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Intraoperative Direct Electrical Stimulation of the Lamina Quadrigemina in a Case of a Deep Tectal Cavernoma

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Summary

Despite the recent neuro-imaging and microsurgical advances, a high rate of postoperative morbidity still remains in brain stem surgery. We report an original case of cavernous angioma of the right inferior colliculus without extension to the surface, operated on using brain stem electrical stimulations. Peroperative ocular motor responses were obtained, allowing identification of essential neural structures before dissection of the brain stem surface, and accurate definition of the limits between the lesion and functional tissue in depth. Total removal of cavernoma and surrounding gliosis was then performed, with normal postoperative neurological status.

As already reported at the cortical level, peroperative direct brain stem stimulations constitute a safe and easy method of functional mapping. A more intensive use of this neurophysiological technique might permit one to extend the indications for brain stem surgery, with minimisation of postoperative morbidity and maximisation of tumour resection.

Keywords: Direct electrical stimulation; brain-stem mapping; brain-stem surgery; cavernous angioma.

Introduction

Despite development of magnetic resonance imaging (MRI) combined with advances in microsurgical techniques [9, 10, 12, 18, 21, 33, 34], the risk of significant neurological morbidity still remains in brain stem surgery, even when excising encapsulated lesions such as cavernomas [17, 37]. Moreover, for many authors, deep lesions in the brain stem without superficial extension are unlikely to have good outcomes because normal structures will be injured in reaching the lesion [19, 38]. The major factor contributing to operative morbidity in these cases is the resection of functionally intact tissue during the surgical approach [6, 25]. Consequently, an early identification of these surface structures may contribute to preservation of brain stem function.

Peroperative direct electrical stimulation is already advocated to map function at other sites of the central nervous system, with good accuracy and reliability: in the sensory-motor [1, 30] and language cortex [15, 28], most recently in the spinal cord [3, 7], and also in the brain stem at the level of the floor of the fourth ventricle [24, 31, 32].

We report an original case with peroperative stimulation of the lamina quadrigemina in a patient with a tectal cavernoma which had not reached the surface of the brain stem.

Case Report

This 63-year-old man was hospitalized in our institution after a first episode of acute headaches three weeks before admission, followed by acute diplopia ten days later. Neurological examination on admission revealed mild diplopia when the patient looked left and up without other abnormality. Hearing was normal. MRI showed a typical cavernous angioma of the right inferior colliculus, with no superficial extension to the surface of the brain stem (Fig. 1). However, surgical intervention was decided upon because of the high risk of early rebleeding with potentially severe neurological complications, after 2 typical initial successive episodes of clinical bleeding [8].

Surgery was performed under general anaesthesia in the sitting position, with a transtentorial suboccipital approach. Brain stem auditory evoked potentials were not recorded. Both superior and inferior colliculi were exposed. The right inferior colliculus seemed more convex than the left, with downward displacement of the fourth cranial nerve, but there was no lesion visible on the surface, neither discoloration of the thin membrane covering the cavernoma. We then used tectal mapping using direct electrical stimulations, with a 3-mm spaced tips bipolar probe. A train of constant current biphasic square wave pulses was used with a pulse frequency of 60 Hz and a single pulse phase duration of 1 ms. The current amplitude was 0.5 mA (Ojemann Cortical Stimulator, Radionics). An elevation of the left eye was obtained when stimulating around but not exactly on the right inferior colliculus. No other motor response was noted elsewhere. A 3-mm incision was then made at the precise site of the colliculus without response, and at a depth of approximatively

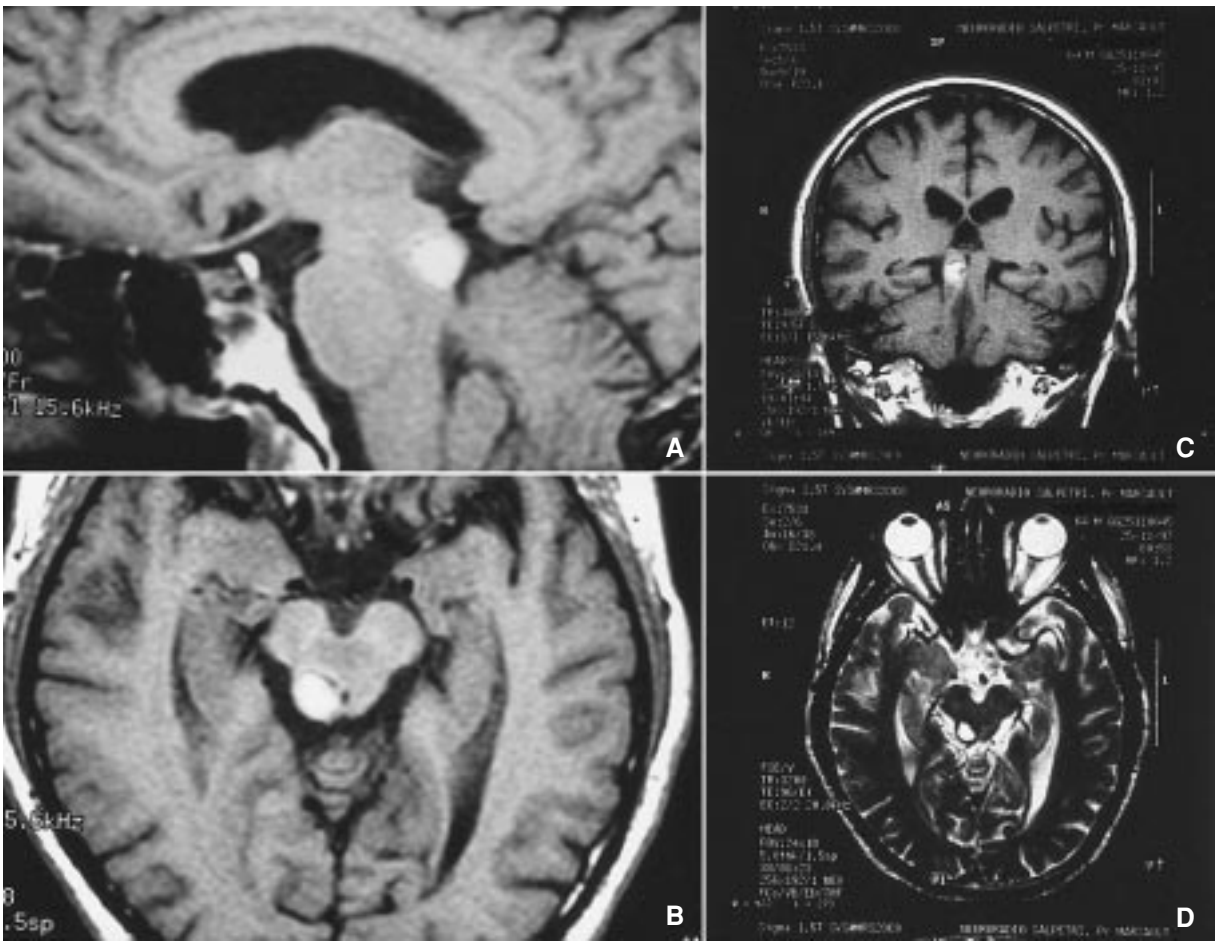

Fig. 1. Sagittal (A), axial (B) and coronal (C) T1-weighted gadolinium-enhanced and sagittal T2-weighted (D) MRI showing a right inferior collicular cavernoma without extension to the surface of the brain stem

3 mm, the cavernoma was found with evidence of recent bleeding. The lesion and the pericavernomatous gliosis were macroscopically totally removed, with no further resection when the same left eye elevation was obtained during direct stimulation on the edges and particularly on the deep side of the cavity. There were no modifications of the haemodynamic and cardiac parameters during electrical stimulations.

Postoperative course was uneventful with recovery to a normal neurological examination without diplopia.

Discussion

The surgical treatment of deep brain stem cavernous angiomas remains controversial. Indeed, the risk of surgery is considered by many authors too high because the operative access would have injured the perilesional intact brain stem [5, 19, 38]. On the other hand, cavernomas are documented as a malformation with high risk of rebleeding after a first *clinical* episode [35] (with or without macro-haemorrhage radiologically visible), this rebleeding being well known for its early recurrence and severity [8]. Then to maximize surgical indications and quality of resection, with minimizing postoperative neurological morbidity, reliable identification of functional brain stem surface structures prior to dissection is mandatory.

Although some investigators tried to study the relationships between these superficially functional structures and the visible anatomical landmarks, particularly at the level of the floor of the fourth ventricle [22]; there is no reliability because the space-occupying lesions cause displacement of the normal anatomy [11]. Electrophysiological methods have therefore been developed and reported to be helpful in monitoring brain stem function during surgery: brain stem early and middle-latency auditory evoked potential [4, 13, 16, 20], somato-sensory evoked potential [36] and motor evoked potential [23]. However, these conven-

tional techniques, sometimes difficult to perform in the operating room, do not contribute to identification of surface structures prior to dissection of the brain stem, and do not provide electrophysiological coverage of crucial structures such as cranial motor nerves.

Identification and preservation of essential neural structures can be achieved using method of direct electrical stimulation. This is an accurate (without electrical diffusion) [14], reliable, easy and safe technique, already successfully used for detection of cortical areas and sub-cortical pathways of motor, sensory, and language functions, and memory [1, 2, 3, 27, 28, 30]. More recently, stimulations were used for identification of pyramidal tracts during spinal cord surgery [3, 7]. At least, stimulations were also reported for brain stem surgery, in cases of infiltrative internal temporal tumour for detection of the cerebral peduncle [3], and for mapping of the floor of the fourth ventricle [24, 31, 32].

At the level of the inferior colliculus, direct electrical stimulations are particularly useful, not only for brain stem surface mapping but also for precise definition of the limits of resection. Indeed, Bognar [4] reported that it is possible to completely remove a (right) inferior colliculus without apparent neurological and auditory consequences. However, it remains essential to know where the resection must be stopped in depth. Precise boundaries were given in our patient by direct brain stem stimulations at the surface level but also in the depth of the cavity, with conclusion of the removal when a motor response was obtained (left eye elevation in this case). This response was probably generated by stimulation in the depth of the cavity of the medial longitudinal fasciculus, constituted by fibers which associate homo- and contralateral oculomotor nuclei [26]. As already mentioned, these crucial structures cannot be identify by "conventional" electrophysiological techniques such as brain stem early and middle-latency auditory evoked potentials, somatosensory evoked potentials and motor evoked potentials. Moreover, accurate mapping of the brainstem using direct stimulation allows one to achieve total resection of the cavernoma and also of surrounding modified tissue, which often contains vascular malformations such as telecgiectasias with the same risk of rebleeding in case of incomplete removal [8, 29].

Nevertheless, it seems interesting to propose to combine electrical stimulation and brain stem evoked potentials with the aim of improving the safety of brain stem surgery.

Conclusion

As already described at the cortical level, direct electrical brain stem stimulations constitute a safe and easy neurophysiological method of mapping, which allows:

- Direct identification of essential neural structures before dissection of the brain stem surface;
- Consequently the choice of the optimal approach in cases of lesions without extension to the surface;
- And the definition of the limits between the lesion and functional tissue, giving the boundaries of resection in depth, by direct stimulations on the deep side of the cavity.

A more intensive use of stimulation might permit one to extend the indications for brain stem surgery, with minimisation of postoperative morbidity and maximisation of tumour resection.

References

1. Berger MS, Kincaid J, Ojemann GA, Lettich E (1989) Brain mapping techniques to maximize resection, safety and seizure control in children with brain tumors. Neurosurgery 25: 786–792
2. Berger MS, Ojemann GA, Lettich E (1990) Neurophysiological monitoring during astrocytoma surgery. Neurosurg Clin North Am 1: 65–80
3. Berger MS, Ojemann GA (1992) Intraoperative brain mapping techniques in neuro-oncology. Stereotact Funct Neurosurg 58: 153–161
4. Bognar L, Fisher C, Turjman F, Michel F, Villanyi E, Guyotat J, Lapras Cl (1994) Tectal plate gliomas. Part III: Apparent lack of auditory consequences of unilateral inferior collicular lesion due to localized glioma surgery. Acta Neurochir (Wien) 127: 161–165
5. Bouillot P, Dufour H, Roche PH, Lena G, Graziani N, Grisoli F (1996) Malformations vasculaires angiographiquement occultes du tronc cérébral. A propos de 25 cas. Neurochirurgie 42: 189–201
6. Bricolo A, Turazzi S, Cristofori L (1991) Direct surgery for brainstem tumors. Acta Neurochir [Suppl] (Wien) 53: 148–158
7. Duffau H, Capelle L (1997) Interest of peroperative direct medullary stimulation during surgery of infiltrative intramedullary tumors. XIIth Meeting of the World Society for Stereotatic and Functional Neurosurgery. Stereotact Funct Neurosurg 67, Lyon, p 123 (abstract)
8. Duffau H, Capelle L, Sichez JP, Faillot T, Van Effenterre R, Bitar A, Arthuis F, Fohanno D (1997) Early rebleeding from intracranial cavernous angiomas: report of 12 cases and a review of the literature. Acta Neurochir (Wien) 139: 914–922
9. Epstein F, Wisoff JH (1988) Intrinsic brainstem tumors in childhood: surgical indications. J Neurooncol 6: 309–317
10. Fahlbusch R, Strauss C, Huk W (1990) Surgical removal of pontomesencephalic cavernous hemangiomas. Neurosurgery 26: 449–457
11. Fahlbusch R, Strauss C (1991) The surgical significance of brain stem cavernous hemangiomas. Zentralbl Neurochir 52: 25–32

12. Fassano VA, Urciuoli R, Punzio RM, Lanotte MM (1986) The effects of new technologies on the surgical management of brainstem tumors. Surg Neurol 25: 219–226
13. Fisher C, Bognar L, Turjman F, Villanyi E, Lapras (1994) Auditory early- and middle-latency evoked potentials in patients with quadrigeminal plate tumors. Neurosurgery 35: 45–51
14. Haglund MM, Ojemann GA, Blasdel GG (1993) Optical imaging of bipolar cortical stimulation. J Neurosurg 78: 785–793
15. Haglund MM, Berger MS, Shamseldin M, Lettich E, Ojemann (1994) Cortical localization of temporal lobe language sites in patients with gliomas. Neurosurgery 34: 567–576
16. Hecox K, Galambos R (1974) Brainstem auditory evoked responses in human infants and adults. Arch Otolaryngol 99: 30–33
17. Heffez DS, Zinreich SJ, long DM (1990) Surgical resection of intrinsic brain stem lesions: an overview. Neurosurgery 27: 789–799
18. Hoffman HJ, Becker L, Craven MA (1990) A clinically and pathological distinct group of benign brainstem gliomas. Neurosurgery 7: 243–248
19. Isamat F, Conesa G (1993) Cavernous angiomas of the brainstem. Neurosurg Clin N Am 4: 507–518
20. Kalmanchey R, Avila A, Symon L (1986) The use of the brainstem auditory evoked potentials during posterior fossa surgery as a monitor of brainstem function. Acta Neurochir (Wien) 82: 128–136
21. Konovalov AN, Spallone A, Makhmudov UB, Kukhlajeva JA, Ozerova VI (1990) Surgical management of hematomas of the brain stem. J Neurosurg 73: 181–186
22. Lang J Jr, Ohmachi N, Lang J Sr (1991) Anatomical landmarks of the rhomboid fossa (floor of the 4th ventricle), its length and its width. Acta Neurochir (Wien) 113: 84–90
23. Mc Pherson RW (1990) Motor tract evoked potentials: is there a future in intraoperative monitoring? J Neurosurg Anesthesia 2: 70–72
24. Morota N, Deletis V, Lee M, Epstein FJ (1996) Functional anatomic relationship between brain stem tumors and cranial motor nuclei. Neurosurgery 39: 787–794
25. Newton HB, Miner ME (1991) "One and a half" syndrome after a resection of a midline cerebellar astrocytoma: case report and discussion of the literature. Neurosurgery 29: 768–772
26. Nieuwenhuis R, Voogd J, Van Huijzen C (1988) The human central nervous system, 3 edn. Springer, Berlin Heidelberg New York Tokyo
27. Ojemann GA, Dodrill CB (1987) Intraoperative techniques for reducing language and memory deficits with left temporal lobectomy. In: Wolf P, Dam M, Janz D, Dreifuss F (eds) Avances in epileptology, vol 16. Raven, New York pp 327–330
28. Ojemann GA, Ojemann JG, Lettich E, Berger MS (1989) Cortical language localization in left, dominant hemisphere. An electrical stimulation mapping investigation in 117 patients. J Neurosurg 71: 316–326
29. Requena I, Arias M, Lopez IL, Pereiro I, Barba A, Alonso A, Monton E (1991) Cavernomas of the central nervous system: clinical and neuroimaging manifestations in 47 patients. J Neurol Neurosurg Psychiatry 54: 590–594
30. Skirboll SS, Ojemann GA, Berger MS, Lettich E, Winn R (1996) Functional cortex and subcortical white matter located within gliomas. Neurosurgery 38: 678–685
31. Strauss C, Romstöck J, Fahlbusch R (1993) Intraoperative mapping of the floor of the IVth ventricle. In: Loftus CM, Traynelis VC (eds) Intraoperative monitoring techniques in neurosurgery. McGraw-Hill, New York, pp 213–218
32. Strauss C, Romstöck J, Nimsky C, Fahlbusch R (1993) Intraoperative identification of motor areas of the rhomboid fossa using direct stimulation. J Neurosurg 79: 393–399
33. Stroink AR, Hoffman HJ, Hendrick EB, Humphreys RP (1986) Diagnosis and management of pediatric brain-stem gliomas. J Neurosurg 65: 745–750
34. Symon L, Jackowski A, Bills D (1991) Surgical treatment of pontomedullary cavernomas. Br J Neurosurg 5: 339–347
35. Tung H, Giannotta SL, Chandrasoma PT, Zee CS (1990) Recurrent intraparenchymal haemorrhages from angiographically occult vascular malformations. J Neurosurg 73: 174–180
36. Watanabe E, Schramm J, Schneider W (1989) Effect of subdural air collection on the somatosensory evoked potential during surgery in the sitting position. Electroencephalogr Clin Neurophysiol 74: 194–201
37. Weil SM, Tew JMJr (1990) Surgical management of brain stem vascular malformations. Acta Neurochir (Wien) 105: 14–23
38. Zimmerman RS, Spetzler RF, Lee KS, Zabramski JM, Hargraves RW (1991) Cavernous malformations of the brainstem. J Neurosurg 75: 32–39

Comments

This paper is a case report on a cavernoma of the inferior colliculus which was resected following stimulation of the pericollicular tissue avoiding those areas were stimulation yielded a motor response. To my knowledge this is the first case report where the principle of direct brain stem stimulation in order to map motor function was applied to the collicular region. Therefore it is of interest of the neurosurgical community.

J. Schramm

This is an interesting case report of a patient with a cavernoma in the right inferior colliculus of the midbrain. Intra-operatively, the authors used direct tissue stimulation to identify a 'silent' area for the approach and then to remove the lesion. The patient recovered from surgery with no neurological deficit. The use of neuromonitoring techniques for lesions in this particular anatomical localization has obviously not been reported before and therefore this is an original contribution.

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