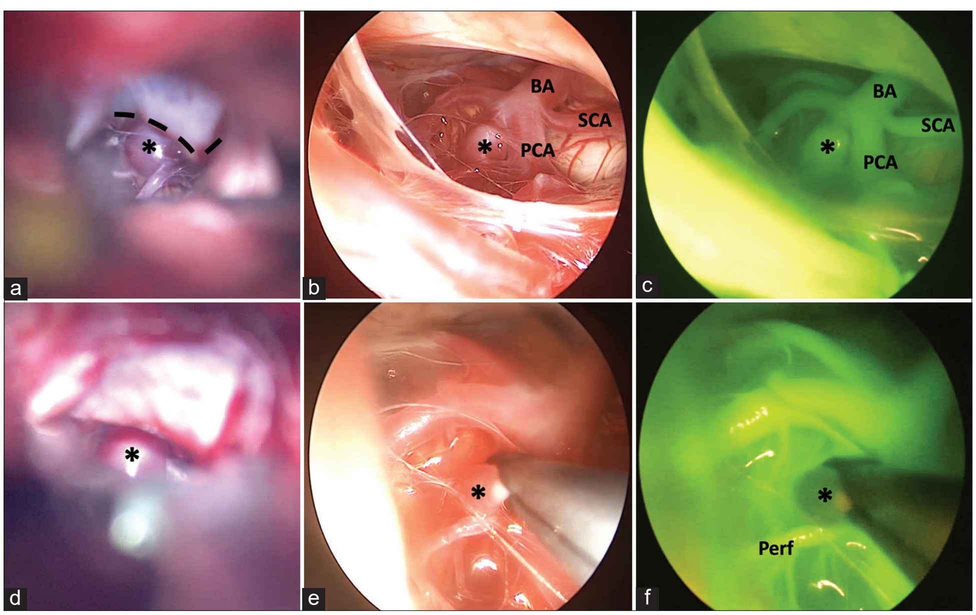

Figure 4: Basilar apex aneurysm (a) microscopic exposure through oculomotor carotid window obstructed by the posterior clinoid (dashed line) (b) endoscopic exposure (c) endoscopic indocyanine green angiography (d) aneurysm clip placement (e) endoscopic view of clip construct (f) endoscopic indocyanine green angiography demonstrating complete aneurysm obliteration with maintenance of perforating arteries. BA: Basilar artery, SCA: Superior cerebellar artery, PCA: Posterior cerebral artery, Perf: Perforator artery, *: Basilar apex aneurysm.

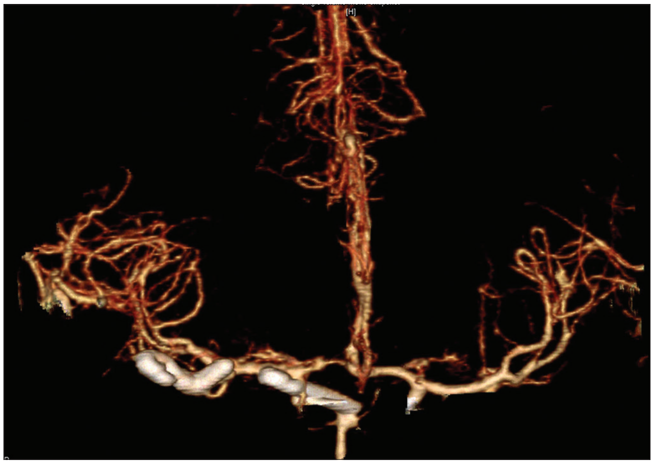

Figure 5: Three-dimensional reconstruction of a computed tomography angiogram demonstrating clipping of the right middle cerebral artery and basilar apex aneurysms.

clip while maintaining patency of the parent vessel and perforators. Intraoperative strategies to achieve this include electrophysiological monitoring, microDopplers, digital subtraction angiography (DSA), and ICG-VA.[10,24,35] While intraoperative DSA remains the gold standard for evaluating postclipping success, it adds significant intraoperative time and potential morbidity given its invasive nature.[4,15,20,32] Furthermore, the lack of widespread capability to perform intraoperative DSA precludes it from being more generally applicable to some practices. ICG-VA offers many distinct advantages due to its simple and non-invasive ability to directly visualize flow, or lack thereof, within the vasculature after clipping and showing superiority in visualizing small perforators when compared with DSA.[6] Since the conception of fluorescence microscopy by Feindel *et al.* in 1967 and its first use in aneurysm surgery by Raabe *et al.* in 2005, it has become an indispensable tool in assessing proper clip placement. Prior studies have shown that the use of mICG-VA leads to clip modifications in up to 38% of cases.[6,8,27,29] Essential to ICG-VA is the need for a direct visual line of sight from the microscope to the area of interest and a large enough exposure to allow sufficient fluorescent light to bathe the field. As a result, mICG-VA is only as applicable as the surgical exposure the approach provides.

Classically, approaches to BX aneurysms were through subtemporal, pterional, or orbitozygomatic craniotomies. While the subtemporal approach offers a shorter working distance and a more exposed view of the proximal BA, which can be useful for low lying BX aneurysms, it is significantly limited by the inability to visualize contralateral perforators as well as the need for temporal lobe retraction.[17,33,37] The pterional and orbitozygomatic approaches provide visualization of bilateral perforators off the BX through either the OCW or carotid-oculomotor window (COW). These neurovascular "gateways" become optical bottlenecks for the microscope, limiting the field of view deep to them. Low-lying BX aneurysms are further obscured by the posterior clinoid process. This restricted window presents a challenge when utilizing mICG-VA. To overcome this, a host of adjuncts to these approaches has been utilized including orbital osteotomies, anterior clinoidectomy, ICA mobilization, and posterior communicating artery and tentorial transections. These techniques increase the working areas of the OCW and COW.[3,7,13,16,17,21,34,38] In addition, a posterior clinoidectomy can be performed for low riding BAs where the aneurysm lies within the shadow of the clivus and posterior clinoid process.[7,17,30,38] These techniques to increase exposure, however, come with risks of CSF fistulas, oculomotor and abducens nerve palsies, vascular injury, and intraoperative hemorrhage.[17,38]

Improved exposure and visualization of deep-seated structures can alternatively be achieved using endoscopes. By advancing the ocular lens past visually obstructive proximal structures and through the OCW or COW, these gateways become pivot points for the camera rather than bottlenecks.[22] The closer wide-angled view of the aneurysm afforded by the use of the endoscope allows for a closer inspection of the aneurysm neck, perforators, parent vessels, and, ultimately, clip placement.[12,14,25,28,36] However, despite the superior visualization afforded by the endoscope, the use of endoscopes has still been limited by the microscopic exposure and field of view, as postclipping ICG assessment had only been available through the microscope. This meant that endoscopes could only be used as an adjunct rather than a true visualization tool that could help reduce the necessary surgical exposure since anything performed under endoscope outside the microscope field would not be confirmable through mICG-VA.

In 2013, Bruneau *et al.* described the first reported use of eICG-VA in aneurysm surgery for a patient with an unruptured anterior communicating artery aneurysm.[1] eICG-VA was used as an adjunct to the mICG-VA. The development of fluoroscopy-enabled endoscopes has further improved the success of the surgical treatment of aneurysms offering superior angiographic evaluation over mICG-VA. As a confirmatory test, eICG-VA allows for a closer inspection of the vasculature and the ability to see around "dead angles" inaccessible to the microscope leading to reported clip readjustments after mICG-VA-assisted clipping in as high as 40% of cases.[1,2,5,9,11,23,26]

There have been relatively few studies on the use of eICG-VA and most studies to date offer an evaluation of eICG-VA as compared to mICG-VA. As such, surgical exposure was achieved to allow for mICG-VA evaluation and only then was eICG-VA deployed to further scrutinize clip placement.[1,2,5,9,11,23,26] This approach, however, does not maximize the potential of eICG-VA as it does not utilize the endoscope to minimize the exposure itself. Furthermore, there have been exceedingly few reports on the use of eICG-VA in the treatment of posterior circulation and BX aneurysms with only five reported cases of BX aneurysms – all treated through a subtemporal or pterional approach.[9,11]

In this report, we describe the first minimally invasive keyhole approach for the surgical clipping of a BX aneurysm using eICG-VA. As with any aneurysm clipping, but paramount in BX aneurysms, careful evaluation of preoperative imaging studies as well as a strong understanding of the anatomy is critical to the success of the surgery. Furthermore, knowing the individual strengths and limitations of both the microscope and the endoscope allows you to use them in a complementary fashion to reduce unnecessary exposure and morbidity while maintaining the quality of clip placement. In this case, we were able to estimate the amount of BX exposure we would achieve with a supraorbital approach.[31] This estimation was confirmed intraoperatively and, as predicted, visualization of the BA beyond the aneurysm neck was not adequate under the microscope. Using an endoscope allowed substantially increased visualization that obviated the need to perform a posterior clinoidectomy. This shortened the length of the procedure reduced the invasiveness and eliminated potential risks. Since that visualization could only be achieved with endoscopy, use of mICG-VA would be insufficient postclipping to confirm satisfactory placement. The availability of eICG-VA then gave us the ability to perform the clipping knowing that we could obtain an expanded angiographic assessment provided by the endoscope. Of note, obtaining proximal control in an endoscopic environment may be more challenging and therefore adenosine should be available.

While endovascular technology continues to evolve, there remains a subset of aneurysms that could benefit from definitive surgical clipping. The full use of surgical technology such as endoscopes and eICG-VA can allow for reduced invasiveness and morbidity while maintaining efficacy in treatment.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Conflicts of interest

There are no conflicts of interest.

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