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Dr. Sudipta Chatterjee
Professor, Department of Neurosurgery, Bangur Institute of Neurosciences and IPGMER, Kolkata, West Bengal, India

Dr. Dasuk Lang Roy D'siar
Resident, Department of Neurosurgery, Bangur Institute of Neurosciences and IPGMER, Kolkata, West Bengal, India

Dr. Subhasis Ghosh
Professor and Head, Department of Neurosurgery, Bangur Institute of Neurosciences and IPGMER, Kolkata, West Bengal, India

Dr. Gitanjali Datta
Associate Professor, Department of Neurosurgery, Bangur Institute of Neurosciences and IPGMER, Kolkata, West Bengal, India

Dr. Shubhamitra Chaudhuri
Assistant Professor, Department of Neurosurgery, Bangur Institute of Neurosciences and IPGMER, Kolkata, West Bengal, India

Corresponding Author:
Dr. Dasuk Lang Roy D'siar
Resident, Department of Neurosurgery, Bangur Institute of Neurosciences and IPGMER, Kolkata, West Bengal, India

Use of Neuronavigation in posterior fossa and pineal region tumour surgery: Technical challenges

Dr. Sudipta Chatterjee, Dr. Dasuk Lang Roy D'siar, Dr. Subhasis Ghosh, Dr. Gitanjali Datta and Dr. Shubhamitra Chaudhuri

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Abstract
Aim: To evaluate use of Neuronavigation in posterior fossa & pineal region tumour surgery.
Material and Method: The present prospective non-randomised observational study was conducted at Neurosurgery Department, Bangur Institute of Neurosciences (B.I.N) / IPGMER & PG Hospital, Kolkata from Dec 2018 - Dec 2020. 50 cases were diagnosed with posterior fossa & pineal region tumour during the study period. Cranial image guided score (IGS) was calculated by the summation of grading during designing the flap/burr hole, delineation of the intraoperative anatomy, navigation and access to the lesion and resection of the lesion or completion of the procedure. The scoring ranged from 0-12 and the utility of IGS in cranial neurosurgical procedures was calculated based on the total points for each surgery. At the time of discharge/1 month/3 months/6 months/12 month's outcome was assessed according to Glasgow outcome scale. One month after surgery, according to Karnofsky, the patient's condition was divided into good and poor.
Results: Biopsy, subtotal resection and gross total resection was achieved in 11 (22%), 15 (30%) and 24 (48%) subjects respectively. According to cranial IGS score, neuronavigation was more useful than conventional methods and irreplaceable among 52% and 26% of the subjects respectively. Only in two cases, it was not helpful.
Conclusion: This study proved that the employed neuronavigation system is versatile and safe and that there are no adverse effects, complications or surgical mortality due to the device.

Keywords: Neuronavigation, posterior, pineal, tumour surgery

Introduction

The pineal region is anatomically located posteriorly in the midline between the roof of the third ventricle dorsally and the tectum of the midbrain caudally. Pineal region tumours are rare. They are more common in children than in adults, accounting for 3–11% of all childhood brain tumours [1]. The pineal region tumors are surrounded by important blood vessels and nerves. The pineal region is a challenging surgical location, in part due to the rarity of pineal region neoplasms, which comprise only 0.5% to 1.6% of all intracranial tumors [2]. Surgical intervention is required to establish a tissue diagnosis, alleviate hydrocephalus, and enable resection [3]. The operation may be difficult because of long distance and poor light under microscope. Damage to the deep veins may lead to death. The repertoire of surgical approaches to pineal region tumors has evolved considerably over the past 100 years with an associated decline in operative mortality from 100% to less than 4% [4-6]. Given the associated morbidity, operative mortality (as high as 80%), and a lack of evidence demonstrating a therapeutic benefit from resection, many neurosurgeons came to rely on indirect therapy, consisting of CSF shunting and radiation [7-8].

As minimally invasive surgery becomes the standard of care in neurosurgery, it is imperative that surgeons become skilled in the use of image-guided techniques. The development of image-guided neurosurgery represents a substantial improvement in the microsurgical treatment of tumors, vascular malformations, and other intracranial lesions. Recently there is development of neuronavigation. Navigation has become a standard technique for pediatric neuro-oncological surgery, and indeed much of all cranial neurosurgery. However it is not without limitations: It is subject to error during the fusion of different image sequences, and at the point of registration to the patient. Once craniotomy and durotomy have been performed, the brain will be permitted to shift. The variable degree to which this occurs can unpredictably diminish navigation's accuracy to the intracranial anatomy. This inaccuracy increases with progressive tumor resection as the brain shifts more. Operating theaters can be crowded with staff and equipment; it can be challenging to ensure the navigation camera's field of view can see the optical reference points at all times [9].

Furthermore, two recent Cochrane reviews have highlighted the lack of evidence for intraoperative neuro-navigation in terms of tumor resection and quality of life [10, 11]. Furthermore, there has been a paucity of reports in the literature investigating perioperative management and clinical outcomes in this population as well as whether or not surgical approach affects functional status. Hence this study was conducted to evaluate the use of Neuronavigation and its technical challenges among subjects having Posterior Fossa & Pineal Region Tumour Surgery.

Material and Method

The present prospective non-randomised observational study was conducted at Neurosurgery Department, Bangur Institute of Neurosciences (B.I.N)/IPGMER &PG Hospital, Kolkata from Dec 2018 - Dec 2020. 50 cases were diagnosed with posterior fossa & pineal region tumour during the study period. Subjects with age groups >3 years were included in the study while subjects having prior surgery in another centers and unwillingness to perform surgery were excluded from the study.

History taking and clinical examination with help of pre-designed and pre-tested proforma was done. Patients underwent routine hematological and biochemical test as well as NCCT Brain and MRI Brain (P+C) + MRS with spinal screening according to specified Protocol.

All patients were treated surgically with the use of Neuronavigation equipment. Microsurgical technique with the use of magnification was introduced in all patients. The efficacy of the image guidance was graded according to a point's scale in which points were awarded ranging from 0 to 3. Cranial image guided score (IGS) was calculated by the summation of grading during designing the flap/burr hole, delineation of the intraoperative anatomy, navigation and access to the lesion and resection of the lesion or completion of the procedure. The scoring ranged from 0-12 and the utility of IGS in cranial neurosurgical procedures was calculated based on the total points for each surgery.

Grading and utility score

A. Grading scale of utility of Neuronavigation

0: Not helpful/detrimental

1: Helpful but can proceed without it

2: More useful than conventional methods

3: Irreplaceable

B. Cranial IGS score

a. Design of flap/burr hole

b. Delineation of anatomy

c. Navigation/access to lesion

c. Resection

0-3: Not helpful/detrimental

4-6: Helpful but can proceed without it

7-9: More useful than conventional methods

10-12: Irreplaceable.

Fig 1: Brainlab Neuronavigation

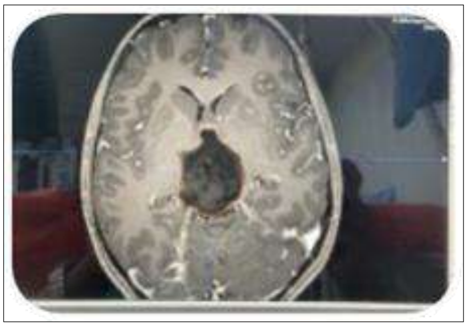

Fig 2: Delineation of pineal tumour surgical anatomy

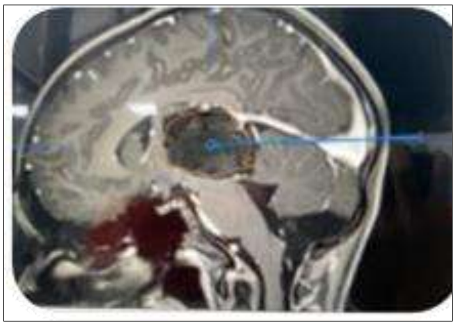

Fig 3: Planned trajectory via infratentorial supracerebellar (ITSC) approach

Fig 4: Positioning of the patient

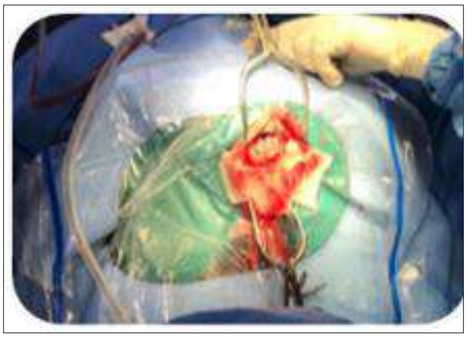

Fig 5: Craniotomy flap

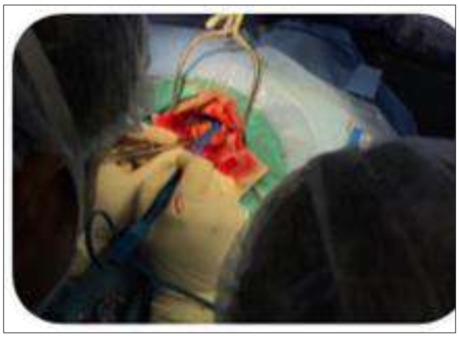

Fig 6: Neuonavigation-guided ITSC surgical approach

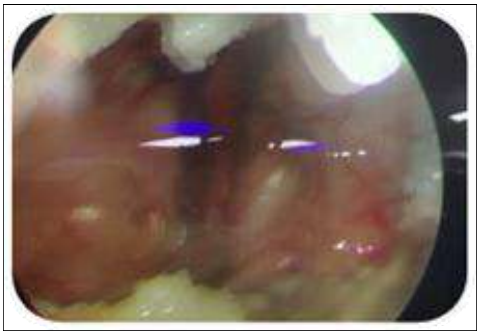

Fig 7: Microscopic view of pineal tumour (white)

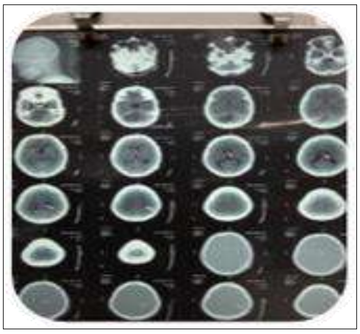

Fig 8: Pre-op imaging of posterior fossa tumour

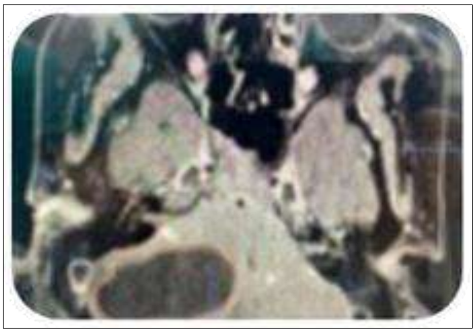

Fig 9: Neuronavigation guided tumour delineation

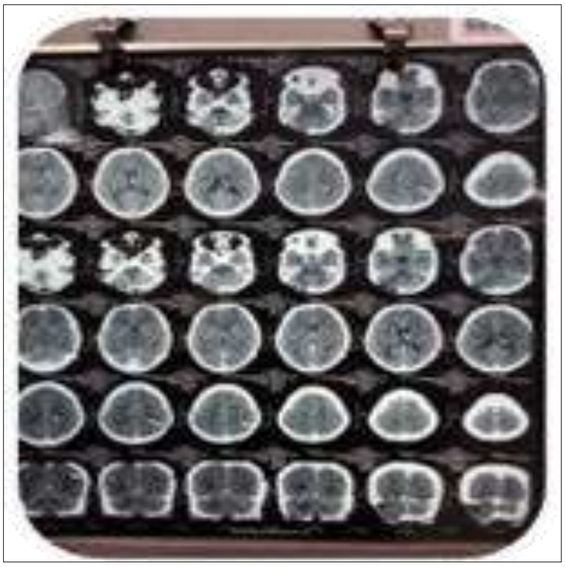

Fig 10: Post-op imaging showing gross total resection

At the time of discharge/1 month/3 months/6 months/12 months outcome was assessed according to Glasgow outcome scale. One month after surgery, according to Karnofsky, the patient's condition was divided into 2 level based on KPS Karnofsky rating:

- Good results: (KPS from 60-100 points),
- Poor results: (KPS from 10-50 points).

Statistical analysis

Data so collected was tabulated in an excel sheet, under the guidance of statistician. The means and standard deviations of the measurements per group were used for statistical analysis (SPSS 22.00 for windows; SPSS Inc, Chicago, USA). Difference between two groups was determined using chi square as well as Fisher exact test and the level of significance was set at $p < 0.05$.

Results

Out of 50 cases, 32 (64%) and 18 (36%) were male and female respectively. All the subjects in pineal tumour were having age less than 20 years with maximum subjects were from the age group of 6-10 years (45%) followed by 3-5 years (30%). In case of subjects with posterior fossa tumour, maximum subjects were from the age group of 21-40 years (33.33%) followed by 41-60 years (23.33%) as shown in table 1.

Table 1: Age distribution among the study subjects according to tumour

Age group in years	Pineal tumour		Posterior fossa tumour		Total	
	N	%	N	%	N	%
3-5	6	30	1	3.33	7	14
6-10	9	45	2	6.67	11	22
11-20	5	25	5	16.67	10	20
21-40	0	0	10	33.33	10	20
41-60	0	0	7	23.33	7	14
>60	0	0	5	16.67	5	10
Total	20	100	30	100	50	100

Most common symptom among the study subjects was nausea/vomiting (52%) followed by double vision (22%) and weight loss/fatigue (16%) as shown in table 2.

Table 2: Presenting signs and symptoms among the study subjects

Symptoms	N	%
Nausea/Vomiting	26	52
Double Vision	11	22
Weight Loss/Fatigue	8	16
Ataxia	7	14
Sensory Changes	5	10
Dizziness	4	8
Seizure	2	4
Loss of Consciousness	1	2

Biopsy, subtotal resection and gross total resection was achieved in 11 (22%), 15 (30%) and 24 (48%) subjects respectively. 14 (28%), 24 (48%) and 12 (24%) subjects stayed in ICU for 0-1, 2-7 and >7 days respectively. 36%, 44% and 20% of the subjects stayed in hospital for 0-7, 8-14 and >14 days respectively. Mean ICU and hospital stay among the study subjects was 5.6±7.59 and 12.38±8.13 days respectively (table 3).

Table 3: Intraoperative parameters among the study subjects

Variables	N	%
Extent of Resection		
Biopsy	11	22
Subtotal Resection	15	30
Gross Total Resection	24	48
ICU stay (In days)		
0-1 Days	14	28
2-7 Days	24	48
>7 Days	12	24
Length of stay in hospital (In days)		
0-7 Days	18	36
8-14 Days	22	44
>14 Days	10	20

Immediate post-operatively, moderate and severe disability was reported among 62% and 24% of the subjects while 8% of the subjects were in persistent vegetative state. After 15 days of surgery, none of the subject was in persistent vegetative state while 26% of the subjects had good recovery. When Glasgow outcome scale was compared among the study subjects, immediate and after 15 days of surgery, it was found to be statistically significant as $P<0.05$. KPS score kept improving with the time. When KPS score was compared among the study subjects, immediate, after 15 days and 1 month of surgery, it was found to be statistically significant as $P<0.05$ (table 4)

Table 4: Glasgow outcome scale among the study subjects immediate post-operative and after 15 days

Glasgow outcome scale	Immediate		After 15 days		Fisher exact test	*p* value
	N	%	N	%		
Good recovery	3	6	13	26	2.09	0.03*
Moderate disability	31	62	33	66		
Severe disability	12	24	4	8		
Persistent vegetative state	4	8	0	0		
Death	0	0	0	0		

Time Interval	KPS score			
	Good results (60-100)		Poor results (10-50)	
	N	%	N	%
Before	50	100	0	0
Immediate	31	62	19	38
After 15 Days	38	76	12	24
After 1 Month	43	86	7	14
Chi Square Test	9.31			
p value	<0.01*			

*: Statistically significant

According to grading scale of utility, neuronavigation was more useful than conventional methods and irreplaceable among 46% and 38% of the subjects respectively. Only in one case, it was not helpful. According to cranial IGS score, neuronavigation was more useful than conventional methods and irreplaceable among 52% and 26% of the subjects respectively. Only in two cases, it was not helpful.

Table 5: Grading scale of utility and cranial IGS score of Neuronavigation among the study subjects w.r.t outcome

Grading scale	N	%
Not Helpful/Detrimental	1	2
Helpful but can proceed without it	7	14
More useful than conventional methods	23	46
Irreplaceable	19	38
Cranial IGS score		
Not Helpful/Detrimental	2	4
Helpful but can proceed without it	9	18
More useful than conventional methods	26	52
Irreplaceable	13	26
Total	50	100

Discussion

The introduction of microsurgical techniques, advances in neuro-anesthesiology, magnetic resonance imaging (MRI), neuronavigation, endoscopy, high-speed drills, and hemostatic agents have dramatically changed the management of these tumors. The main goal of these techniques is to enhance surgical exposure by means of bony resection in order to minimize the need for brain retraction. When brain retraction is necessary, experienced neurosurgeons have replaced fixed retraction with dynamic retraction, thus limiting the risk of injury to underlying brain[12]. The present prospective non-randomised observational study was conducted in the Neurosurgery Department, Bangur Institute of Neurosciences (B.I.N)/ IPGMER &PG Hospital, Kolkata. During the study period 50 diagnosed cases of posterior fossa & pineal region tumour were included in the study.

There was male dominancy in our study. B. L. Pettorini *et al.* [13] and Abecassis IJ *et al.* [3] too in their study revealed similar male dominancy.

Most common symptom among the study subjects was nausea/vomiting (52%) followed by double vision (22%) and weight loss/fatigue (16%). The study of Jiang *et al.* [14], published in 2016 including 67 patients, found that the most common clinical presentation were symptoms of increased intracranial tension as nausea or vomiting (69%), headache (29%) and cerebellar dysfunction such as ataxia and diplopia in 45% and 3% of patients, respectively. In another study of 45 patients in 2016, the most common symptoms were headache (51%), nausea & vomiting (36%) visual disturbance (18%), and gait disturbance (18%) [15].

In the present study; biopsy, subtotal resection and gross total resection was achieved in 11 (22%), 15 (30%) and 24 (48%) subjects respectively. Mean ICU and hospital stay among the study subjects was 5.6±7.59 and 12.38±8.13 days respectively. Similar findings were reported by Abecassis IJ *et al.* [3] in their study. Pettorini *et al.* [13] in their study revealed that gross total resection was achieved in nine of the 13 patients who underwent surgery (70%), which is higher as compared to our study. This might be due to the difference in the staging of tumour.

In this study, immediate post-operatively, moderate and severe disability was reported among 62% and 24% of the subjects while 8% of the subjects were in persistent vegetative state. After 15 days of surgery, none of the subject was in persistent vegetative state while 26% of the subjects had good recovery. In Mohamed Emara *et al.* [15] study, excellent surgical outcome was observed in 12 cases (27.3%), good in 22 cases (50.0%), while poor outcome was observed in 10 cases (22.7%).In Shaikh *et al.*

[16] study, 66 patients concluded the surgical outcome into good in 77% of their studied group while poor outcome (moderately disable, not to perform daily activities independently or have neurological deficit) in 23%.

In our study, on admission, mean KPS among the study subjects was 75.91±14.79 and 10.51±9.88 respectively. KPS score kept improving with the time. When KPS score was compared among the study subjects, immediate, after 15 days and 1 month of surgery, it was found to be statistically significant as $P<0.05$. Similarly Abecassis IJ *et al.* [3] in their study found that patient's survived beyond 2 months all had identical KPS scores at 2-month follow-up and at most recent clinical follow-up. Overall, 6 patients (13%) had worsened KPS, 8 (17%) were unchanged, 14 (29%) had a 10-point improvement, 10 (21%) had a 20-point improvement, and 9 (19%) had a 30-point improvement. The average postoperative (2 months and most recent follow-up) KPS score was 88 ± 21.

According to grading utility scale, Neuronavigation was more useful than conventional methods and irreplaceable among 46% and 38% of the subjects respectively. Only in one case, it was not helpful. According to cranial IGS score, neuronavigation was more useful than conventional methods and irreplaceable among 52% and 26% of the subjects respectively. Only in two cases, it was not helpful. R Shirane *et al.* [17] in their study examined the role of assisted systems, to determine whether they could provide minimally invasive keyhole surgery. They found that endoscopy combined with neuronavigation permitted identification of the primary tumour and provided images of such high resolution that they could more accurately assess the surrounding tissue and vascular anatomy. Micro-endoscopy also definitely eliminated the need for large craniotomy, by permitting visualization of tumour remnant which was located in the anterior third ventricle. These high-resolution images also allowed us to identify normal variations of deep-seated venous structures, particularly in paediatric patients and patients requiring histological proof of glioma because of a poorly demarcated margin between tumour and normal brain. Therefore, the use of assisted systems with keyhole surgery enabled us to predict resectability more reliably in these patients.

The limitation of the present study was small sample size. Also the follow-up was not for a longer period of time. Due to lack of literature on neuronavigation, the present study findings were not compared in depth. Therefore more longitudinal study with larger sample is required to validate the findings of the present study.

From the results, we believe the implication of our findings for navigation in posterior fossa &pineal region tumour surgery is that image-guided removal is feasible and reliable. Although further investigations of the nature of post-imaging brain distortion and appropriate application and design of intra-operative image-updating methods are needed, the above findings predict good reliability for neuronavigation in the treatment of posterior fossa &pineal region lesions.

Conclusion

This study proved that the employed neuronavigation system is versatile and safe and that there are no adverse effects, complications or surgical mortality due to the device. It enabled the surgeon to plan smaller sized and better centered skin incisions and craniotomies and to approach the target lesion with less dissection of intact brain tissue. Due to the use of intraoperative imaging (with ultrasound) the experience provides a unique basis for next generation neuronavigation system.

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