Neuro-navigation: An Adjunct in Craniofacial Surgeries: Our Experience

Harsha Chauhan · S. Girish Rao · B. A. Chandramurli · S. Sampath

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Abstract

Purpose Due to the destruction of osseous landmarks of the skull base or paranasal sinuses, the anatomical orientation during surgery of frontobasal or clival tumors with (para) nasal extension is often challenging. In this relation, Neuro-navigation guidance might be a useful tool. Here, we explored the use of Neuro-navigation in an interdisciplinary setting.

Methods and Materials The surgical series consists of 3 patients who underwent Lefort-I access osteotomy and surgical decompression of the tumor. The procedures were planned and assisted by neuro-navigation techniques with image fusion of CT and MRI. Two of the patients were diagnosed to have clival chordoma and one had extensive JNA.

Results The application of Neuro-navigation in the combined approaches was both safe and reliable for delineation of tumors and identification of vital structures hidden or encased by the tumors. There was no perioperative mortality. Tumors were either removed completely, or subtotal resection was achieved.

Conclusion Craniofacial approaches with intra-operative neuro-navigational guidance in a multidisciplinary setting

allow safe resection of large tumors of the upper clivus and the paranasal sinuses involving the anterior skull base. Complex skull base surgery with the involvement of bony structures appears to be an ideal field for advanced navigation techniques given the lack of intraoperative shift of relevant structures.

Keywords Neuro-navigation · Neuro-navigator · Lefort I access osteotomies · Clival chordoma

Introduction

Tumors of the paranasal sinuses with frontobasal extension or tumors of the upper clival region often require an interdisciplinary Maxillofacial and neurosurgical approach for complete tumor resection. The craniofacial resection technique was introduced by Ketcham and colleagues in 1963 [1]. Improvements of computer technology and neuro imaging software have led to the development of intraoperative computer assistance and of its wide use in craniomaxillary surgery [2, 3]. Neuro-navigation systems allow an exact transfer of the individual patients image data onto the operative field. It, thus provides intraoperative orientation to the surgeon helping him define tumour margins or margins of other areas of the brain and the surrounding neurovascular structures [4].

It is through instrument navigation systems that the interactive, intraoperative application of 3D image data has been realized [5, 6]. Image guided neuro-navigation utilizes the principle of stereotaxis and is based on creating complex mathematical algorithms via robust computer technologies describing a proposed “fiducial coordinate system” in a closed geometric volume like skull, which can be divided by three imaginary intersecting spatial planes,

H. Chauhan (✉) · S. G. Rao
Faciomaxillary Surgery, D.A.P.M.R.V. Dental College and Hospital, Bangalore, India
e-mail: harshadoc@yahoo.co.in

S. G. Rao (✉)
Department of Oral and Maxillofacial Surgery, D.A.P.M.R.V. Dental College and Hospital, No. CA 37, 24th Main, J.P.Nagar 1st Phase, Bangalore 560 078, Karnataka, India
e-mail: girishrao66@gmail.com

B. A. Chandramurli · S. Sampath
Neurosurgery, NIMHANS, Bangalore, India

orthogonal to each other (Horizontal, frontal and Sagittal). These fiducial markers are used as a reference to describe with high accuracy the position of specific structures within this arbitrarily defined space [4]. In this way the observations done via neuro-imaging technologies (CT, MRI, angiography) are related to the actual patient during surgery.

Due to the extensive destruction of osseous landmarks of the skull base, the anatomical orientation is often difficult. In this situation, neuro-navigation guidance may provide a useful tool to enhance safety and radicality of tumor resection. We report on our surgical approach guided by neuro-navigation in three patients, one with JNA involving the skull base and two with Clival Chordoma in an interdisciplinary setting.

Patients and Methods

Our case report included 3 patients, who underwent neuro-navigation guided craniofacial resection via Lefort I access osteotomy.

Surgical Approach

The surgical approach consisted of a transoral approach using a Lefort I access osteotomy (Fig. 1, 2).

The procedures were planned and assisted by advanced neuro-navigation techniques with image fusion of preoperative CT and MRI. The neuro-navigator used in our study was a pointer based system using Stealth station (Medtronic USA). It consists of a digital instrument (Patient tracker) a mounted array of three charge couple device, infrared camera for transmission of signals and a mobile computer work station with image analysis software, a high resolution monitor, a dynamic reference frame (DRF) attached to a Mayfield head holder and free hand held stereotactic pointing device. DRF and pointing device are mounted with infra red light emitting diodes. Camera array measures the location of these LED that are processed to three dimensional co-ordinates in the computer workstation therefore a direct line of sight must be maintained between LED and camera. Tumors included were two recurrent clival chordoma and one JNA (Table 1). All patients were male. mean age at surgery was 28 years (14–40 years).

Radiology

Preoperative CT and MRI scans were obtained in all cases. Significant intracranial tumor extension through the anterior fossa was observed in both chordoma cases. Invasion of the infratemporal fossa following erosion of the sphenoid bone seen in one patient with JNA. Frontobasal

osseous destruction due to tumor involvement and upper clival osseous destruction was observed in the other two patients with clival chordoma.

Surgery

Surgery was performed under general anaesthesia, using the operating microscope and microsurgical instrumentation in one case. The head of the patient was fixed in a Mayfield clamp in the supine position. Registration in the neuro-navigation system was achieved via surface matching (Medtronic Stealth Station). The transoral approach was performed through a Lefort I access osteotomy. Routine vestibular incision was used to expose the anterior maxillary wall. Maxilla down fractured and access to tumour achieved. Surgical decompression carried out in two patients and total resection was done in one patient with JNA. Margins for tumor resection were determined by neuro-navigational guidance as well as with the assessment of intraoperative histological frozen section in one case. Skull base reconstruction was performed in one case using Fibrin Glue (Reliseal) and a lumbar drainage was inserted at the end of surgery in the same patient.

Results

Clinical Features

The main symptom was headache and double vision in both patients with clival chordoma while nasal congestion and epistaxis in patient with JNA. Other symptoms included hyponasal speech, hoarseness of voice and dyspnoea.

Neuro-navigational Guidance

The accuracy of neuro-navigation was verified preoperatively and intraoperatively. There were no problems with the shift of anatomical structures during the course of surgery. The tumor border itself was well demarcated on preoperative CT or MRI images. Intraoperatively, tumor margins were defined by using neuro-navigation and also by histological frozen sections in one patient obtained from resection borders and was revealed to be tumor negative.

Outcome

There were no significant postoperative complication like CSF leak, wound dehiscence, infection, haemorrhage, hematoma etc. There was no perioperative mortality (30-day mortality) directly related to surgery in this series. No tumor recurrence was found on follow up. There was no perioperative mortality. Tumors were either removed

Fig. 1 Case No. 1: 30 year old gentleman with recurrent chordoma of the clivus. Pre-operative photograph of the patient and sagittal view of the tumor on MRI (a–b), Patients head stabilized on Mayfield clamp (c), Pre-operative registration on the neuro-navigator screen (d), Lefort I access osteotomy to approach chordoma of the clivus.

Maxilla osteotomized, downfractured, tumor approached and surgical decompression of the tumor carried out. Downfractured segment relocated following decompression (e–h), Pre operative and post operative clearance seen on the navigator monitor (i–j)

completely, or subtotal resection was achieved allowing targeted postoperative radiotherapy.

Discussion

Neuro-navigation began in 1990s and has adapted to new neuroimaging technologies, to transfer information in operating room for 3-D localization, real time neuro-monitoring robotics and new and better algorithms to handle data via more sophisticated computer technologies. It gained popularity during the 1940s, particularly in Germany, France and the US, with the development of surgery for the treatment of movement disorders.

Initially, anterior craniofacial resection was associated with significant morbidity. Ketcham and colleagues reported an 80% morbidity and a 7% mortality rate in their early series [7]. With the development of new surgical techniques, especially reconstructive methods of the skull base, and improved perioperative care, morbidity and mortality rates have been reduced to 30–50% [8].

Neuro-navigation techniques may help delineating tumor margins for tailored resection and also provide assistance in spatial orientation as anatomical landmarks are frequently lost due to tumor destruction. Image guided surgery at the skull base. The use of intraoperative navigation for surgery of the anterior skull base has been mainly described by ENT or maxillofacial surgeons in the past, [9] and are already well established in neurosurgery [10].

The contribution of navigated surgery in various anterior skull base lesions exposed through a broad subcranial, subfrontal approach was evaluated in a recent report [11]. The authors concluded, neuro-navigation was helpful for anterior skull base tumors especially for the exposure of tumor extensions located at the parasellar sphenoclival complex with concomitant distortion of anatomic landmarks. The suitability and usefulness of intraoperative image guided surgery of the anterior skull base in patients with tumors or trauma was evaluated in other studies. They stated that navigation reliably allowed to visualize the extent of tumor configuration and risk zones [12]. Despite

Fig. 2 Case No. 3: A 14-year-old boy presenting with a large intra-extracranial Juvenile nasopharyngeal angiofibroma (a–c). View of the tumor through the Lefort I approach (d–f). Intraoperative application of neuro-navigation through the Lefort I approach with the

corresponding tumor margin in Sagittal and Axial section (g–h). Postoperative sagittal and axial MRI demonstrating complete tumor removal (i–j)

Table 1 List of patients who underwent Surgical decompression of the tumor via Lefort I access osteotomy

Case No.	Age	Sex	Main symptoms	Location	Approach	Radicality	Morbidity	Histology
1.	30 yrs	M	Hoarseness of voice	PNS, Clivus	Le fort I access	Sub-total	Nill	Recurrent Clival Chordoma
2.	40 yrs	M	Enophthalmos, Diplopia, Visual disturbances	PNS, Clivus	Le fort I access	Sub-total	Nill	Clival Chordoma
3.	14 yrs	M	Nasal congestion, Anosmia, Epistaxis	Right Nostril, Infratemporal space with intracranial extension	Le fort I access	Total	Nill	Juvenile Nasopharyngeal Angiofibroma

the destruction of anatomical landmarks related to tumor invasion or intraoperative bone removal, neuro-navigation proved to be helpful allowing more radical resection associated with less morbidity in a series of 11 patients. Another report emphasized that navigation can provide sufficient precision and reproducibility in frontal skull base surgery and may help to optimize the surgical corridor in

transfrontal approaches and the reconstruction procedure for a good functional and cosmetic result [9].

Our experience with neuro-navigation to guide surgical resection of upper clival tumors and JNA is through a Lefort I access craniofacial. Regarding the lavish surgical corridor through the Lefort I access osteotomy, spatial orientation becomes somewhat more easier and the

contribution of image guided surgery is being appreciated better as with smaller surgical approaches like lateral rhinotomy. Compared to image guided surgery in intracerebral lesions, its application at the skull base as used in our experience is less influenced by intraoperative shifts of relevant anatomic structures.

Image guided surgery rapidly is becoming a well accepted technique in craniofacial surgery. It is still a matter of debate, however, whether the use of image guidance indeed contributes to improved safety and better outcome of surgery. In the present series, morbidity and mortality rates were low. Future studies may provide additional data on long-term results and long-term benefit of neuro-navigation in the field of craniofacial and skull base surgery.

Conclusion

Image guidance is a useful and reliable tool in most of the cranial neurosurgical procedures. Neuro-navigation permits excellent orientation and provides high accuracy for lesions targeted and defines the surrounding neurovascular structures. Frameless stereotaxy reduces the intraoperative risks and hazards. Craniofacial approaches with intraoperative neuro-navigational guidance is both safe and reliable for delineation of tumors and identification of vital structures hidden or encased by the tumors. In a multidisciplinary setting, it allows safe resection of large tumors of the upper clivus and the paranasal sinuses involving the anterior skull base. Complex skull base surgery with the involvement of bony structures appears to be an ideal field for advanced navigation techniques. It is an extremely useful technique for craniofacial tumours especially with intracranial extension.

Ethical Standards

All human studies have been approved by the appropriate ethics committee and have therefore been performed in

accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. All persons gave their informed consent prior to their inclusion in the study.

References

1. Ketcham AS, Wilkins RH, Vanburen JM, Smith RR (1963) A combined intracranial facial approach to the paranasal sinuses. *Am J Surg* 106:698–703
2. Marmulla R, Mühling J, Wirtz CR, Hassfeld S (2004) High-resolution laser surface scanning for patient registration in cranial computer-assisted surgery. *Minim Invasive Neurosurg* 47(2):72–78
3. Bonsanto MM, Metzner R, Aschoff A, Tronnier V, Kunze S, Wirtz CR (2005) 3D ultrasound navigation in syring surgery—a feasibility study. *Acta Neurochir* 147(5):533–540 discussion 540–1
4. Ganslandt O, Behari S, Gralla J, Fahlbusch R, Nimsky C (2002) Neuronavigation: concepts, techniques and procedures. *Neurol India* 50:244–255
5. Halßfeld S, Mühling J, Zöller J (1995) Intraoperative navigation in oral and maxillofacial surgery. *Int Oral Maxillofac Surg* 24:111–119
6. Hassfeld S, Mühling J (2001) Computer assisted oral and maxillofacial surgery—a review and an assessment of technology. *Int J Oral Maxillofac Surg* 30:2–13
7. Ketcham AS, Hoyer RC, Van Buren JM, Johnson RH, Smith RR (1966) Complications of intracranial facial resection for tumors of the paranasal sinuses. *Am J Surg* 112(4):591–596
8. Ganly I, Gross ND, Patel SG, Bilsky MH, Shah JP, Kraus DH (2007) Outcome of craniofacial resection in patients 70 years of age and older. *Head Neck* 29(2):89–94
9. Schipper J, Maier W, Arapakis I, Spetzger U, Laszig R (2004) Navigation as a tool to visualize bone-covered hidden structures in trans frontal approaches. *J Laryngol Otol* 118(11):849–856
10. Grunert P, Darabi K, Espinosa J, Filippi R (2003) Computer-aided navigation in neurosurgery. *Neurosurg Rev* 26(2):73–99
11. Laedrach K, Remonda L, Lukes A, Schroth G, Raveh J (2001) Evaluation of the contribution of CAS in combination with the subcranial/sub frontal approach in anterior skull base surgery. *Skull Base* 11(1):59–76
12. Wiltfang J, Rupprecht S, Ganslandt O et al (2003) Intraoperative image guided surgery of the lateral and anterior skull base in patients with tumors or trauma. *Skull Base* 13(1):21–29