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Technical Note

Technical nuances of subtemporal approach for the treatment of basilar tip aneurysm

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Abstract

Background: Basilar tip aneurysms are one of the most complex vascular lesions to treat surgically because of their location, depth of the approach, and close proximity of vital neurovascular structures such as the mesencephalon, cranial nerves, perforating arteries to the thalamus. There are different surgical approaches utilized to reach basilar tip aneurysms, namely, pterional, pretemporal, orbitozygomatic, subtemporal, and anterior petrosectomy. Each of them has its advantages and limitations.

Methods: In this paper, we present our personal experience with the use of subtemporal approach. The technique is described in detail including its nuances and potential pitfalls.

Results: The subtemporal approach is indicated for basilar tip aneurysms located at the level of the floor of the sella turcica to 1 cm above the dorsum sellae.

Conclusion: Subtemporal approach offers good surgical corridor for the management of these complex vascular lesions.

Key Words: Aneurysmal clipping, basilar artery aneurysms, Osirix software, subtemporal approach

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INTRODUCTION

Posterior circulation aneurysms account for approximately 15% of all intracranial aneurysms, however, when ruptured are related to higher morbidity and mortality due to their location deep within the brain and close proximity to vital neurovascular structure.[11,31] As an incidental finding, their natural history is known to be related with a higher risk or rupture, dependent of their size.[11,31] Therefore, when diagnosed even as an incidental finding, these lesions have to be treated. In recent years, endovascular management has become the mainstay treatment modality for these lesions after the results from the studies ISAT and BRAT.[18,28,29] However, microsurgical clipping, in expert hands, still offers comparable long-term results to the endovascular modality with a higher rate of permanent occlusion, and thus, still has to be regarded as a viable treatment option.[9,10,14,27-29]

There are various surgical approaches described for the treatment of basilar tip aneurysms, such as pterional, pretemporal, orbitozygomatic, transcavernous,

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subtemporal, anterior and petrosectomy.[1,4-6,13,16,19,20,25] Each offer particular advantages and limitations. Herewith we present our experience with subtemporal approach for the treatment of basilar tip aneurysm. The technique is described in detail with emphasis on the technical nuances and potential pitfalls.

RELEVANT SURGICAL ANATOMY

The floor of the middle cranial fossa is formed by the tentorium, the superior surface of the petrous bone, and the intracranial surface of the greater sphenoid wing. In axial plane, the middle fossa floor is on the same level as the superior surface of the root of the zygomatic arch. The interpeduncullar cistern is projected in coronal plane on the temporomandibular joint because the anterior border of the cistern corresponds to the posterior third of proc. mandibulars of the zygomatic arch.[22,23]

The main structure forming the interpeduncular cistern is the Lilliequist membrane.[3,7] In the sagittal plane, it is composed of three parts. Two of them, i.e., sellar and diencephalic part constitute one of the components, which projects obliquely upward from the diaphragm of sella turcica (dorsum sellae) to the mammillary bodies. The third part, called the mesencephalic, forms the second plane and is projected as a curtain in front of the interpeduncullar fossa and reaches the pontomesencephalic sulcus, where it borders the prepontine cistern in the caudal plane.[3] Laterally, interpeduncullar cistern borders with the ambient cistern where P2 branch of the posterior cerebral artery (PCA) is found. As a border between the two cisterns, most authors indicate the third cranial nerve, which is the lateral limit of the Lilliequist membraine, and the nerve itself is found in the interpeduncullar cistern. Therefore, the interpeduncullar cistern is limited between the space of the two oculomotor nerves in the axial plane and between the pontomesencephalic sulcus and the mammillary bodies in the sagittal plane.

The high of the basilar artery bifurcation is individual, however, in 87% of the adult population, it is located 1 cm below or at the level of dorsum sellae [Figure 1a].[32] The PcomA length is important because it limits the surgical window above PCA, where the aneurysmal fundus is located. Moreover, the probability of adhesions between the aneurysm and the PcomA is far more common with shorter PcomA. The distance between the PCA and SCA roots is 1–3 mm average, however, PCA is at a supratentorial location, as SCA is infratentorial.[32] The distance between the origins of the two arteries is significant for the possible use of a temporary clip on the BA between the two arteries. In average, 8 (3–18) perforating arteries arise from the posterior and lateral part of the BA, as the majority of them branch 5 mm from the artery trunk [Figure 1b].[22] The perforating arteries from the P1 segment of PCA are less (average: 4) and branch from the superior and posterior surface of P1, and very rarely from the anterior surface of the artery.[26]

The trochlear and the oculomotor nerves has parallel trajectory. The trochlear nerve is located dorsal and lateral compared to the oculomotor nerve. The oculomotor nerve pierces the dura mater of the cavernous sinus in the area of the oculomotor triangle [Figure 1c].[23] The trochlear nerve pierces the inferior surface of the tentorium approximately 9 mm behind the entrance point of the oculomotor nerve. After that, the nerve courses in the edge of the tentorium anterior and lateral to the lateral wall of the cavernous sinus and enters the sinus lateral of the oculomotor nerve.[23]

PREOPERATIVE CONSIDERATION

A detailed preoperative radiological evaluation is planned including computed tomography angiography (CTA), digital subtraction angiography (DSA) (in all ruptured basilar tip aneurysms), and magnetic resonance imaging (MRI) (in nonruptured aneurysms). The aneurysm anatomy is studied in relation to its position, dome configuration and location, neck size (length of the aneurysm clip planning), and anatomy of the ipsi/contralateral PcomA (use of fenestrated clip). The location of the aneurysm in relation to the posterior clinoid process is very important – very high riding

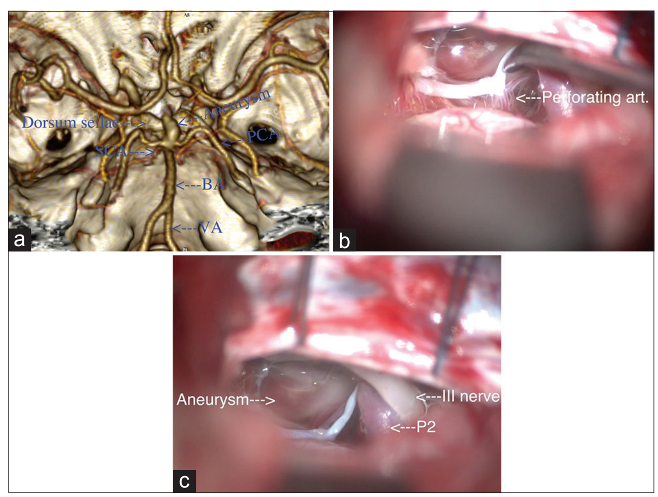

Figure 1: (a) Three-dimensional reconstruction using OsiriX software[24] presenting the anatomy of the basilar artery and an associated basilar tip aneurysm. Note the relation between the aneurysm and dosum sellae (posterior clinoid process), which is important in the preoperative evaluation of the correct surgical approach. (b) View through right-sided subtemporal approach. A brain retractor is placed on the mesial temporal lobe. Two retraction sutures are placed on the tentorium. The aneurysm is visualized. Note the fine BA perforating arteries to the thalamus, which have to be protected during clip placement. (c) Right-sided subtemporal approach. The third nerve is visualized as it enters the dura in the oculomotor triangle

aneurysm might not be suitable for subtemporal approach and may require pterional, OZ or pretemporal approach; on the contrary, very low riding aneurysms might require anterior petrosectomy technique in order to reach the lesions [Table 1].

The Digital Imaging and Communications in Medicine (DICOM) files of 1 mm thickness and non-overlapping CTA slices are imported into OsiriX open-source imaging software (Version 5.8.1; free download from http://www.osirix-viewer.com/) on a mid. 2011 model Apple MacBook Pro computer (Apple, Inc.) running OS X.[24] We use the OsiriX software in order to carefully simulate the patient positioning during surgery, visualize the superficial vascular anatomy (STA and its branches), simulate the craniotomy and measure its size, and navigate intracranialy to see the relationship between the aneurysm, other associated vessels, and bone structures [Figure 2]. We find this approach particularly useful in preoperative planning and as a teaching tool for young residents unfamiliar with this complex approach and the related anatomy [Video 1].

Using OsiriX software and its functions in three-dimensional (3D) volumetric rendering, one can easily recreate the craniotomy in the 3D work screen. There are two main possible functions:

- utilizing the "Crop" tool with the cropping cube; by reducing the walls of the cube one can recreate a bone window to the aneurysm
- Using the "Clipping mode" where one could represent only the desired corridor to the lesion, and have a much better understanding of the lesion itself by selectively eliminating the surrounding tissues.

Table 1: Indications and limitations of the subtemporal approach for the treatment of basilar tip aneurysms

Indications	Limitations
(1) The high for the basilar bifurcation from the level of the basilar bifurcation to 1 cm above dorsum sellae (2) Nonbled aneurysms of the basilar tip (3) Bled aneurysms of the basilar tip in patients with Hunt and Hess I-II	Clinical limitations: Acute SAH in patients III-V grade Hunt and Hess owing to difficulties and very traumatic temporal lobe retraction Multiple aneurysms-in this case, the trans-silvien route allows for concomitant clipping of the other associated aneurysms Localization A low riding basilar tip aneurysm, below the sella turcica, where the anterior petrosectomy approach can be more appropriate High riding basilar tip aneurysm above the sella turcica (>1 cm) where the orbitozygomatic approach could be more appropriate

These two techniques are very fast and can provide a lot of useful information regarding the anatomy of the aneurysm. Detailed description of the technique of 3D reconstruction in OsiriX is not the subject of this paper and can be found elsewhere.[12,15,17]

DESCRIPTION OF THE SURGICAL TECHNIQUE [VIDEO 2]

We use the lateral position with the superior part of the operating table tilted as the patient's head is above the level of the heart.[16] The sagittal suture is positioned parallel to the floor of the operating theater and the vertex is tilted 10–15° to the floor. This position facilitates adequate venous flow. We routinely place spinal drainage for brain relaxation and to reduce temporal lobe trauma [Figure 2].

CRANIOTOMY

The surgical incision is of a "question mark" type, followed by interfascial temporalis dissection,[21,30] exposure of the superior surface of the zygomatic root, and retraction of the temporalis muscle anterior and towards the cranial

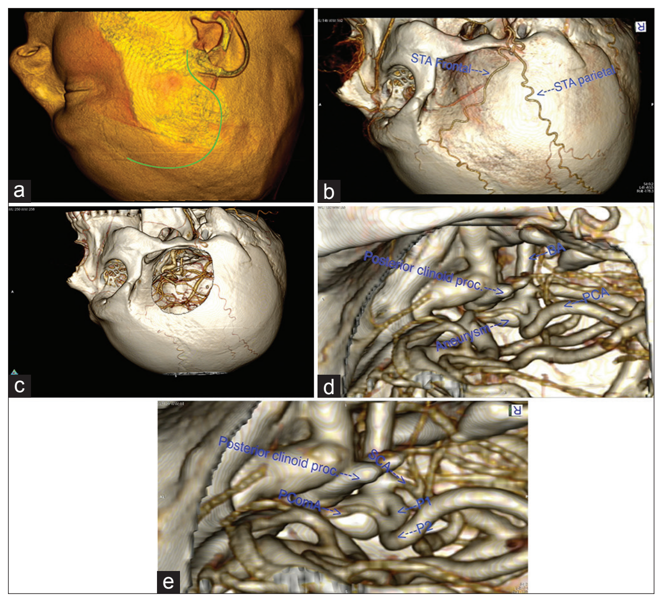

Figure 2: (a) Preoperative simulation of the patient's head positioning and skin incision using OsiriX software.[24] The skin incision is of "question mark" type starting from the root of the zygoma, close to the tragus of the ear, continues superiorly, and curves above to superior temporal line, ending just behind the hairline. (b) The superficial vascular anatomy of the SCA is presented, which can be preoperatively visualized and spared intraoperatively. (c) Preoperative simulation of the approach using OsiriX software.[24] The craniotomy is 5/5 cm dimensions, located below the superior temporal line, and centered in the coronal plane above the root of the zygoma. (d and e) View through surgical perspective of the aneurysm and the associated vascular/bone anatomy. Note the position of the P1 and SCA (temporary clip placement), posterior clinoid process, PcomA and P2, which are all important for the correct planning of the approach and surgical strategy

base. When necessary, we utilize a small incision of the temporalis muscle parallel to the zygomatic arch and behind it. In this manner, the soft tissue dissection is lengthier in comparison of the linear skin incision used by Drake,[20] however, the working area is increased and the venous oozing from the muscle is reduced.

The craniotomy is 5/5 cm in dimensions, located below the superior temporal line and centered in the coronal plane above the root of the zygoma [Figure 2]. Using Kerrison punches and high-speed drills, the craniotomy is extended in the basal direction and anteriorly as the edges reach the floor of the middle cranial fossa and the temporal pole. With high-speed drill, the high of the zygomatic arch is decreased in order not to interfere with the surgical corridor to the middle fossa. If any mastoid air cells are opened, they have to be thoroughly waxed in order to avoid postoperative cerebrospinal fluid (CSF) leaks. Thus, the craniotomy is centered more anteriorly in comparison to the standard subtemporal craniotomy and is a predisposition of potentially increased temporal lobe retraction. However, it has greater chances of decrease for potential injury to the vein of Labbé, and projects the surgical visual field anteriorly, increasing the chances for earlier visualization of the contralateral P1.

ARACHNOID DISSECTION

We incise the dura C-shape fashion centered toward the cranial base. The intradural part of the operation is done under microscopic magnification. After evacuation of approximately 40 ml of CSF from the spinal drainage, the temporal lobe is gradually retracted. We use wide 1.2 cm brain spatula placed on the level of the root of the zygoma. The Labbé vein is located dorsally and is at a sufficient distance from the working field in order not to be retracted and exposed to injury. Other small venous tributaries from the temporal lobe to the middle cranial fossa that interferes with the surgical corridor to the aneurysm could be coagulated and sectioned. Using scalpel No. 11 the arachnoid of the ambient cistern is incised. This allows for more release of CSF and additionally reduces the temporal lobe retraction. After opening of the ambient cistern, the P2, SCA, and between them the oculomotor nerve can be identified. We widely open the arachnoid above the nerve in order to visualize the PcomA and its perforating arteries, which point superior and posteriorly. Medial to the third cranial nerve a thickened arachnoid is usually found composed of two layers, which is actually the lateral wall of the interpeduncullar cistern. After incision of this arachnoid, the aneurysmal fundus is visualized. At this moment, we cease the dissection in this direction and point our attention towards the space below and posterior to the third cranial nerve to provide access to the basilar artery (BA) and the aneurysm. Most often during the dissection below the nerve, the space is limited from the tentorial edge [Figure 3]. In order to avoid this limitation, we place two sutures on the tentorial edge and pull the tentorium in a lateral direction as we suture it to the middle cranial fossa. By this maneuver, we visualize the posterior clinoid. Other authors used different techniques including holding the incised tentorial edges with aneurysm clips.[8]

Following the SCA in the medial direction and the incision of the abovementioned thickened arachnoid, defining the lateral edge of the interpeduncular cistern below the third cranial nerve, the BA is reached, as well as the SCA, P1, and the aneurysmal fundus. In this manner, two working channels are formed – below and above the III cranial nerve. Above the oculomotor nerve, a space is formed which is limited by the uncus of the parahypocampal gurys, posterior clinoid process, and the mammillary bodies. In the superior space PcomA, P2 and the perforating arteries are located. In the inferior working space, the SCA and the BA are found. The location of the aneurysmal neck and the beginning of the P1 depends on the high bifurcation of the BA and the bifurcation angle of both P1 arteries. Depending on the direction of the aneurysm, the aneurysmal fundus can be: (1) Adherent to the sella turcica (in case of aneurysm pointing anteriorly), (2) mammillary bodies and hypothalamus (aneurysm pointing superiorly), and (3) mesencephalon (aneurysm pointing posteriorly).

ANEURYSMAL DISSECTION

The aneurysm dissection starts from its neck. Adhesions are rarely located around the neck, independent of

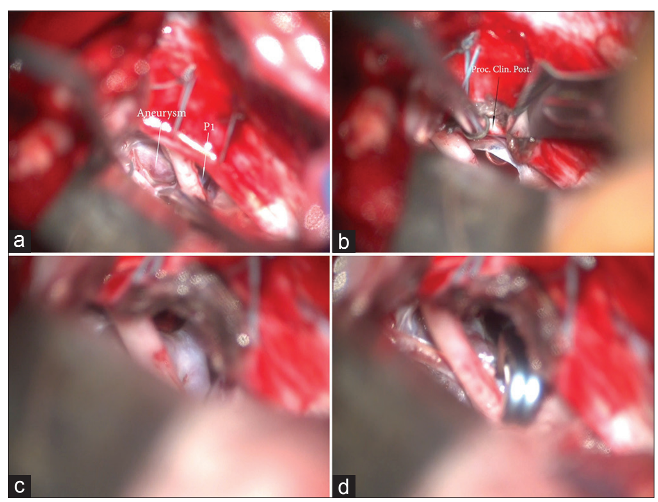

Figure 3: (a) Surgical view through right subtemporal approach. Two sutures are placed on the tentorium. The basilar tip aneurysm is visualized as well as the P1. Between them the oculomotor nerve courses and pierces the dura in the oculomotor triangle. (b) Splitting of the tentorium between the two sutures. This maneuver increases the visualization and exposes the posterior clinoid process. (c) After the tentorium is split, the neck of the aneurysm is exposed, as well as P1. (d) Surgical view after successful clip placement

the direction of the aneurysmal sac. According to our experience, there is always space between the aneurysmal neck and the mesencephalon posteriorly, as well as the aneurysmal neck and dorsum sellae anteriorly.

In order to dissect the perforating vessels located behind the aneurysmal neck, we develop the arachnoid plane above ipsilateral P1 using microscissors, microdissector, and ball angle microdissector. Exposing the anterior and inferior surface of P1, an arachnoid plane is created, which is continued towards the BA and the aneurysmal fundus. Following this plane, it is easy to dissect the aneurysm neck from the arachnoid in the following order: (1) Ipsilateral – from the ipsilateral P1; (2) anterior – from the dorsum sellae with attention to dissect the aneurysm neck only, without the fundus, as the later can be adherent to the dorsum sellae; (3) posterior –the arachnoid together with perforating vessels as curtain is detached from the aneurysmal neck as the arachnoid serves as a protective layer for perforating arteries; (4) contralateral – with the angle ball-tip dissector anterior and posterior corridors are developed in contralateral direction around the aneurysm neck, as this manoeuver should be done very carefully to avoid premature aneurysm rupture. During the dissection of the contralateral site of the aneurysm, an attempt can be made to palpate the contralateral P1 to find free space between the aneurysm neck and the contralateral P1.

Keeping the dissection close to the wall of the aneurysm neck allows mobilizing the contralateral arachnoid together with the contralateral P1 perforating arteries away from the aneurysm neck. If the aneurysm is pointed posteriorly, the dissection behind the aneurysmal neck requires careful retraction of the cerebral peduncle because the aneurysm is embedded in the interpeduncullar fossa and there is no visibility. When the bifurcation angle of the BA is sharp, it is not always possible to perform the above described dissection due to adhesions of the ipsilateral and/or contralateral P1 towards the neck and the fundus of the aneurysm. In such cases, we dissect the space in front of P1 and the aneurysmal neck, and after that behind the ipsilateral P1 and behind the perforating arteries of P1. This dissection space is created behind the aneurysmal neck and the perforating arteries of P1, and in front of the perforating arteries of the BA in order to place fenestrated clip. The aneurysm clip window envelops the ipsilateral P1 together with its perforating vessels and the perforating vessels of the BA are left behind the clip towards the mesencephalon. It is important to dissect the perforating vessels behind the aneurysm at a sufficient distance of their length in order not to be bended or kinked by the aneurysm clip.

CLIPPING OF THE ANEURYSM

When the dissection of the aneurysm neck is completed from every site, a pilot clip could be placed. The aneurysms of the basilar tip are characterized by a wider neck in the coronal plane than in the sagittal plane.[20] Therefore, placement of the clip in the coronal plane is the optimal way to clip these aneurysms. The subtemporal approach provides such optimal positioning of the clip placement, and we consider that this a particular advantage of this surgical route for basilar tip aneurysms. Before clip placement, a decrease in the optical magnification is preferable to provide a panoramic view and visualization of all the components of the working canal. We use a straight clip according to the length of the neck of the aneurysm. According to the direction of the aneurysm and bifurcation angle, the use of a straight fenestrated clip with window size of 5 mm can be used. We generally use such clips in cases of sharper bifurcation angle and with aneurysms pointing posterior and superior. We place the aneurysm clip very slowly with a gradual opening and advance the clip deeply as we aim to exert the same pressure to the aneurysm with the two clip branches, otherwise the risk of aneurysm kinking with subsequent rupture is high. After placement of the pilot clip, we revise its position with the use of a dissector, and under a direct visual control and higher optical magnification with great attention towards the tips of the clip as well as contralateral P1 and contralateral perforating vessels. According to our experiences, it is easier to observe in front of the aneurysm because with dissector the aneurysm base is gently compressed in order to acquire contralateral visualization. When we doubt incomplete aneurysm occlusion or kinking, as well as occlusion or kinking of the contraltateral P1 or perforating vessels, we reposition the clip. After successful aneurysm clipping, we puncture the aneurysm fundus using a 27 G needle, which induces very little opening of the fundus. This facilitates, in case of incomplete clipping, easier control of the bleeding with placement of piece of cotton above the bleeding site.[2]

IN CASE OF INTRAOPERATIVE RUPTURE, WE DO THE FOLLOWING STEPS [VIDEO 3]

(1) We place the clip above the aneurysm neck, independent of the rupture site; (2) If this manoeuver is unsuccessful, we place a temporary clip on the BA, as the place of the temporary clip position is between the BA and SCA or proximal to the SCA; (3) If the bleeding continues, we make an attempt to dissect the aneurysm in the area of the rupture to visualize the opening of the rupture from every possible angle. We control the bleeding using the aspiration cannula and place a miniclip on the rupture site; (4) After cease of the bleeding, we dissect the aneurysm neck and place a clip over it and removing all the temporary clips. After we have assured successful clipping, we wait for controlled

increase of the systolic pressure to at least 20 Torr above the normal systolic pressure of the patient.

COMPLICATION AVOIDANCE

- The preoperative angiographic evaluation of the position of both P1 – the Towne view is very useful.
- Lateral position for better venous outflow and control of the spinal drain.
- Sharp and wide dissection above and below the third cranial nerve in order to create two wide working fields in case of intraoperative aneurysm rupture.
- Following of the arachnoid plane consequently towards the wall of ipsilateral P1, the wall of BA, aneurysm neck, and fundus.
- Dissection of the perforating vessels behind the aneurysm on sufficient distance of their length in order to avoid their bending or kinking.
- Dissection and clipping of the aneurysm neck without temporary occlusion of the BA. We utilize temporary occlusion only in cases of impossible dissection despite the use of all the abovementioned techniques.
- Clipping through the space above or below the third cranial nerve depending on the height of the bifurcation of the BA and the bifurcation angle of the artery.

COMPARISON WITH THE PTERIONAL APPROACH

According to generally accepted principles the aims of the approach in the aneurysmal surgery are:

- The approach must have the shortest possible trajectory towards the target
- The approach must take a short amount of time
- The approach must be extra-axial, respecting the integrity of the brain
- The approach must allow access to afferent arteries and to the aneurysmal neck, after that to the efferent arteries, and after that to the aneurysm fundus.

When the aneurysm points upwards and posteriorly, the subtemporal approach has all the prerequisites in comparison to the trans-silvien approach. In the aneurysms that point anteriorly toward the basilar tip, one of the major disadvantages of the subtemporal approach seen is the lack of visibility of the contralateral P1. In this type of aneurysms, the contralateral P1 is visualized after the pilot aneurysm clip is placed. With the use of the trans-silvien approach in aneurysms pointing anteriorly, this disadvantage is overcome and it provides visibility of the contralateral P1. However due to its trajectory – pointing anteriorly and superiorly – first the aneurysm fundus is visualized and after that the aneurysm neck.

CONCLUSION

Subtemporal approach for the treatment of basilar tip aneurysms offers a direct route for this vascular lesion. A detailed understanding of the aneurysm, in particular its anatomy in relation to the bone and associated vessels anatomy, as well as careful evaluation of the preoperative radiological studies and meticulous following of microsurgical steps in the aneurysmal preparation and clipping is of great importance for the correct planning of the approach and avoiding intraoperative complications.

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Conflicts of interest

There are no conflicts of interest.

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