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Krause approach to pineal tumour with intraoperative oculomotor nerve monitoring

Bhushan Thombre [a], Harsh Deora [a,*], Suparna Bharadwaj [b], Malla Bhaskara Rao [a]

[a] Department of Neurosurgery, National Institute of Mental Health and Neurosciences, Bangalore, India
[b] Department of Neuroanesthesia, National Institute of Mental Health and Neurosciences, Bangalore, India

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ABSTRACT

Background: The supra-cerebellar infratentorial approach to pineal region tumours is versatile and safe corridor to lesions located below the deep veins. Monitoring of the extra-ocular muscle pathways using the evoked compound muscle action potential can lead to safer resections.
Technical note: To describe the use of electrooculography and a three handed retractor less method for pineal region tumour surgeries.
Material and methods: Intraoperative electrooculography uses recording done from two channels (horizontal and vertical)by inserting disposable subdermal needle electrodes along the periorbital area. The oculomotor nerve is being monitored as it exits the midbrain. Retractor-less three-handed-technique allows for minimal handling of the cerebellum while maximizing the operative corridor.
Result: The oculomotor nerve was stimulated post resection and correspondingly led to improved symptoms post-operatively.
Discussion and conclusion: We demonstrate a method for the intraoperative monitoring of the continuity of the oculomotor tracts and a three handed retractor-less method of resection of pineal region tumours. The placement of electrodes and area of stimulation need sound knowledge of anatomy of the region. Haemostasis at every step is absolutely essential to be able to visualize in the narrow corridor.

1. Background and introduction

Pineal region tumors comprises an extensive array of pathological entities originating within one of the most complex areas of the intracranial cavity.[1] The intricate arrangement of the anatomical structures therein makes surgical excision of these tumors always a challenging task. Microsurgical excision is the mainstay of management for most pineal region tumors. During surgery to treat lesions in this region, minimizing postoperative oculomotor nerve palsy (diplopia and ptosis) is crucial, so as not to compromise the quality of life of patients after surgery.[2–7] To prevent such complications, intraoperative localization of the oculomotor nerve and extra-ocular muscle monitoring is required. However, reports on intraoperative oculomotor nerve monitoring have been sparse.[2,3] Evoked compound muscle action potentials a needle electrode was inserted into the space just beneath the superior roof of the orbit.

Among various intraoperative electrophysiological monitoring methods, muscle action potential recordings have the advantage that they do not require time-consuming averaging to yield recognizable waveforms, as do brainstem auditory evoked potential or somatosensory evoked potential recordings. Muscle action potentials recordings provide real-time information, on the basis of which surgeons can establish their location in the surgical field as soon as the electrical stimulation is applied. Theoretically and practically, this is the most precise and efficient way to record the muscle action potential generated in each muscle, because the uninsulated tips of the electrodes are within the muscle itself.

2. Case illustration

A 52year old lady presented with ptosis and superior gaze restriction with diminished visual acuity. The Magnetic resonance imaging showed a small enhancing lesion in the pineal region with a cyst on the right side causing obstructive hydrocephalus. Serum tumour markers i.e. Alpha-

* Corresponding author.
E-mail addresses: bdthombre@gmail.com (B. Thombre), demo5601@gmail.com (H. Deora), acharya.suparna@gmail.com (S. Bharadwaj), brmalla@gmail.com (M.B. Rao).

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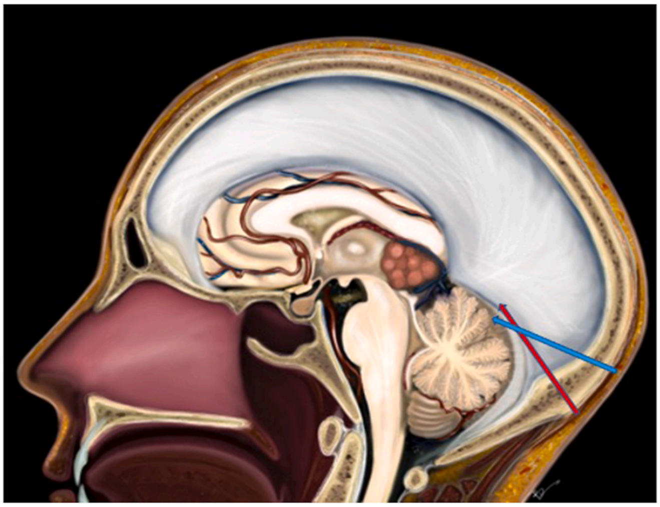

Fig. 1. Figure demonstrating the need for camera angle correction (from red to blue) to visualize the pineal region after opening the posterior arachnoid to avoid dissection towards the Vein of Galen. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

fetoprotein, beta-HCG and placental alkaline phosphatase sent prior to surgery were within normal range. We decided to proceed with direct tumour decompression in order to avoid the need of CSF diversion and its attendant complications. Electrooculography requires the application of intramuscular electrodes that can be performed quite safely as long as the electrode is inserted far enough from the globe within the intra-orbital space and is fixed so that the tip of the electrode is directed away from the globe. Standard micro-neurosurgery techniques with avoidance of a fixed retractor led to swift recovery.

2.1. Surgical approach

Although deep the pineal region is deep it is accessible without violating any eloquent structures. The adjacent structures are the posterior commissure, the corpus callosum, and the habenular commissure. The dorsal internal cerebral veins join the basal veins of Rosenthal to form the vein of Galen before draining into the straight sinus. The blood supply of these tumors is from branches of the medial and lateral posterior choroidal arteries with multiple anastomoses to the pericallosal, posterior cerebral, superior cerebellar, and quadrigeminal arteries. While approaching any pineal tumor this anatomy needs to be constantly revised and adhered too. After the sagittal and transverse sinus are exposed after craniotomy the dura is opened in a Y shape up to the tentorium and bridging veins are divided releasing the cerebellum from the same. The precentral cerebellar vein leading to the superior vermian vein can be sacrificed safely. This vein travels from the anterior vermis toward the vein of Galen. Other more anterior diencephalic veins residing on the brainstem should be preserved. There is a thick veil of arachnoid encasing the precentral vein. The cerebellum gradually descends with dissection of the supracerebellar arachnoid bands, exposing the pineal region and the tumor. The camera angle is adjusted (Fig. 1) to avoid dissecting towards the vein of galen and arachnoid dissection exposes the internal cerebral veins. The rest of the dissection follows the basic principles of tumor microsurgery, namely, tumor debulking and devascularization followed by extracapsular dissection. The assistant holds the area open using bayonet forceps while the surgeon decompresses the lesion (three handed technique). Once the lesion is removed the pulvinar and midbrain is visible. The oculomotor nerve can then be stimulated to confirm the integrity of the pathway. Haemostasis and closure proceed in a standard manner.

3. Video timeline with audio-script

3.1. 00:00:00

In this video we will demonstrate the Krause approach to pineal region tumors with intra-operative electro-physiological monitoring of extraocular muscles.

3.2. 00:08:00

Patient is a 52-year-old lady with headache since 6 months. On examination she had left eye visual acuity of 6/36 and right eye of 6/12 with up gaze palsy.

3.3. 00:12:00

Preoperative MRI shows a small enhancing lesion at the pineal region with a cyst cavity on its right side causing upstream hydrocephalus. It was decided to proceed with direct tumour decompression which will avoid the need of a shunting procedure.

3.4. 00:14:00

Intra-operative electromyographic (EMG) monitoring of 3rd,4th and 6th cranial nerves requires complex and skilful placement of recording electrodes into ocular muscles. The recording is done from two channels horizontal and vertical by inserting disposable subdermal needle electrodes along the periorbital area. For the horizontal channel, active electrode was at the medial canthus and the reference at the lateral. For vertical channel, the active electrode was on the upper rim of the orbit and the reference at the lower. Ground electrode was placed on the mentum.

3.5. 00:19:00

Here, pre-operative MRI showing lesion in the posterior third ventricular region, which was solid cystic in nature. In the right image you can see the enhancing component on gadolinium contrast and cyst on right side.[1]

3.6. 00:45:00

Patient was positioned in Concorde position with the neck mildly flexed and elevated. A midline suboccipital incision was taken. Craniotomy was done with four burr holes to expose the torcula along with the sagittal and transverse sinus. A rescue burr-hole in the occipital region was marked via navigation, in case of brain bulge. The same was however, not used.

3.7. 00:58:00

After that dura was opened in Y-shaped. After haemostasis of dural edges cerebellar hemispheres were retracted down with dynamic handheld retractor.[3] The arachnoid adhesions with the tent were then coagulated and cut with scissors.

3.8. 01:43:00

Once cerebellar hemispheres were free they can be retracted downward to reach the incisura.[4]

Pre-cerebellar vein could be seen on the surface which can be safely sacrificed to gain more exposure if required without causing much deficits. Here you can see the coagulation of the vein and afterward its detachment. This step essential here to gain access to the tumor as it was densely adherent.

3.9. 01:02:00

Now cerebellum could be retracted freely to reach the tumor in the posterior third ventricle.

3.10. 02:42:00

Further arachnoid dissection was done to gain more exposure in this narrow space. Appropriate sense of midline is paramount during this dissection to avoid injury to deep venous system.[5] After dissection was completed the internal cerebral veins on both sides could be seen.

3.11. 03:03:00

At this point a neuro-navigation probe was inserted to gain a sense of direction to approach the tumor. Before proceeding with further dissection, the angle of the microscope was changed to reach the tumor from the posterior most part.

3.12. 03:31:00

Tumor was identified and tumor wall was coagulated and cut before entering the tumor. After that the tumor wall and underling tissue was biopsied with tissue biopsy forceps and sent for frozen section. Haemostasis was confirmed at each step to keep the operative field clear.

3.13. 03:58:00

Before proceeding further a "*three hand technique*" was used in which the assistant surgeon holds open corridor for dissection with one hand. It simultaneously allows to depress and expand the operative corridor while the operating surgeon uses the two-handed method to dissect and decompress the lesion.

314. 04:22:00

Tumor decompression with ultrasonic aspiration was continued further. Cavitron ultrasonic aspirator was used for tumor decompression. As can be seen here the greyish tissue helps identify the tumor.[6]

3.15. 04:47:00

As can be seen here the tumor cyst wall was opened on right side and CSF was released. Further dissection was continued and wall of the tumor were dissected. Ultrasonic aspirator helps a lot during this step. Margins of the tumor were dissected with dissector as can be seen here and some part of tumor wall which was remaining was dissected out. Cerebellum was lax during this procedure.

3.16. 05:41:00

Capsule was further dissected and tumor clearance was achieved in all four walls. Once this was done the depth can be assessed for tumor clearance. At the depth the both sides of the pulvinar can be visualized which indicates the end of the dissection.

3.17. 05:47:00

The oculomotor nerve fibers leave the midbrain through the most medial part of the cerebral peduncle and enter the interpeduncular cistern where it can be stimulated for monitoring. After the oculomotor nerve emerges from the interpeduncular fossa, it enters the cavernous sinus slightly lateral and anterior to the dorsum sellae. Stimulation is applied directly to the surface and/or inside of the midbrain by means of a monopolar stimulator that allows for a diffuse spread of current and thus confirms the anatomical and functional preservation of the oculomotor tracts."

3.18. 05:50:00

Haemostasis was confirmed and Oculomotor nerve stimulator was inserted. Rectangular pulses with a frequency of 4.7 Hz, pulse duration of 0.2 ms and intensity of 1 mA were applied. Stimulator settings were: Sensitivity 100 μv/div, time base 3 ms/div, low-frequency filter 10 Hz and high-frequency filter 1 kHz. Responses were recorded as a negative deflection when the eye moves toward the active electrode and as a positive deflection when the eye moves away from the active electrode in a given channel. When oculomotor nerve was stimulated, the eye ball moved toward the active electrode in the vertical channel and a positive followed by a negative deflection is seen.

3.19. 05:53:00

Haemostasis was confirmed at this point and tumor cavity was once again inspected for any residual tumor before closure.

Bone flap was replaced back with mini plates and screws.

3.20. 06:13:09

Post op MRI was done which showed complete resection of tumor and reduction in hydrocephalus. Histopathology report came as Pineal Parenchymal tumor WHO grade II/III with MIB index of 7–8 percent. Follow up after 1 month showed improved in up gaze palsy and healthy wound.

4. Discussion

Electrooculography is a simple and reliable method for monitoring the extraocular movements and thereby cranial nerves responsible for those movements. EOG is the response recorded at the periorbital skin using surface electrodes placed around both eyes whenever the eyeball moves following electrical stimulation or surgical manipulation. The electrical stimulation used in our cases was through monopolar stimulating electrode. Monopolar stimulation provides a radial diffusion of current that covers an approximately spherical space around the stimulating electrode with a relatively high volume of tissue activated during stimulation, hence requiring lower current intensity. We used monopolar stimulation since it is useful in a focused and deep operative field, easy to manipulate and can also be used as a tumour dissector. With this method, it is quite easy to apply the recording electrodes, but a disadvantage may be that the surface electrodes around the orbit easily detect facial muscle movement. During needle electrode insertion, the tip of the electrode may not always be placed exactly within the muscle, and this may decrease the amplitude of the response. This may make it somewhat difficult to accurately identify the nerve or nucleus stimulated. It is likely that the evoked responses recorded by the needle electrode in the superior intra-orbital space are the summed potentials from the superior rectus muscle and the levator palpebrae superioris muscle, considering the anatomic location of the electrode.

Extra-ocular muscle monitoring during midbrain surgery has been previously described by group of investigators developed a ring electrode and stimulated the ocular motor nerves electrically in 22 patients and recorded compound muscle action potentials from the extraocular muscles with the electrode placed epiconjunctivally.[3] Another method of ring electrode fixation

microsurgical procedure by attaching the electrode with the help of sutures through the ring and into the extraocular muscles. Another method is placing transcutaneous needle electrodes near the orbital muscles to monitor III, IV and VI nerves.[9] Intra-operative EMG was monitored in 18 patients in another study by placement of single shafted bipolar electrodes in the extraocular muscles under the guidance of B-mode ultrasound. There was no distinct relationship between ocular

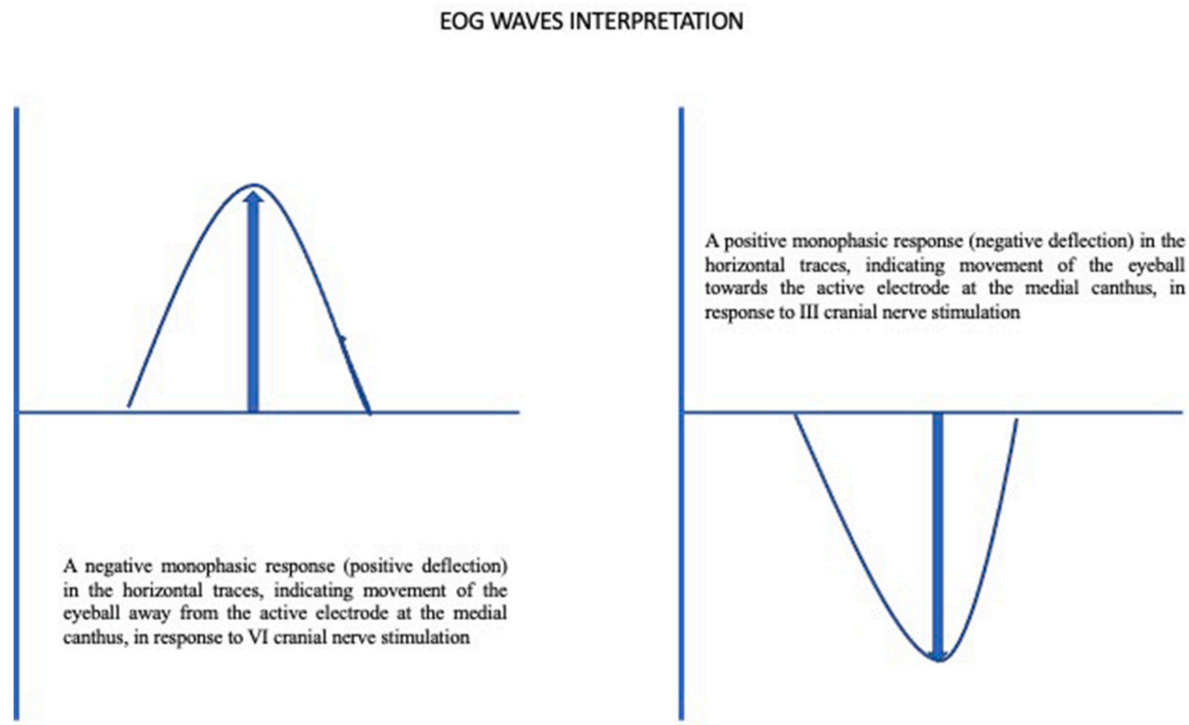

Fig. 2. Stimulation Waves and the significance of its direction in the monitoring of IIIrd nerve during electrooculography.

motor nerve function and neurophysiological parameters and the predictive value for the clinical outcome was poor.[10] Neuro-navigation optical tracking system was also used to place percutaneous needle electrodes into the lateral rectus, inferior rectus and superior oblique muscle along the axis of a hand-held pointer or by means of an electrode applicator.[11] EOG is a novel, efficient and simple method to prevent post-operative extraocular motor nerve palsy.[11–14]

4.1. Electrode insertion

The technique is a modification of the surface electrode placement used for electro-oculography.[15] Instead of surface or skin electrodes which may get dislodged during surgery needle electrodes are placed in the peri-orbital area as shown in the video. Depending on the eye movement and polarity of the wave in the EOG recording, the III and VI nerves could be identified in the horizontal orientation channel. Mechanical manipulation during tumour dissection yielded polyphasic waves with polarity opposite to that of electrical EOG response. Thus, the two can be differentiated, although careful dissection was done in the area of mechanical manipulation. The responses could be interpreted by the anaesthesiologist and did not demand the constant presence of neurologist or neurophysiology technician in the operating room. However, they were immediately available in the hospital for any technical snag or difficulty in interpretation.

4.2. EOG waves and their interpretation

The electro-oculography (EOG)[8] is based on the working principle that the eyeball represents an electrical dipole with the positive pole at the cornea and negative at the retina and axial eye movements lead to changes in the corneoretinal resting potential. It was first described by Geoffrey Arden in 1962 and has since been used to evaluate oculomotor abnormalities and in the diagnosis of retinal and macular pathologies with newer applications being developed such as sleep pattern studies and human computer interface systems for persons with motor impairment. This method based on the fact that the electrical potential difference between the cornea and the retina changes in accordance with eyeball movement. For monitoring near the medial canthus and the reference near the lateral canthus for the monitored eye. For vertical channel, the active electrode was placed on the upper and the reference electrode on the lower side of the orbital margin. Ground (anodal) electrode was placed on the mentum/sternum. Oculomotor (III) and abducent (VI) nerves could be identified using the horizontal tracing as they stimulate the medial rectus and lateral rectus respectively. Electrical stimulation of the III CN yields a positive monophasic response in horizontal channel traces, indicating movements of the eyeball towards the active electrode (Fig. 2). Electrical stimulation of the VI CN yields a negative monophasic response in horizontal channel traces, indicating movements of the eyeball away from active electrode.[9–11] Vertical traces can be stimulated by both Oculomotor (III) and trochlear (IV) nerve stimulation and yields a biphasic wave[12–14] in the vertical channel traces as seen in the video.

5. Conclusion

We demonstrate a replicable and reliable method for oculomotor nerve monitoring during pineal region tumour surgery. The three handed dissection method shown prevents the use of fixed retractors and may prevent retractor related cerebellar contusions or oedema.

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CRediT authorship contribution statement

Bhushan Thombre: Funding acquisition, Conceptualization, Validation, Data curation, Project administration, Writing – original draft, Formal analysis, Investigation, Methodology, Resources, Visualization, Writing – review & editing. **Harsh Deora:** Resources, Conceptualization, Investigation, Supervision, Visualization, Writing – original draft, Project administration, Methodology, Validation, Data curation, Formal analysis, Funding acquisition, Software, Writing – review & editing. **Suparna Bharadwaj:** Software, Supervision, Validation, Writing – review & editing, Methodology, Writing – original draft, Project administration, Resources. **Malla Bhaskara Rao:** Validation, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Abbreviations

EOG Electro-oculography

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.wnsx.2024.100292.

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