·Minireview·

A young and booming approach: the extreme lateral supracerebellar infratentorial approach

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Abstract: Surgical accesses to lesions of the posterolateral pontomesencephalic junction (PMJ) region and the posterolateral tentorial gap remain a challenge in the field of neurosurgery. Since the first report of application of the extreme lateral supracerebellar infratentorial (ELSI) approach in resecting the PMJ lesions in 2000, a few articles concerning the ELSI approach have been published. The present review mainly provided an intimate introduction of the ELSI approach, and evaluated it in facets of patient position, skin incision, craniectomy, draining veins, retraction against the cerebellum, exposure limits, patient healing, as well as advantages and limitations compared with other approaches. The ELSI approach is proposed to be a very young and promising approach to access the lesions of posterolateral PMJ region and the posterolateral tentorial gap. Besides, it has several advantages such as having a shorter surgical pathway, causing less surgical complications, labor-saving, *etc*. Still, more studies are needed to improve this approach.

Keywords: extreme lateral supracerebellar infratentorial approach; tentorial gap; neurosurgery

1 Introduction

The supracerebellar infratentorial (SCIT) approach was first proposed by Horsley[1] one century ago, who took advantage of the supracerebellar infratentorial interval in surgeries, and later the paramedian[2] and the lateral[3] variants were presented. In 2000, Vishteh *et al.*[4] proposed the extreme lateral supracerebellar infratentorial (ELSI) approach for the first time to resect lesions located at the posterolateral mesencephalon. Since then, a few articles[5-9] concerning the ELSI approach have been published, which improves the cognition for this approach and promotes its clinical application. The present review mainly introduced the status and tendency of the ELSI approach application, and evaluated it in facets of patient position, skin incision, craniectomy, draining veins, retraction against the cerebellum, exposure limits, patient healing, as well as advantages and limitations compared with other approaches.

2 An anatomic overview

The tentorial gap between the upper brainstem and the incisural edges communicates with the supratentorial and infratentorial spaces, and is divided into the anterior, the middle, and the posterior gaps. The anterior tentorial gap locates anterior to the brainstem and extends upward around the optic chiasm to the subcallosal area. The middle tentorial gap locates lateral to the brainstem and is closely related to hippocampal formation in the medial part of the temporal lobe. The posterior tentorial gap locates posterior to the midbrain and corresponds to the pineal region[10-12].

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3 The milestones in the development of the SCIT approach

In 1910, Horsley performed the median SCIT approach for the first time[1]. The earliest description of the median SCIT approach was published in 1913[13] by Oppenheim and Krause. This approach was depicted more systematically in 1926 by Krause[14], and thus the median SCIT approach was named "Krause approach". In 1971, Stein revised and popularized this approach for pineal region tumors[15], using microsurgical techniques. Later on, the paramedian variant of the median SCIT approach was described in detail in 1984 by Yaşargil[2]. In 1989, Matsushima *et al.* proposed the infratentorial lateral supracerebellar approach to carry out the microsurgical decompression trigeminal neuralgia[3]. In 2000, Vishteh *et al.* proposed the ELSI approach[4].

4 Categories and locations of related lesions

In the report of Vishteh *et al.*, 5 cavernous malformations, 2 juvenile pilocytic astrocytomas, and one peripheral superior cerebellar artery aneurysm located at pontomesencephalic junction (PMJ) and cerebellar peduncles were approached in 8 patients[4]. Besides, Vougioukas *et al.* have presented 7 upper brainstem gliomas[7], and De Oliveira *et al.* have reported 13 cavernous malformations resected via the ELSI approach[9]. These mentioned lesions cover almost all the feasible ones in the middle and the posterolateral tentorial gaps.

5 Patient position

As has been reported, during surgery, patients are in a supine position with the head turned, in a lateral park bench position with the lesion side up[4,9], or in a sitting position[7]. In the cadaveric studies, heads are positioned imitating the sitting or semisitting position[5,6,8], while in the prone position, the head is turned and extended to place the ipsilateral mastoid at the highest point in the operation field[4,9]. When patients are in a sitting position, the placement of brain retractors is not necessary since the cerebellum is pulled down by gravity[7]. Thus in this position, the retraction-related injury is reduced. The main disadvantage of the sitting position is the risk of air embolism, which however, can be minimized with a thorough preoperative echocardiogram and the intraoperative use of a precordial ultrasonography[7]. In our opinion, the sitting position is better because of the less probability of retraction-related injuries if air embolism is well prevented. Furthermore, Vougioukas *et al.* have reported that bleeding from a suboccipital sinus, which often occurs in pediatric cases, may be easier to be controlled while having the patient in the sitting position than having the patient in the prone position[7].

6 Skin incision

The most common style of skin incision is the C-shaped skin incision which is based laterally. It extends from the tip of the mastoid bone to the posterior temporal scalp[5,6,8]. Besides, other styles of skin incision can also be used, such as the slight S-shaped incision beginning 2 cm lateral to the mastoid process used by Vougioukas *et al*.[7] and a straight incision used by De Oliveira *et al*.[9]. We think that the C-shaped skin incision is better when skeletonization of the sigmoid sinus is needed in the procedure of craniotomy.

7 Craniectomy

Vishteh *et al.* depicted that the craniotomy begins suboccipitally and extends above the transverse sinus. The supratentorial craniotomy which unroofs totally the transverse sinus and skeletonization of the sigmoid sinus are important, because these maneuvers could enable the effective mobilization of the transverse and sigmoid sinuses[4]. Vishteh's means was mostly adopted in latter research[5,6,8,9] and has been supplemented in some details. Ammirati *et al.* depicted that it started 3 cm from the midline, extended to the transverse and sigmoid sinus and was completely exposed to just proximal to the jugular bulb[5]. According to the depiction of Pakrit Jittapiromsak *et al.*, the craniotomy should be extended inferiorly just enough to approach the cisterna magna[8]. In the study of Vougioukas *et al.,* the sigmoid sinus was just partially skeletonized, probably because that the lesions were just located at the upper brainstem[7].

8 Dural incision

The dura opening is made most commonly in an inverted-

T fashion at the corner of the transverse and sigmoid sinuses, which is based on the inferior margin of the transverse sinus and the posterior margin of the sigmoid sinus[4,5,8,9]. The sinuses could be retracted superiorly and anteriorly with tacking sutures[5]. However, in the report of Vougioukas *et al.*, the dura was opened parallel to the transverse sinus[7], probably because that they only aimd at the upper brainstem, with no need to skeletonize the sigmoid sinus completely.

9 Draining veins

In the study of Ammirati *et al.*, a few bridging veins draining into the transverse-sigmoid junction were occasionally severed during the dissection of the cadaveric heads[5]. Vishteh *et al.* consider that draining veins should not be sacrificed unless they interfere with the approach or retraction[4]. Jittapiromsak *et al.* reported that the superior petrosal vein can cause obstruction to the ELSI approach[8]. De Oliveira *et al.* depicted that although less commonly, bridging veins may also be encountered through this route and attention must be given to the superior petrosal vein at the angle formed by the transverse and sigmoid sinus. They summarized that the more lateral the approach is, the fewer are the bridging veins that cross the surgical approach[9]. According to our experience, some bridging veins exist on the outer third of the cerebellar suface, and there rarely occur complications if they are sacrificed, whereas the superior petrosal veins should be carefully protected because severe complications may occur if they are injured.

10 Retraction against the cerebellum

In the prone position, a retractor can be placed on the cerebellar surface which is inferiorly retracted[4,6,8,9] and the best place should be the quadrangular lobule[6]. An additional retractor on the tentorium is not needed because it may distinctly limit working quarters[4]. When implementing the sitting position, retraction should be slighter or even not needed because the cerebellum will sink due to the gravity[7]. As suggested by Jittapiromsak *et al.*, the size and placement of the retractor on the cerebellar hemisphere should be considered, along with the location of the craniotomy and dural opening. Retractors with wider tips can provide wider horizontal space from the anterior to the posterior PMJ region, but they may not successfully expose the CN V root entry zone. A smaller tip may specifically allow exploration of a smaller region[8].

11 Exposure limits and neurovascular structures exposed

According to the cadaveric study of Ammirati *et al.*, the limits of exposure are the homolateral quadrigeminal plate medially, the anterolateral aspect of the midbrain laterally and the trigeminal nerve in the upper part of the cerebellopontine cistern inferiorly[5], but the upper limit was not mentioned. They summarized that the exposure provided by the ELSI approach was centered on the posterior part of the cerebral peduncle[5]. In the comparatively cadaveric study of Jittapiromsak *et al.*, the exposure space was limited by the petrous ridge anteriorly, homolateral quadrigeminal plate and the originate of the trochlear nerve posteriorly, tentorial edge superiorly, and upper pons with part of middle cerebellar peduncle inferiorly. They reportd that the CN V root entry zone may or may not be accessible, depending on the size and placement of the retractor (in the specimens, 6 of the 8 sides could not be reached)[14]. Most researchers suggest skeletonizing the sigmoid sinus and the transverse sinus[4-9], whereas in our opinion, only synchronous skeletonization of the sigmoid sinus and transverse sinus can increase the work space. In the report of Jittapiromsak *et al.*[8], the mean transverse sinus retraction distance was (3.7±2.0) mm, and the mean medial placement of the sigmoid sinus was (3.0±2.6) mm. According to the clinical experiences, De Oliveira *et al.*[9] reported that the ELSI approach can provide good exposure of the posterolateral aspect of the mesencephalon, including the ipsilateral tectal plate and superior cerebellar peduncle.

When the tentorial hiatus is reached and the arachnoid membrane between the cerebellum and the hiatus is divided, the first structures that come into sight are the IVth cranial nerve and the branches of the superior cerebellar artery[4,7]. The cisternal segment of the IVth nerve is fully exposed, from its origin all the way to the entrance point at which the nerve enters the free edge of the tentorium[7]. The IVth nerve runs infratentorially, partially embedded in the arachnoidal fibers of the ambiens cistern. It is usually immediately evident in the ambiens cistern, but is not easily recognized when it runs close to the free tentorial margin. In such cases, the cerebello-mesencephalic segment of the superior cerebellar artery is a good landmark to quarry the nerve, which is usually located above it, all along the posterior and lateral aspects of the midbrain[4,7].

If needed, the tentorium could be cut to aquire further exposure[4-9], and the styles and purposes are different among individuals. Ammirati *et al.*[6] suggest that the transection of the tentorium must be as posterior as possible behind the superior petrosal sinus, so as to cut the free edge of the tentorium away from the dural entry point of the trochlear nerve. In another report of Ammirati *et al.*, the tentorium was cut in a lateromedial direction, starting 1 cm behind the transverse-sigmoid junction and continuing all the way to the free edge. They depict that this maneuver could provide good visualization of part of the parahippocampal gyrus and the oculomotor nerve medially to the free tentorial edge, between the posterior cerebral artery and the anterior pontomesencephalic segment of the SCA, and uncal prolapse in the anterolateral tentorial gap can be seen in different degrees[5]. It is assumed that the entry site of the trochlear nerve into the tentorium and the tentorial venous sinuses should be carefully identified to reduce the accidental injuries[8]. In the report of De Oliveira *et al.*, the opening of the tentorium provided better exposure of the posteromedial surface of the temporal lobe[9]. The protection of troclear nerve during cutting the tentorium has been greatly emphasized[4-9,16].

Compared with other studies on the ELSI approach, the quantitative study of Jittapiromsak *et al.*[8] is more objective and advanced. For quantifying working distances, they defined 4 anatomic reference points on the lateral surface of the posterolateral PMJ region, namely, the point just medial to the CN V entry/exit zone (R1), the most anterior point in view on the pontomesencephalic sulcus (R2), the point directly superior to R1 on the pontomesencephalic sulcus (R3), and the point at which the pon-tomesencephalic sulcus crosses the lateral mesencephalic sulcus (R4). Other extreme points on the PMJ region were also defined, including the most anteroinferiorly accessible point (1E), the most anterosuperiorly accessible point (2E), the posterosuperior point most accessible along the lateral mesencephalic sulcus (3E), and the posteroinferior point most accessible along the interpeduncular sulcus (the downward extension of the lateral mesencephalic sulcus that separates the superior and middle cerebellar peduncles, 4E). For the superior extreme points (points 2E and 3E), the tentorium did not have to be cut, and data were quantitatively gathered with the tentorial limitation. A total number of 8 anatomic deep points were available for evaluation of each approach. All points were collected by touch using the preregistered navigator instrument tip. For angle measurements, predefined dural and retractor points acting as anatomic external limitations were registered. Four external limiting points were the midpoint of the transverse sinodural opening rim as an upper limit (Ex-S), the midpoint on the retractor rim as a lower limit (Ex-R), the medial margin on the cerebellar traction level as a medial limit (Ex-M), and the lateral dural margin on the same retraction level as a lateral limit (Ex-L). The results are listed in Tables 1-3[8].

In practice, the combination of the ELSI approach with other approaches may be a good choice, depending on the nature or the size of an individual lesion. If wider exposure is

Table 1. Extreme length for each reference point

Margin	Length, mm (mean±SD)
Anteroinferior	8.1±1.7
Anterosuperior	6.8±2.7
Posterosuperior	7.3±2.0
Posteroinferior	8.3±2.5

Adopted from Pakrit Jittapiromsak *et al.*, 2008[8].

Table 2. Angle of attack on point R3

Approach	No.	Angle, degrees (mean±SD)	
		Vertical	Horizontal
Extreme lateral supracerebellar approach	8	19.1±4.7	26.8±2.5

Adopted from Pakrit Jittapiromsak *et al.*, 2008[8].

Table 3. Angle of attack on points along the pontomesencephalic sulcus

Points	Angle of attack, degrees (mean±SD)	
	Vertical angle	Horizontal angle
Point R2: most anterior on pontomesencephalic sulcus	17.7±4.4	24.1±2.4
Point R3: above Cranial Nerve V entry/exit site on pontomesencephalic sulcus	19.1±4.7	26.8±2.5
Point R4: where the pontomesencephalic sulcus crosses the latera lmesencephalic sulcus	19.6 ±4.7	28.6±3.1

Adopted from Pakrit Jittapiromsak *et al.*, 2008[8].

desired due to the lesion location at the middle and posterior tentorial gaps, the combination of the ELSI approach with a median SCIT approach can be adopted, concerning the greater surgical freedom it offers[5]. In practice, ELSI approach and the retrosigmoid approach can be interchanged and combined if multiple vectors of surgical views are needed and the amount of retraction is desired[8]. Hayashi *et al.* have applied the combination of the ELSI approach with the subtemporal transtentorial approach to resect tentorial schwannomas extending from the middle to the posterior tentorial gap[16].

12 Patient healing

In all the 3 clinical studies[4,7,9], patients underwent perfect resection and seldom had any approach-related complications. In the report of Vishteh *et al.*, one patient out of 8 had residual cavernous malformation, which was then resected completely via the ELSI approach 9 months later, and one patient who developed transient paresis of IVth nerve recoverd in 3 weeks after surgery[4]. In the report of Vougioukas *et al.*, among the 7 patients with upper brainstem gliomas, only one patient with a benign tumor required a second procedure due to an expanding cyst arising from tumor remnants, and tumor remissions were seen only in 2 cases with grade IV tumor[7]. Besides, although De Oliveira *et al.* did not show specific data and analysis of the 13 patients who underwent surgeries via the ELSI approach, the outcomes of the 13 patients should be good according to the mean analysis of the whole patients, and they depicted that all cavernous malformations of the brainstem (CMBs) in their series were removed completely on the basis of microsurgical inspection (including 13 lesions resected via the ELSI approach)[9].

13 Advantages over former approaches to the same region

Compared to the ELSI approach, other approachs to the posterolateral mesencephlon and tentorial gap such as the subtemporal, the transpetrosal or combined (subtemporal/transpetrosal) approach all have inherent defects. The subtemporal approach may cause injury to the vein of labbé if more posterior exposures are needed, and the petrosal approaches (transcochlear or translabyrinthine) risk hearing loss or facial nerve paresis[4,5,7,9]. The ELSI approach does not have these risks and is labor-saving and more effective for approching the posterolateral mesencephlon[4]. The infratentorial lateral supracerebellar approach is similar to ELSI approach, except that it does not require skeletonizing the transverse sinus and sigmoid sinus[3,17,18]. In the comparative research of Jittapiromsak *et al.*, the ELSI approach provided a significantly improved view over the lateral supracerebellar approach along the interpeduncular sulcus on the posteroinferior margin of the PMJ region[8].

14 Study limitations

In the 3 articles concerning cadaveric studies[5,6,8], the specimens were fixed and silicon-injected, so the tissue could lose its original nature and may be out of shape more or less. Particularly in dissection, the fixed and silicon-injected vessels cannot stimulate the complete accuracy[8]. Moreover, with the development of the minimally invasive neurosurgery[19], the combination with the minimally invasive technology may greatly enhance the effectiveness of ELSI approach.

15 Conclusion

The ELSI approach is developed from the median SCIT approach and seems to be a complex of the median SCIT approach and the retrosigmoid approach. It is a young approach accessing the posterior and middle tentorial gaps. More importantly, it provides good exposure of the posterolateral PMJ region. Thus, it is a suitable approach for accessing the lesions located in the posterolateral tentorial gap, especially in the posterolateral brainstem, such as cavernous malformation, juvenile pilocytic astrocytoma, peripheral superior cerebellar artery anuerysm, glioma, *etc*. Moreover, compared with the former approaches to the same region, ELSI approach causes less approach-related injuries, and its trajectory is more direct and shorter. ELSI is proposed to be a good choice for removing lesions on the posterior part of the middle tentorial gap and the dorsolateral brainstem. Refined microsurgical techniques, proficiency in anatomic knowledge, and neuronavigational assistance will be helpful to ensure the safe surgical resection of lesions via the ELSI approach.

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极外侧幕下小脑上入路—— 一个具有广阔应用前景的神经外科手术入路

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摘要：神经外科手术中，后外侧小脑幕切记间隙以及后外侧脑桥中脑结合部是很难到达的区域，切除这些部位的病变在神经外科领域一直是个很大的挑战。自从2000年极外侧幕下小脑上入路被首次报道可用于切除后外侧脑桥中脑结合部位的病变以来，这一新入路为解决神经外科手术难题提供了新的方案。本文主要从手术体位、皮肤切口、骨瓣形成、入路相关引流静脉的处理、小脑牵引、暴露范围及内容、病人手术效果等方面对该入路进行了全面的综述。极外侧幕下小脑上入路是在后外侧小脑幕切迹间隙和后外侧脑桥中脑结合部等部位切除病变的可选入路，相较于其他入路有手术路径短、手术并发症少、省力等诸多优点，值得在临床工作中推广。

关键词：极外侧幕下小脑上入路；小脑幕切迹间隙；神经外科手术