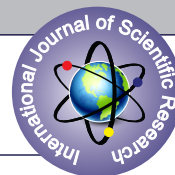


A PROSPECTIVE STUDY TO EVALUATE THE EFFICACY AND COMPLICATIONS OF IMAGE GUIDED NEUROSURGERY IN VARIOUS INTRACRANIAL LESIONS



Neurosurgery

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ABSTRACT

BACKGROUND: Image guided neurosurgery provides a patient specific three dimensional anatomy for preoperative planning and intra-operative navigation thus helping surgeon to perform complicated procedures with improved accuracy and safety.

METHODS: This is a prospective interventional study of patients with intracranial lesions over a period of 18 months .A total of 60 Patients with non traumatic intracranial lesions were included in the study which were equally divided amongst IGS and conventional surgery groups. The data was analysed using SPSS software version 17. P value of 0.05 was considered as statistically significant.

RESULTS: Length of incision, accuracy of placing craniotomy, post operative pain and radicality of excision is significantly improved by the use of IGS.

CONCLUSION: Neuronavigation should be routinely used in planning incision and craniotomy in supra tentorial lesions as its usage adds up to significant benefits for the patients.

KEYWORDS

IGS: Image Guided Surgery SPSS: Statistical Package for Social Science Supratentorial Neuronavigation

INTRODUCTION

Outline

Image-guided procedures are medical interventions that are based on computer-based systems to provide virtual image overlays to help the physician precisely visualize and target the surgical site. Image guided neurosurgery (Neuronavigation) or Frameless stereotactic surgery has made a tremendous impact over a last few years. The advent of frame based stereotaxy has heralded a new era however it was very cumbersome .Frameless stereotaxy has all the benefits of stereotaxy without its limitations. It provides a patient specific three dimensional (3D) anatomy for preoperative planning and intra-operative navigation.^{1,2}

The development of frameless image-guided neurosurgery

The era of frameless image-guided neurosurgery was launched in 1986.³ Until the mid-eighties, image-guided neurosurgery depended solely on frame-based stereotactic (from Greek: στερεος = three-dimensional, τασσω = to probe) localization technique.⁴⁻⁸ Neuronavigation is a neologism that refers to computer assisted localization methods equivalent to those used in frameless image-guided neurosurgery.⁹

The problem of brain shift

Because the brain is a non-rigid organ, the configuration of the brain is susceptible to morphological changes during the course of open neurosurgery.

Intra-operative computed tomography has been proposed long ago to acquire images during surgery.^{10,11}

Intra-operative MRI (iMRI) offers higher image quality but poses extra requirements to the operating room.^{12,13}

Apart from the use of a two-dimensional B-mode in intra-operative ultrasound (iUS) imaging¹⁴, one can also move a small hand-held probe over the cortex to acquire three-dimensional ultrasound imaging data.¹⁵⁻¹⁷

In experimental studies, the use of tumor specific nanoparticles is an emerging technique for direct visualization of tumor mass.¹⁸⁻²⁰

Frameless stereotaxy in India

Sri Sathya Sai Institute of Higher Medical Sciences was the first hospital in India to acquire the Stealth Neuro-navigation unit in 2001.²¹

Review of Literature

Image-guided neurosurgery

In this review, we have tried to historically follow the development of interactive image-guided neurosurgery and to show the possibilities existing nowadays to exploit the information being inherent to the three-dimensional volumetric data sets to the benefit of the surgeon and, therefore, to the benefit of the patient he or she is operating on.

Stereotaxy

The first apparatus that could be considered an ancestor of modern stereotactic frames was constructed in 1889 by Zernov.²²

The first stereotactic device and a related anatomical atlas were developed by Horsley and Clarke in the first decade of this century.²³ For human surgery the device was not used until 1947 when Spiegel and Wycis actually performed the first stereotactic operation in humans.²⁴

In 1949, Talairach²⁵ and Leksell²⁶ were the next to describe stereotactic frames based on arcs, as opposed to the rectilinear system constructed by Horsley and Clarke.

In 1979 Brown devised a method for localizing any point on the CT scan with respect to the stereotactic head frame.²⁷

In 1986, Kelly et al. described the resection of intra-axial brain neoplasms with a computer-assisted stereotactic laser.²⁸

Neuro navigator arms

In the end of the 1980's the first so-called three-dimensional digitizers or neuro navigators appeared in the scientific literature. Neuro navigator arms are passive intraoperative position sensing systems.

In the beginning, for computerized tomography lead balls were employed as fiducials. Later, many other kinds of markers came into use. A non-invasive, reattachable skull fiducial marker system which attaches to the maxillary teeth was presented by Howard et al.²⁹

The question where to place the fiducials was answered in many different ways. In 1995, Doshi and coworkers found increasing numbers of fiducials to increase the achieved accuracy and the more widespread the fiducials were, the better was the registration accuracy.³⁰

Armless neuro navigator devices

The sonic digitizers were first one to be tried with accuracy of ± 5 mm as per Mösges & Lavallée.³¹ Then came the magnetic digitizers which had short period of trial after which a more robust technology of optical tracking arrived.³²⁻³⁵

Role of Image guided surgery : Current evidences

Deepali et al.

Deepali J in her original article compared frame based stereotaxy, frameless stereotaxy and ultrasound based biopsy procedures and concluded that near real time intra-operative imaging provided by frameless stereotaxy gives best yield of tissue for diagnosis though their difference was statistically not significant.³⁶

Ohue et al.

Ohue S et al evaluated the utility of a new ultrasound (US)-linked navigation system for brain tumor surgery in 64 patients with intracranial tumors and concluded that the integration of the US scanner with the navigation system allowed comparisons between the intra-operative US and preoperative images. This US linked navigation system provides information on brain shift, and improves the accuracy and utility of image-guided surgery.³⁷

Present status

Although the number of prospective randomized studies is low at the moment, the controversies to use image-guided neurosurgery for the resection of cerebral glioma (either low or high graded) increasingly are unjustified. That is what Kubben et al. concluded in their review too.³⁸ However the sufficiency of evidence we have now for glioma surgery is not so high for other tumor entities (for instance meningioma or hypophysis adenoma) as well as for vascular malformations as was mentioned by Rohde and Thomale in their papers.^{39,40}

Aims and Objectives

- 1 To study various non traumatic intracranial space occupying lesions and identify and define the current indications for image guided neurosurgery.
- 2 To evaluate if image guided neurosurgery alters the approach of an experienced neurosurgeon.
- 3 To compare complications of image guided neurosurgery with conventional surgery.
- 4 To compare image guided surgery with conventional surgeries in terms of hospital stay, length of incision, accuracy in placement of craniotomy, residual lesion and post operative pain.
- 5 To assess if Glasgow outcome score (GOS) of patients is changed at 3 months due to use of image guided surgery as compared to conventional surgery.

Materials and Method Outline

This prospective interventional Neurosurgery study was conducted in Department of Neurosurgery, Safdarjung Hospital associated with Vardhman Mahavir Medical College, New Delhi. A prospective analysis of neurosurgery patients with intracranial / skull lesions over a period of 18 months between from July 2010 to Jan 2012, was carried out in the Department of Neurosurgery.

A total of 60 Patients presented with non traumatic SOL, who fulfilled the inclusion and exclusion criteria and who reported to the Department of Neurosurgery, Vardhman Mahavir Medical College & Safdarjung Hospital, New Delhi were included in the study. Written informed consent was obtained from the patients enrolled in the study and they were further worked up. Only those neurosurgery patients whose pathology status was not known at the time of reporting to the hospital were included in the analysis. Presumptive diagnosis was made on the basis of CT scan and clinical signs/symptoms as per the applicable and widely accepted protocols.

Study Design

This was a cross sectional, interventional study done in Neurosurgery patients visiting Department of Neurosurgery, Safdarjung Hospital attached to Vardhman Mahavir Medical College, New Delhi. Sixty

neurosurgery patients fulfilling the inclusion criteria coming to hospital were enrolled for investigation, diagnosis and management.

Study centre

The study was conducted at the Department of Neurosurgery, Safdarjung Hospital and associated Vardhman Mahavir Medical College, New Delhi.

Study population

The study was done on patients with non traumatic SOL admitted through outpatient department / emergency of Department of Neurosurgery, Safdarjung Hospital and associated Vardhman Mahavir Medical College, New Delhi.

Duration of study

A prospective review for the period of over a period of 18 months between from July 2010 to Jan 2012, was carried out in the Department of Neurosurgery.

Selection of cases

Subjects satisfying all the inclusion criteria and none of the exclusion criteria were enrolled in the study. All patients presenting to this hospital having an intracranial lesion that warranted neurosurgical intervention were included in this study.

Inclusion criteria

- Age no restriction
- Both male and female
- Primary indications for surgery present
- GCS > 8
- Did not have any external sign on skull (that could aid localization)

Exclusion Criteria

- Previously operated lesions
- Lesions with external signs on skull such as sinus, bone swelling etc.
- Poor general condition
- High surgical risks due to patient factors (Poor GCS, unresponsive shock, high risk co-morbidities)

Sampling technique

Patients were being interviewed after checking their suitability as per the inclusion and exclusion criteria irrespective of the age, sex, income, occupation, socio economic status and place of residence. Non traumatic SOL patients after reporting to hospital underwent initial history taking, examination, investigations and diagnosis.

Patients were randomly allocated to both the arms one by one. Thirty patients had undergone conventional surgery where as rest 30 underwent image guided surgery

Sample size

Total Number of patients: 60
Conventional surgery: 30
Image guided surgery: 30

Sample size is based on the availability of the cases in the hospital as per the records of the hospital as well as time and resource constraint.

Ethical considerations

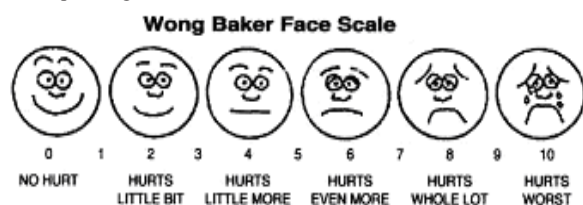
The study was conducted according to Good Clinical Practice guidelines vide World Medical Association's Declaration of Helsinki, sixth edition and ICMR guidelines on research on human subjects, 2006 after permission of Institutional Ethical Committee, Safdarjung Hospital attached to Vardhman Mahavir Medical College, New Delhi.

Methodology

A total of 60 patients were included in the study. The study procedure was explained to the patients and informed consent was obtained from them. Medical case record sheets of the patients were reviewed.

1. The selected patient's history was noted in study proforma with following considerations:-
 - a. Detailed history of symptoms (onset, duration and progression) including co-morbidities if any.
 - b. Clinical examination with special consideration for neurological signs.
 - c. Baseline laboratory investigations – Including Hemogram, Urea,

- creatinine, random blood sugar, serum electrolytes, PT(INR)
- Special studies such as neuro ophthalmological and radiological studies.
 - The patients who have presented with all investigations including contrast imaging done elsewhere were taken as control patients who were compared with patients presenting primarily at our hospital so that the imaging (Contrast CT / MRI) could be done according to established image guided protocols. However if it was felt that patient will be benefitted by image guided procedure then he / she underwent image guided procedure only which means that best treatment was made available to the patient at all times as per best clinical practice. In all patients the reason was noted down for placing them in their respective groups.
 - The preoperative imaging was studied in detail and surgical roadmap was decided in patients that were not undergoing image guided surgery. In patients who were planned for neuronavigation, the surgical approach was decided on operation table as per the shortest route seen under neuronavigation or avoiding eloquent cortex if any.
 - All the procedures were done as routine procedures by consultants or under direct observation by them. Informed consent was obtained from all patients before surgery which included the procedure in detail, its complications and alternative treatment modalities (Including no treatment).
 - The control patients (not undergoing their procedure under neuronavigation) were taken in OT and were instituted GA / LA + sedation and incision was marked. The initial craniotomy was made with attempts to keep it within the limits of lesion however if an extension was felt mandatory subsequently then it was extended.
 - The image data on CD containing DICOM axial images was transferred to planning unit and lesion was marked using Brain Labs software iPlan 5. The planned data was transferred to Vectorvision on a dedicated pen drive. Image guided surgery was done using BrainLabs Vectorvision II.
 - The head of patients undergoing image guided surgery was fixed on Mayfields 3-pin head rest in supine position after which the image registration was carried out. Once patient was registered on neuro navigation, the incision was marked and infiltrated with 1% xylocaine with 1:400,000 adrenaline solution. The surgery was then carried out according to its location and the aim decided preoperatively. Extent of resection was checked intermittently to assess completeness of resection. In all cases tissue was sent for culture / histopathological examination for confirmation of diagnosis.
 - Intraoperative findings were noted in proforma and non contrast post op imaging was done within 48 hours in all cases to assess the approximate extent of resection achieved during procedure. Then another imaging (contrast enhanced) was done at 4 weeks to assess residual lesion.
 - Post operative pain was assessed using Wong-Baker face scale (Picture 1). Patients were postoperatively monitored for major or minor complications. Complications were considered major if they persisted beyond 30 days after surgery or if they required surgical intervention for their correction otherwise they were labeled as minor complications. The factors considered as complications were death, reoperation, brain edema, brain hematoma, new neurological deficits, seizures, surgical site infection, sub cutaneous or sub galeal collections and poor bone flap setting.



Picture 1 – Wong-Baker Face scale for post-op pain assessment

10. Patients were discharged from hospital as soon as they were stable hemodynamically and off intravenous medications with advice to review for suture cutting with HPE report. They were subsequently examined 3 months later for assessing their Glasgow outcome score (Table 1). Good GOS was considered when GOS>3 while poor outcome GOS was considered when GOS<3.

Table 1 – Glasgow outcome Score

Score	Description	Detail
1	Dead	
2	Persistent Vegetative state	Unable to interact with environment; unresponsive
3	Severe Disability	Able to follow commands/ unable to live independently
4	Moderate disability	Able to live independently; unable to return to work or school
5	Good recovery	Able to return to work or school

Statistical Analysis

Data was simultaneously entered into proforma and was updated during review at 3 months. It was entered into Microsoft excel (MS Office 2007) and Master Chart prepared. The data were analysed using SPSS software version 17.0. Statistical analysis of data among groups was done. Nominal data (such as gender, complications) were presented as number and percentages while continuous data (such as age etc.) were expressed as mean, standard deviation and range. Chi-Square test was applied as appropriate for comparison of nominal data. P value of 0.05 was considered as statistically significant (Confidence interval of 95% was taken into account).

Observation and Results

Outline

A total of 60 Patients presented with non traumatic intracranial lesion, who fulfilled the inclusion and exclusion criterion and who reported to the Department of Neurosurgery, Vardhman Mahavir Medical College & Safdarjung Hospital, New Delhi were included in the study. Written informed consent was obtained from the patients enrolled in the study and they were followed up.

Demographics

General

In our study mean age of sample population was 36.08 years with standard deviation of 18.17 years.

Table 2 – Mean age of patients

N	60
Mean age	36.08 years
Std. Deviation	18.17 years
Range	73 Years

Gender Distribution

Table 3 – Gender distribution of patients

S. No.	Sex Distribution	Type of Surgery			
		Image Guided	Surgery	Conventional Surgery	
		N	%	N	%
1.	Male	19	63.3	15	50.0
2.	Female	11	36.7	15	50.0
	Total	30	100.0	30	100.0

$$\chi^2=1.086, P=.217(NS)$$

Age Distribution

Table 4 – Age distribution of patients

S. No.	Age Group	Type of Surgery				TOTAL	
		Image Guided	Surgery	Conventional Surgery			
		N	%	N	%	N	%
1.	5-25	12	40.0	8	26.7	20	33.3
2.	26-45	11	36.7	12	40.0	23	38.3
3.	46-65	5	16.7	8	26.7	13	21.7
4.	>65	2	6.7	2	6.7	4	6.7
	Total	30	100.0	30	100.0	60	100.0

$$\chi^2=1.536, P=.671(NS)$$

Benefit derived by Image guided surgery

The way the neuronavigation added value to surgery over conventional surgery in our various lesions is depicted in following table.

Table 5 – Advantages achieved by neuronavigation

S.No	Advantage achieved	Cases
1	Assisting planning trajectory through non-eloquent brain	11
2	Small craniotomy and limited cortical opening for deep lesions	11

3	Small craniotomy for superficial lesions	5
4	Placing burr hole for abscess aspiration	1
5	Avoiding C-arm in Pituitary surgery	2

Diagnosis and Anatomic location in Brain

Disease entities

Most lesions were malignant tumors with 16 patients in image guided surgery group and 15 patients in conventional surgery group.

Table 6 – Distribution of cases and their diagnosis

S. No.	Disease group	Diagnosis	Image Guided Surgery	conventional surgery
1.	Malignant Tumors	Astrocytoma	7	6
		GBM	5	6
		ODG	2	2
		Ependymoma	1	0
		Pineoblastoma	1	0
		Metastasis	0	1
2.	Benign Tumors	Meningioma	2	7
		Pituitary Adenoma	2	0
		Epidermoid	0	1
		Choroid Plexus Papilloma	0	1
3.	Arachnoid Cyst		2	0
4.	Infection	Abscess	3	2
		Tuberculoma	1	1
		Osteomyelitis	0	2
5.	Arterio – Venous Malformation	AVM	1	0
		Cavernoma	3	0
6	Others	Calcified EDH	0	1
Total	30	30		

Anatomic location of Lesions

There were 61 lesions treated in this study, of which majority were in frontal and parietal lobes.

Table 7– Anatomic location of lesions in brain

Anatomic location of lesions	Type Of Surgery					
	Image Guided Surgery		Conventional Surgery		Total	
	Count	%	Count	%	Count	%
Frontal	2	7%	9	30%	11	18%
Parietal	10	32%	8	27%	18	30%
Temporal	5	16%	0	0%	5	8%
Fronto-Parietal	0	0%	5	17%	5	8%
Fronto-Temporal	1	3%	1	3%	2	3%
Parieto-Occipital	3	10%	4	13%	7	12%
Parieto-Temporal	5	16%	2	7%	7	11%
Midline	3	10%	1	3%	4	7%
Posterior fossa	2	3%	0	0%	2	3%
Total	31	100.0	30	100.0%	61	100.0%

Remarks: 1 patient had two small meningioma's which were operated under neuronavigation in single sitting thus making the number of total lesions to be 31 in image guided surgery group.

Lateralization of lesions

We have 19 right sided lesions and 37 left sided lesions in total. (Table 8)

Table 8 - Lateralization of Lesions in brain

Side of lesions	Type Of Surgery					
	Image Guided Surgery		Conventional Surgery		Total	
	Count	%	Count	%	Count	%
Right Sided Lesions	12	39%	7	23%	19	31%
Left Sided Lesions	15	48%	22	73%	37	61%
Midline Lesions	4	13%	1	4%	5	8%
Total	31	100.0%	30	100.0%	61	100.0%

Distribution of complications

The incidence of complications is depicted below.

Table 9- Complications and their distribution

S.No.	Complication	Image guided Surgery	Conventional surgery
1	Wound Infection	8	5
2	Wound Collection	4	5
3	Poor Bone Flap Setting	1	5
4	Significant Hematoma	1	2
5	Minor Hematoma	1	0
6	Hemiparesis	0	2
7	Hemiplegia	3	3
8	Diabetes Insipidus	1	0
9	Residual Lesion Requiring Re-exploration	1	2
10	CSF Leak	0	1
11	Aphasia	0	1
12	No Complication	10	4

$$\chi^2=12.708, P=.166(NS)$$

Results

Hospital Stay

Table 10- Hospital Stay among subjects

S. No.	Hospital Stay in Days	Type of Surgery					
		Image Guided Surgery		Conventional Surgery		TOTAL	
		N	%	N	%	N	%
1.	<6	11	36.7	14	46.7	25	41.7
2.	6-10	12	40.0	10	33.3	22	36.7
3.	11-15	3	10.0	5	16.7	8	13.3
4.	16-20	2	6.7	1	3.3	3	5.0
5.	>20	2	6.7	0	.0	2	3.3
Total		30	100.0	30	100.0	60	100.0

$$\chi^2=3.375, P=.385(NS)$$

Length of incision

In majority of patients i.e. 47(78.3%) patients, the incision was between 5-10 cm with 25 patients in image guided subset and 22 patients in conventional surgery group.

Table 11 – Length of incision

TOTAL LENGTH OF INCISION (Length/ No of lesions)	Type Of Surgery					
	Image Guided Surgery		Conventional Surgery		Total	
	N	%	N	%	N	%
<5	5	16.7	2	6.7	7	11.7
5-10	25	83.3	22	73.3	47	78.3
>10	0	0	6	20.0	6	10.0
Total	30	100.0	30	100.0	60	100.0

$$\chi^2=7.477, p<0.05$$

Accuracy of craniotomy placement

The placement of craniotomy under neuronavigation was exact and did not require extension for adequate exposure in all but 2 (93%) cases.

Table 12- Extension of craniotomy

S. No.	Craniotomy Extended By	Type of Surgery					
		Image Guided Surgery		Conventional Surgery		TOTAL	
		N	%	N	%	N	%
1.	None	28	93.3%	16	53.3%	44	73.3%
2.	1-5mm	0	.0%	14	46.7%	14	23.3%
3.	Not Available	2	6.7%	0	.0%	2	3.3%
Total		30	100.0%	30	100.0%	60	100.0%

$$\chi^2=19.273, p<0.05 \text{ Table}$$

Residual lesion

No residual lesion was found among 13 (43%) out of total 30 patients who underwent image guided surgery where as 10 (33%) patients who underwent conventional surgery were without residual lesion. This difference in residual lesion is significant with P values being <.05.

Table 13 - Residual lesion in patients

Residual Lesion	Type of Surgery					
	Image Guided Surgery		Conventional Surgery		Total	
	N	%	N	%	N	%
None	13	43.3	10	33.3	23	38.3
<10	11	36.7	7	23.3	18	30.0
10-30	6	20.0	5	16.7	11	18.3
30-50	0	.0	7	23.3	7	11.7
>50	0	.0	1	3.3	1	1.7
Total	30	100.0	30	100.0	60	100.0

$\chi^2=9.371, P<0.05$

Post operative average pain score

Table 14 - Distribution of average pain score

Average Pain Score	Type of Surgery					
	Image Guided Surgery		Conventional Surgery		Total	
	Count	%	Count	%	Count	%
0	1	3.3%	0	.0%	1	1.7%
1	12	40.0%	5	16.7%	17	28.3%
2	7	23.3%	4	13.3%	11	18.3%
3	10	33.3%	21	70.0%	31	51.7%
Total	30	100.0%	30	100.0%	60	100.0%

$\chi^2=8.604, p<0.05$

GOS at 3 months

Table 15 - GOS at 3 months

S. No.	GOS at 3 Months	Type of Surgery					
		Image Guided Surgery		Conventional Surgery		TOTAL	
		N	%	N	%	N	%
1.	1	2	6.7	0	.0	2	3.3
2.	2	0	0	1	3.3	1	1.7
3.	3	5	16.7	6	20.0	11	18.3
4.	4	3	10.0	7	23.3	10	16.7
5.	5	20	66.7	16	53.3	36	60.0
Total		30	100.0	30	100.0	60	100.0

$\chi^2=5.135, P=0.175(NS)$

DISCUSSION

Outline

Despite being widely reported in the recent literature as valuable adjuncts for surgical planning and intra-operative navigation during open intracranial procedures, frame-based stereotactic technology is still generally considered as the gold standard for delivering a probe in a well-defined target.⁸

Demography

After analysis of data, two subgroups of 30 cases each for conventional & Image guided Surgery (IGS) were identified. There were no statistically significant differences in sex, age, or size or location of the tumors between the two populations.

Complications

Total number of events of complications in case of image guided surgery was 20 while in cases of conventional surgery was 30.

The incidence of neurological deficits (Hemiparesis, Hemiplegia and aphasia) was higher in conventional surgery patients, which is indirectly suggestive of advantage of surgical approach using neuronavigation. In study published by Kurimoto et al neurological deterioration occurred in 4 of 42 (9.5%) and in 6 of 34 (17.6%) patients after surgery with neuronavigation and surgery without neuronavigation.⁴¹

In a study by Paleologos TS et. al in London severe complications (permanent or requiring additional surgical procedures) were encountered in 14% of the cases in the SS group and 6% of the cases in the IGS group ($P = 0.019$), whereas the rates of minor complications

(resolved within 30 d without further surgery) were similar (8 and 10%, respectively).⁴²

Hospital Stay

In the IGS subset majority of patients i.e. 12 (40.0%), hospital stay was 6-10 days. For patients in conventional surgery group most patients i.e. 14 (46.7%) stayed for 5 days or less

The association of complications to the type of surgery was found to be non significant (P values >0.05) in our patients. Paleologos TS et al in their paper have similar results⁴². In another study Henderson et al in 150 patients reported that patients who underwent image guided surgery had a better pain profile in post operative period, significantly shorter length and cost of hospital stay, length of ICU stay and significantly lower cost of post ICU stay.⁴³

Length of Incision

In majority of patients i.e 47(78.3%) patients, the incision was between 5-10cm with 25 patients in image guided subset and 22 patients in conventional surgery group. This difference in both groups was found to be significant in our study.

Accuracy in placement of craniotomy

In image guided surgery the placement of craniotomy was accurate and there was never any need for significant extension of craniotomy. In 28 patients (all patients in whom craniotomy was done) the need for extension of craniotomy was limited for minor nibbling of bone to smoothen out the irregular margins. In 2 patients, transnasal trans sphenoidal surgery was done. The extension for majority of conventional surgery patients i.e. 16(53.3%) was limited to 5mm or less, however a high number of patients i.e. 14(46.7%) craniotomy needed extension for 6-10mm to make the approach better.

Residual lesion

No residual lesion was found among 13 (43%) out of total 30 patients who underwent image guided surgery where as 10 (33%) patients who underwent conventional surgery were without residual lesion. This difference in residual lesion is significant with P values being $<.05$. In the randomized controlled study by Wirtz et al, the mean amount of residual tumor tissue was 28.9% for standard surgery and 13.8% for surgery involving neuronavigation.⁴⁴ The percentage of a gross total resection mentioned by Kurimoto et al was significantly higher in the neuronavigation group compared to that in the non navigation group (64.3% versus 38.2%).⁴¹

Post Operative Pain

Majority of patients in image guided surgery subset i.e. 12 (40%) were having average pain score of 1 while 10 (33%) had an average pain score of 3. 7 (23%) patients had an average pain score of 2 and 1(3%) patient was completely pain free in his post operative period.

In conventional surgery subset 21 (70%) patients had average pain score of 3 while 5 (17%) and 4 (13%) patients had their average pain scores of 1 and 2 respectively.

This difference in pain scores was significant in our study with P value <0.05 which can in part be attributed to smaller length of incision required in image guided surgery. Henderson et al, in their study in 150 patients also found that the patients undergoing image guided surgery had better pain profile during post operative period.⁴³

Glasgow Outcome score

In 36 patients the GOS was 5 of which 20 were in image guided subset and 16 were in conventional surgery subset. This difference in our study was not significant. In the literature review we did not find a study of image guided surgery in which functional independence was made an attribute. Wirtz et al has shown better outcomes with image guided surgery where prolongation of life is concerned, but they did not comment on functional status of their patients.⁴⁴

Summary and Conclusion

1. We started with aim to identify the indications for use of image guided surgery and we can safely conclude that in our study and literature, neuronavigation has stood the test of time for planning craniotomy in supratentorial lesions. In performing biopsies of deep seated lesions also frameless stereotaxy is helpful, however frame based stereotaxy reigns its supremacy. Thus neuronavigation should be routinely used in planning incision

and craniotomy in supratentorial lesions.

2. Image guided surgery does helps to reduce complications.
3. The main complications suffered by image guided surgery patients was wound infection followed by sub galeal collection at operative site. There was no significant difference in incidence of these complications as compared to the complications in conventional surgery group.
4. Length of incision, accuracy of placing craniotomy, post operative pain and radicality of excision is significantly improved by use of image guided surgery. The hospital stay of patient however was not affected by use of either procedure in our study.
5. The functional outcome of patients in either group was not significantly different in our study.

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