DOI: https://doi.org/10.70749/ijbr.v3i6.1624

INDUS JOURNAL OF BIOSCIENCE RESEARCH
https://induspublishers.com/IJBR
ISSN: 2960-2793/ 2960-2807

Comprehensive Analysis of Speech Deficits after Dominant Hemisphere Glioma Surgery having Integrated Exoscopic Neuronavigation, fMRI and DTI at Punjab Institute of Neurosciences, Lahore

Hamza Noman[1], Adeeb Ul Hassan[2], Bakht Nawaz[1], Syed Shahzad Hussain Shah[1], Usman Ahmed Kamboh[1], Muhammad Ubaid ur Rehman Bhutta[1]

[1]Department of Neurosurgery Unit II, Punjab Institute of Neurosciences, Lahore General Hospital, Lahore, Punjab, Pakistan.
[2]Department of Neurosurgery, King Edward Medical University, Mayo Hospital, Lahore, Punjab, Pakistan.

ARTICLE INFO

Keywords: Glioma, Exoscope, Neuro Navigation, Fmri, DTI.

Correspondence to: Hamza Noman
Department of Neurosurgery Unit II, Punjab Institute of Neurosciences, Lahore General Hospital, Lahore, Punjab, Pakistan.
Email: hamxanoman@gmail.com

Declaration
Authors' Contribution
All authors equally contributed to the study and approved the final manuscript

Conflict of Interest: No conflict of interest.

Funding: No funding received by the authors.

Article History
Received: 20-05-2025 Revised: 14-06-2025
Accepted: 21-06-2025 Published: 25-06-2025

ABSTRACT

Background: The surgery for gliomas involves resection of as much tumour as possible without causing neurological deficit. Speech is one of the modalities most at risk of impairment in these surgeries especially around perisylvian cortices. With modalities such as fMRI, DTI and exoscopic neuronavigation, we can hope to reduce these impairments to a minimum. **Objectives:** 1. To determine the frequency of speech deficits in post operative patients of dominant hemisphere gliomas using the quick aphasia battery.

2. To assess the benefits of functional MRI, Diffusion tensor imaging tractography and exoscopic neuro-navigation in surgery of these patients.

Materials & Method: In this study, a cohort comprising 60 patients was analysed. Data collection spanned from February 2025 to May 15, 2025. Prior to surgical intervention, all patients underwent comprehensive preoperative imaging assessments – fMRI, DTI and neuronavigation protocol MRIs. To evaluate speech, assessments were performed on all patients both before and after surgery using the Quick aphasia battery (QAB) – a validated scale for speech assessment, with follow-up evaluations conducted at 1 month postoperatively. The speech impairments were correlated with factors such as size and location of tumour. **Results:** Preoperatively, all 60 patients exhibited intact neurological function. However, in the postoperative phase, 33 patients experienced speech impairments. Notably, these deficits exhibited an encouraging trend toward gradual improvement, ultimately reaching a state of normalcy in many patients (20/33) over a span of 1 month. Glioma location and glioma size were variables significantly associated with frequency of speech deficits. **Conclusion:** Our findings highlight the significance of using these advanced modalities in management of dominant hemisphere gliomas and what to expect in terms of speech deficits with respect to the size and location of tumours.

INTRODUCTION

Gliomas are neuroepithelial tumours of supporting glial cells in the nervous system. WHO classifies tumours based on their histological features such as nuclear atypia, anaplasia, microvascular proliferation, and necrosis into Grades I to IV. Low grade gliomas are considered as WHO grade II tumours, while grades III and IV are high grade.[1]

In general, the management of gliomas involves surgical resection of as much tumour as possible without causing neurological deficit, with consideration for adjuvant chemoradiotherapy for those deemed "high risk."[3] Surgical resection, however, carries a risk of leaving patients with post op deficits such as aphasia. It is therefore of utmost importance that such deficits be prevented by any means necessary. This is especially true when surgery is being performed near eloquent speech areas. The gold standard for locating language cortices is electrical stimulation mapping (ESM).[4] However, this technique is not without obstacles. Unlike intraoperative mapping of motor regions, patients must be awake and able to respond. This requirement leads to longer operative times, a higher chance of intraoperative seizures, possibility of airway compromise and the potential for considerable patient distress.[4]

Functional MRI

One of the ways in which Language areas can be identified is Functional MRI (fMRI.) fMRI works by identifying blood oxygen level dependent (BOLD) changes in MRI signal that arise when neuronal activity occurs following a stimulus or task, for example motor task or speech production.

Neuronal activity in a region of cortex stimulates

Copyright © 2025. IJBR Published by Indus Publishers
This work is licensed under a Creative Commons Attribution 4.0 International License.

increased blood flow to the region. This excess perfusion exceeds the normal demand of the brain tissue leading to a decrease in level of deoxyhemoglobin in the region. While oxyhemoglobin is not very different from other tissues or water, de-oxyhemoglobin is significantly paramagnetic. This results in signals that decay slowly and thus are stronger when recorded. This small increase is the BOLD signal and is the basis of functional MRI.

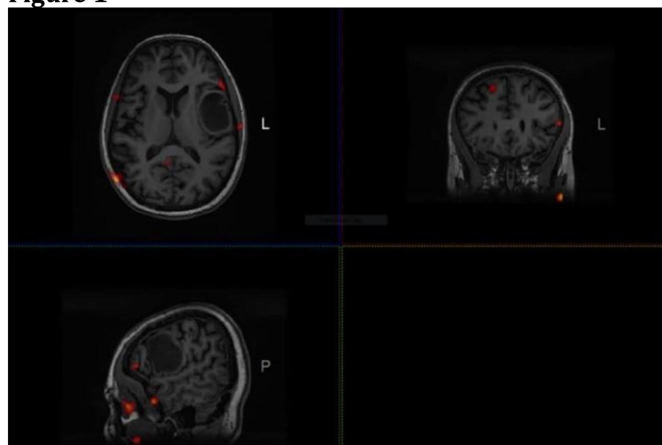
Most fMRI are performed using "snapshot" methods of which echoplanar imaging is the main model. Echoplanar imaging has the drawback of a low spatial resolution (lower quality images) but excels in its high temporal resolution – meaning its ability to record images at a very fast pace (typically about 50-100ms). This is much faster than conventional MRI images and hence they do not suffer from blurring due to physiological changes, they allow imaging of the entire brain in a few seconds and permit sampling of haemodynamic responses that is used in functional MRI.

The MRI suite in which fMRI is to be performed is equipped with at least 1.5 Tesla MRI and ability to perform echoplanar imaging. It also has (optionally) stimulation equipment, specifically designed to give commands and stimuli to the patient during acquisition of fMRI.

The patient is taken to the MRI suite, and the operator gives commands to the patient while MRI echoplanar imaging is being executed, for example in speech fMRI, the stimulation equipment will display a word on the screen and the operator will ask the patient to think of the word without saying it. This will theoretically increase BOLD signal in the Wernicke's area which is involved in word comprehension, this BOLD signal can then be recorded in the fMRI.[5]

These signals of BOLD can then be merged to high resolution conventional brain MRIs of the patient to map important areas such as speech, motor, auditory and visual cortices. This can also identify the dominance of language in the brain, which previously was done with invasive testing such as Wada test.[6]

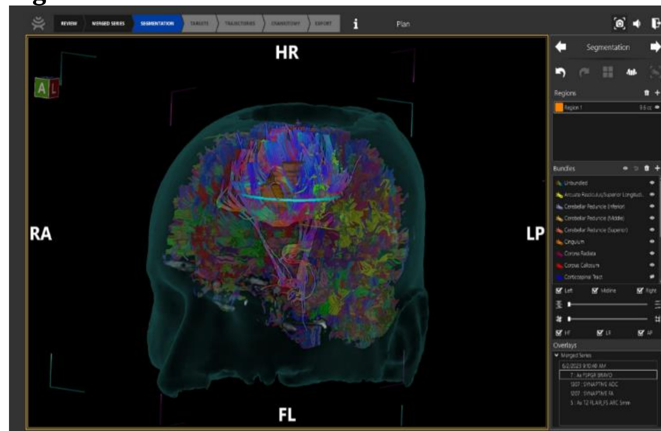
Figure 1



Diffusion tensor imaging (DTI) Tractography

DTI tractography is another modality that has proven to be very helpful. DTI has been used to evaluate the effect of intraparenchymal tumours on adjacent white matter tracts, including displacement, infiltration, and possible disruption by the tumour. When combined with functional imaging data (e.g., fMRI), DTI has been used to identify the subcortical connections between essential eloquent cortices. This identification provides the surgeon with invaluable 3-dimensional information about spatial relationships of eloquent structures and their connectivity intraoperatively, the use of this technology can be useful in aiding the resection of tumours in the eloquent brain.[6,7]

Figure 2



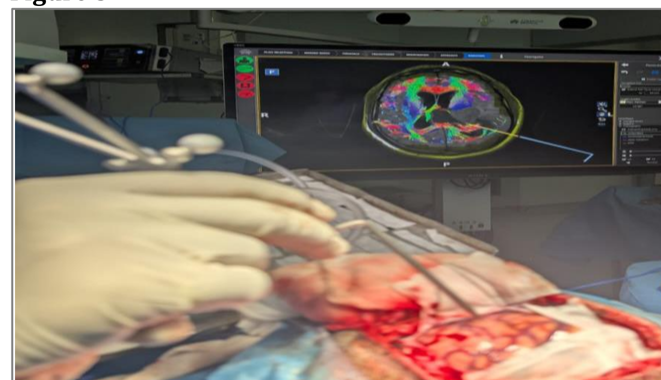
Exoscopic Neuro-navigation

An exoscope is a high-definition, digital imaging system used in surgery to provide a magnified, three-dimensional (3D) view of the surgical field. It transmits real-time, high-definition images to a monitor, offering an alternative to traditional operating microscopes.

Neuro-navigation is a system in which the tip of a pointer can be calibrated to an image space, whereby showing the tip of an instrument in relation to corresponding CT or MRI images, without requiring a stereotactic frame. Therefore, providing valuable precise spatial information to neurosurgeons, to aid in surgery. The neurosurgeon can calculate the localization and approach a small lesion accurately, therefore feeling more confident. It reduces morbidity by allowing the surgeon to identify the relationships of the tumour to important nearby structures such as motor and speech areas.[9]

Exoscopic neuro-navigation incorporates these two gadgets. The same pointer that is used in neuro-navigation is used to guide the exoscope. The exoscope adjusts its position as well as its focus to exactly the point at which the pointer is placed. So that the surgeon can simultaneously figure out where he is at according to the neuro-navigation as well as adjust his view to that point to operate.

Figure 3



Copyright © 2025. IJBR Published by Indus Publishers
This work is licensed under a Creative Commons Attribution 4.0 International License.

Quick Aphasia Battery

The Quick aphasia battery which is a language and speech assessment model that yields multidimensional profiles of individual patients quantifying their strengths and weaknesses across core language domains. Data has shown that QAB is valid and reliable with excellent inter-rater reliability and test-retest reliability.[10]

The QAB includes eight subtests: (1) Level of consciousness; (2) Connected speech; (3) Word comprehension; (4) Sentence comprehension; (5) Picture naming; (6) Repetition; (7) Reading aloud; and (8) Motor speech. Each subtest contains between 5 and 12 items, each of which is scored on a 5-point scale running from 0 to 4.

The points for each measure are not equal and are calculated with the following scheme.

Figure 4

Summary measure	Definition	
Word comprehension	Word comprehension total, corrected for chance by subtracting 8 and clipping at 0; denominator is now 24	
Sentence comprehension	Sentence comprehension total, corrected for chance by subtracting 24 and clipping at 0; denominator is now 24	
Word finding	60%	Picture naming total
	20%	Connected speech: Anomia
	20%	Average of Connected speech: Empty speech, Semantic paraphasias, and Phonemic paraphasias, but capped so as not to exceed Anomia
Grammatical construction	40%	Connected speech: Agrammatism
	20%	Connected speech: Reduced length and complexity
	20%	Connected speech: Paragrammatism, but capped so as not to exceed Agrammatism
	20%	Average of sentence items from repetition and reading subtests
Speech motor programming	Motor speech: Apraxia of speech	
Repetition	Repetition total	
Reading	Reading aloud total	
QAB overall	18%	Word comprehension summary measure
	18%	Sentence comprehension summary measure
	14%	Word finding summary measure
	14%	Grammatical construction summary measure
	8%	Speech motor programming summary measure
	8%	Repetition summary measure
	8%	Reading summary measure
	8%	Connected speech: Overall communication impairment
	2%	Connected speech: Reduced words per minute
	2%	Connected speech: Self-correction

https://doi.org/10.1371/journal.pone.0192773.t001

The QAB, thus provides a comprehensive tool for analysis of speech deficits.

A study from Indiana University Department of Neurosurgery enrolled 7 patients and performed MRI for intraoperative neuronavigation, fMRI with speech and motor mapping and DTI for delineating white matter tracts, they achieved GTR in 1 patient and STR in 6, with only 1 patient out of the 7 having developed mild expressive aphasia (14.3%).[5]

Our study aims to identify and record the frequency of speech deficits in patients that have undergone excision of dominant lobe gliomas with the use of fMRI, DTI tractography and neuronavigation aids, so that we may assess the benefits of such equipment in our tertiary care setup – Punjab Institute of Neurosciences, Lahore.

Objective

To find the frequency of speech deficits that have occurred after dominant lobe glioma surgery having integrated exoscopic neuro-navigation, fMRI and DTI in terms of the quick aphasia battery at Punjab Institute of neurosciences Lahore.

MATERIALS AND METHOD

Study Design

The study is a descriptive case series at Neurosurgery Unit 2, Punjab Institute of Neurosciences, Lahore conducted over a period of 4 months, from February 2025 – May 2025. The protocol of this study has been approved by the institutional review board at Punjab Institute of Neurosciences.

Participants

Inclusion Criteria

1. Patients aged 16-65 years.
2. Both genders.
3. Presenting with brain gliomas in the dominant hemisphere.
4. Operated via craniotomy and excision under fMRI, DTI tractography and neuro-navigation guidance.
5. Cooperative patients able to follow the commands required in fMRI and QAB assessment.

Exclusion Criteria

1. ASA IV or V
2. Patients with brain gliomas in locations other than dominant hemisphere
3. Patients with low post-operative GCS (<15)
4. Patients with pre-op speech deficits.
5. Patients with linguistic barriers and inability to follow fMRI commands.

Variables

The following variables were recorded:

- Demographic details (name, age, MR number, gender)
- ASA grade
- Size of glioma (calculated as approximate volume on MRI)
- Location of glioma: Predominantly frontal, parietal, temporal or occipital
- Date of surgery
- QAB score: The Quick Aphasia battery questionnaire assesses speech and language in 7 categories:
  - Word Comprehension
  - Sentence Comprehension
  - Word finding
  - Grammatical construction
  - Speech motor programming
  - Reading
  - Repetition

A final QAB score is calculated out of 10

- Speech deficit was divided into
  - QAB=10: no speech deficit
  - QAB<10: speech deficit; further subdivided into:
    - QAB = 7 to <10: Mild speech deficit
    - QAB = 4 to <7: Moderate speech deficit
    - QAB <4: Severe speech deficit

Sample size

Sample size (60) is calculated as follows:

As per the reference study on incidence of gliomas in pakistan[11], population proportion = 10.8% (low grade gliomas per total number of brain tumours)

Copyright © 2025. IJBR Published by Indus Publishers
This work is licensed under a Creative Commons Attribution 4.0 International License.

Population size (approximate no. of brain tumours admitted to ns2 in 6 months) = 100
Confidence level = 95%
Margin of error = 5%
Sample size (as calculated by WHO calculator) = 60

Data Collection Procedure

60 patients fulfilling selection criteria were enrolled from ward. Informed consent was obtained from the participants regarding participation in research. The patients were admitted; baseline investigations and workups were performed. A pre-operative Functional MRI and DTI was done, mapping the patient's speech areas by asking him/her to perform commands during fMRI. The changes in brain signal while performing these commands guided as a map to speech areas that need to be preserved when tumour was excised. Programming was done, delineating the tumour and its relation to the functional speech areas and the important fibre tracts as imaged by DTI. This programmed image was synchronized with the neuro-navigation equipment to guide in real time the dimensions in which the tumour was excised. Patients were prepared for surgery after anaesthesia fitness. Patients were operated in elective neurosurgery theatre by the surgical team under neuro-navigation guidance, taking special care to spare the important tracts and functional speech eloquent areas. After surgery, patients were kept admitted for 4-5 days. On the 3rd post-operative day patient's speech was assessed in terms of the Quick aphasia battery questionnaire by the first author (H.N.). After discharge, follow up was done with repeat speech assessment by QAB done at one month follow up, by the first author (H.N.).

Data Analysis

The collected data was entered and analysed by using SPSS version 27. Quantitative variables like age, size of glioma and QAB scores are presented as mean, median, range and standard deviation. Qualitative variables like gender, location of glioma and speech deficit are presented as frequency and percentage. Chi-square test is applied to determine the correlation between speech deficit and location of glioma, and between QAB scores and size of glioma. P value ≤0.05 is considered as significant.

RESULTS

Participants

60 patients fulfilling the criteria were enrolled from ward and speech assessment was done on 3rd post op day in all 60. Follow up assessment was however possible in only 55, 5 were lost to follow up; 2 of the patients had expired at follow up while 3 did not present for follow up visit and could not be contacted.

Descriptive Data

Demographics

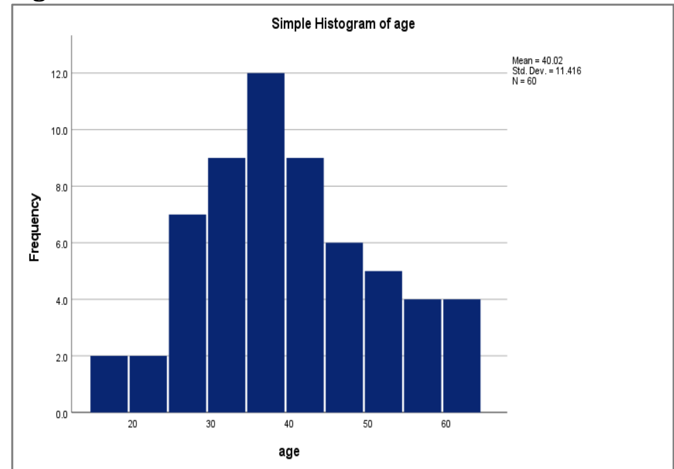
Age

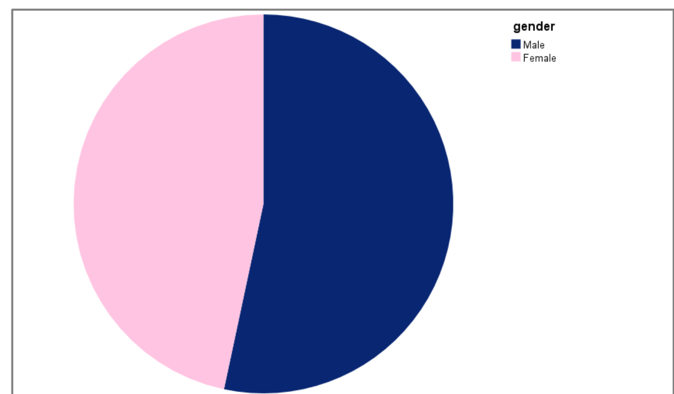
Table 1

Patients with ages 16-65 were included in the study.

N	**Valid**	60
	Missing	0
Mean		40.02
Median		38.50
Std. Deviation		11.416
Range		46
Minimum		17
Maximum		63

Figure 5 & 6





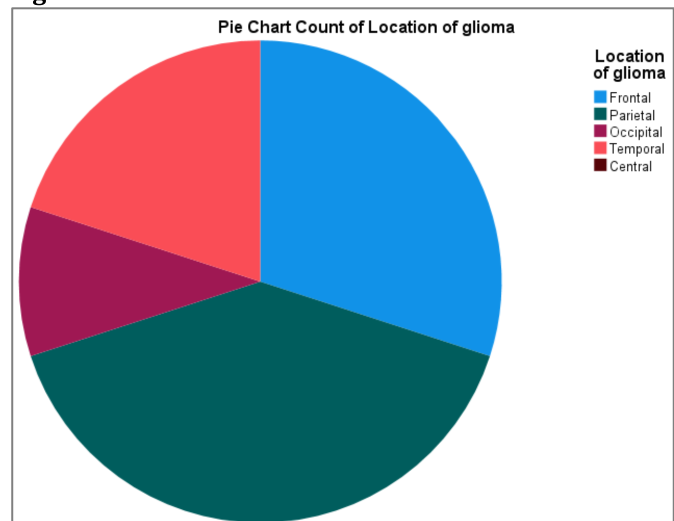
Gender

32 of the patients were male (53.3%) while 28 were female (46.7%)

Location of Glioma

The most common glioma location was parietal with 40%, 30% were in frontal lobe, 20% in temporal while the least common were occipital lesions with 10% frequency.

Figure 7



Copyright © 2025. IJBR Published by Indus Publishers
This work is licensed under a Creative Commons Attribution 4.0 International License.

Table 2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Frontal	18	30.0	30.0	30.0
	Parietal	24	40.0	40.0	70.0
	Occipital	6	10.0	10.0	80.0
	Temporal	12	20.0	20.0	100.0
	Total	60	100.0	100.0	

Size of Glioma

Size of glioma was calculated on preoperative MRI scans. The average size was 30.9 cm^3. Ranging from the smallest being 12cm^3 while the largest being an outlier at 76cm^3.

Figure 8

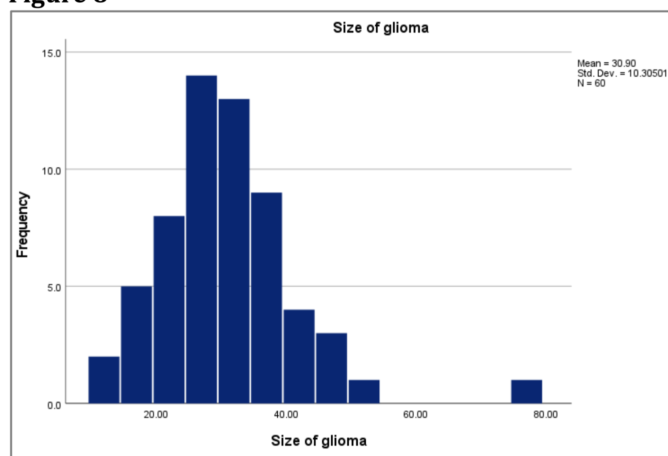
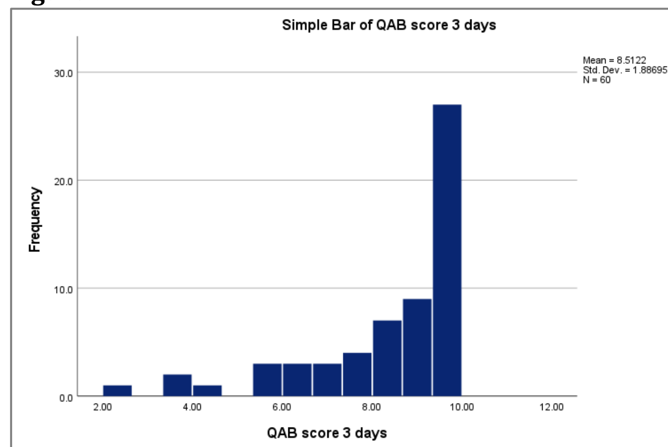


Table 3

N	Valid	60
	Missing	0
Mean		30.9000
Median		30.0000
Std. Deviation		10.30501
Range		64.00
Minimum		12.00
Maximum		76.00

Figure 9



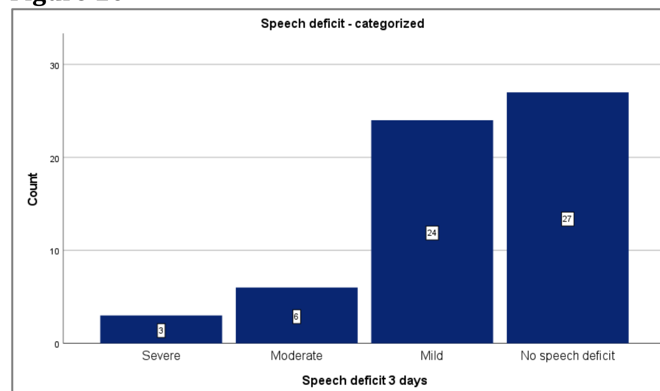
QAB score on 3rd day post operative day

Table 4

N	Valid	60
	Missing	0
Mean		8.5122
Median		9.2000
Std. Deviation		1.88695
Range		7.60
Minimum		2.40
Maximum		10.00

QAB score one 3rd post-operative day was on average 8.51 with 27 out of 60 (45%) having a score of 10 (no speech deficit).

Figure 10



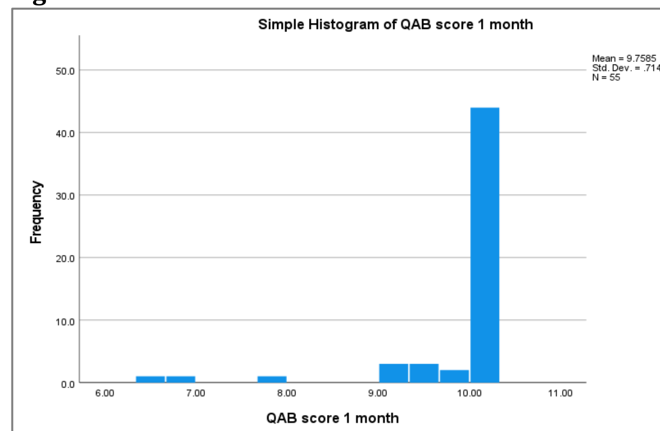
When categorized, 27 out of 60 had no speech deficit (45%). 24 (40%) had mild, 6(10%) had moderate while 3 (5%) had severe speech deficit on 3rd post-operative day.

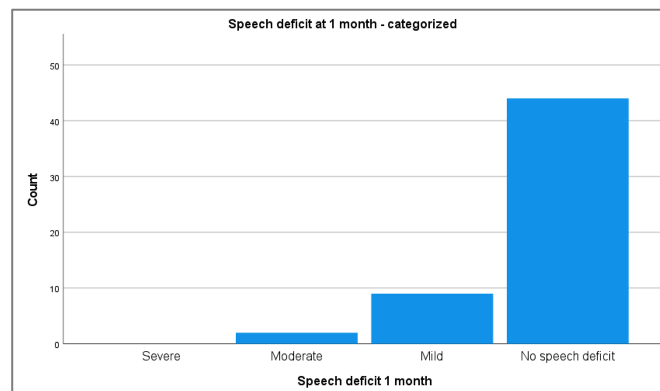
QAB score 1 month after surgery

Table 5

N	Valid	55
	Missing	5
Mean		9.7585
Median		10.0000
Std. Deviation		.71420
Range		3.50
Minimum		6.50
Maximum		10.00

Figure 11 & 12





Copyright © 2025. IJBR Published by Indus Publishers
This work is licensed under a Creative Commons Attribution 4.0 International License.

QAB score 1 month after surgery showed that most of the patients had recovered their speech function completely with 44 out of 55 (80%) having completely normal speech function. While 9 out of 55 (16.3%) having mild dysfunction and only 2 out of 55 (3%) having moderate dysfunction of speech. That adds to a cumulative percentage of 96.3% in patients having either no speech deficit or mild speech deficits.

Multivariate Analysis

Speech deficit vs location of glioma

Table 6

Speech deficit 3 days * Location of glioma Crosstabulation

Count

		Location of glioma				
		Frontal	Parietal	Occipital	Temporal	Total
Speech deficit 3 days	No speech deficit	13	7	6	1	27
	Mild	5	12	0	7	24
	Moderate	0	4	0	2	6
	Severe	0	1	0	2	3
Total		18	24	6	12	60

Table 7

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	25.100[a]	9	.003
Likelihood Ratio	30.011	9	.000
N of Valid Cases	60		

a. 11 cells (68.8%) have expected count less than 5. The minimum expected count is .30.

p- value of 0.03 suggests that the speech deficit was significantly related with location of glioma with only 1 of the 12 gliomas (8.3%) in the temporal lobe having no speech deficit at 3rd post operative day. The parietal lobe scored second with 7 out of 24 (29.1%) having no speech deficit at 3rd post-op day. The frontal lobe gliomas had 13 out of 18 (72.2%) having no speech deficits at 3rd post op day while all 6 patients (100%) with occipital lobe gliomas had no speech deficit at day 3.

Table 8

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Speech deficit 1 month * Location of glioma	55	91.7%	5	8.3%	60	100.0 %

Table 9

Speech deficit 1 month * Location of glioma Crosstabulation

Count

		Location of glioma				
		Frontal	Parietal	Occipital	Temporal	Total
Speech deficit 1 month	No speech deficit	16	17	6	5	44
	Mild	0	4	0	5	9
	Moderate	0	1	0	1	2
Total		16	22	6	11	55

Table 10

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	13.845[a]	6	.031
Likelihood Ratio	16.324	6	.012
N of Valid Cases	55		

a. 9 cells (75.0%) have expected count less than 5. The minimum expected count is .22.

After one month the p-value is 0.031, which still denotes that the correlation between location of glioma and speech deficits was significant. At this time point all 16 in the frontal lobe glioma group had normal speech (100%) as did in the occipital group (100%). 17 out of 22(77.2%) in the parietal group. While 5 out of 11 (45.4%) in the temporal lobe glioma group had no speech deficit, indicating that patients with temporal lobe gliomas fared worse of all with parietal lesion patients in 2nd place.

QAB score vs size of glioma

Table 11

Chi-Square Tests – size of glioma * QAB score 3rd post operative day

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	827.400[a]	728	.006
Likelihood Ratio	220.571	728	1.000
Linear-by-Linear Association	7.703	1	.006
N of Valid Cases	60		

a. 783 cells (100.0%) have expected count less than 5. The minimum expected count is .02.

P value of .006 suggest that the QAB score had a significant correlation with the size of glioma at the 3rd post operative day.

Table 12

Size of glioma * QAB scores 1-month Chi Square Test

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	370.312[a]	297	.002
Likelihood Ratio	88.931	297	1.000

Copyright © 2025. IJBR Published by Indus Publishers
This work is licensed under a Creative Commons Attribution 4.0 International License.

Linear-by-Linear Association	2.392	1	.122
N of Valid Cases	55		

a. 336 cells (100.0%) have expected count less than 5. The minimum expected count is .02.

A p value of 0.002 was calculated, indicating that size of glioma had a significant association with QAB scores at 1 month post op.

Summary of Results

This study evaluated the correlation between glioma characteristics (size and location) and language outcomes post-surgery. QAB (Quick Aphasia Battery) scores depicting speech deficits were assessed at 3 days and 1 month postoperatively. Sixty patients with gliomas were included. Crosstab and chi-square tests were used for statistical analysis. A significant association was found between glioma size and QAB score at 3 days (p = 0.006) and 1 month (p=0.002). A significant correlation was also observed between glioma location(p=0.003) at 3 days and (p=0.031) at 1 month as well. The average glioma sizes were around 30 cm^3. Findings suggest tumour size has impact on early language deficits as does location, with most of the language deficits improving over time of 1 month.

DISCUSSION

Our results showed the incidence of speech deficits in patients of dominant lobe gliomas and what factors affected speech deficits in these patients.

The classical teaching about speech areas was that damage to the Broca's area in the inferior frontal lobe would cause motor aphasia while damage to the Wernicke's area in the supramarginal and angular gyrus of parietal lobe would cause sensory aphasia. Arcuate fasciculus damage would cause conduction aphasia due to severance of the connection between these motor and speech areas. All these areas of speech function are located adjacent to the sylvian fissure, making surgery anywhere near the sylvian fissure a dangerous ordeal regarding the potential detriment to speech.

A study conducted at Sahlgrenska University hospital, Gothenburg, Sweden in 2016 showed that the highest proportion of language impairment was found in the group with a tumour in anatomical language-eloquent areas at all time-points for assessment.[12]

Similarly, our study also showed that location of glioma does have a significant correlation with the frequency of speech deficits. With patients having gliomas in the temporal lobe faring the worst and parietal lobe gliomas second worst, frontal lobe lesions third worst while occipital lesions having no post-operative speech deficits at all.

Size of the glioma also had a significant correlation with post operative speech deficits according to our study. This is likely due to the bigger lesions having more involvement of the cerebral functional speech areas as well as the important white matter tracts such as the arcuate fasciculus.

The occurrence of early post-operative language deficits varies between 22.4% and 60% in patients undergoing awake surgery.[13,14,15,16] While in our study early post-operative deficits (on 3rd day) were 55%.

Given that awake craniotomy ESM is the gold standard procedure for glioma excision in eloquent areas, our study highlights that using techniques of fMRI, DTI and exoscopic neuronavigation, comparable results to awake craniotomies can be obtained.

In a developing country such as Pakistan where the facilities of awake craniotomy may not be available at all centers, fMRI, DTI and neuronavigation may be utilized as an alternative.

Chances of intraoperative seizures or possibility of airway compromise are all complications associated with awake craniotomy but not with fMRI, DTI neuronavigation surgery. Furthermore, awake craniotomy has generally a longer operative time and can put patients through anxiety and distress. If comparable results can be obtained, these techniques can serve as an alternative to awake craniotomies when indicated.

The limitations of this study are that it is a descriptive study and perhaps a comparative study between fMRI, DTI neuronavigation guided excision and awake craniotomy would have yielded a better outcome in comparing these techniques. Another limitation is the lack of longer term follow up.

Nevertheless, the study has produced results that indicate that fMRI, DTI and neuronavigation assisted excision of low-grade gliomas is a viable option for resection of these tumors in the dominant hemisphere without an unacceptably high risk of speech deficits.

CONCLUSION

On 3rd post operative day, the frequency of speech deficits was 33 out of 60 (55%). One month post op follow-up showed that all patients had improved to varying degrees with speech deficit present in only 11 out of 55 (20%) patients. These speech deficits had significant correlations with location of glioma as well as size of glioma. fMRI, DTI and neuronavigation guided excision of dominant lobe gliomas showed results comparable to awake craniotomy in our study.

Acknowledgment

The authors would like to acknowledge the following

- Dr. Nabeel Choudhary – Associate professor neurosurgery Jinnah Hospital Lahore
- Dr. Hassan Ali Khosa – Assistant professor neurosurgery unit 2, PINS, Lahore.
- Dr. Omair Afzal – Assistant professor neurosurgery unit 2, PINS, Lahore.
- Dr. Muhammad Ishfaq – Senior Registrar neurosurgery unit 2, PINS, Lahore.

Copyright © 2025. IJBR Published by Indus Publishers
This work is licensed under a Creative Commons Attribution 4.0 International License.

REFERENCES

1. Forst, D. A., Nahed, B. V., Loeffler, J. S., & Batchelor, T. T. (2014). Low-grade gliomas. *The Oncologist*, *19*(4), 403-413. https://doi.org/10.1634/theoncologist.2013-0345
2. Louis, D. N., Ohgaki, H., Wiestler, O. D., Cavenee, W. K., Burger, P. C., Jouvet, A., Scheithauer, B. W., & Kleihues, P. (2007). The 2007 WHO classification of tumours of the central nervous system. *Acta Neuropathologica*, *114*(2), 97-109. https://doi.org/10.1007/s00401-007-0243-4
3. Morshed, R. A., Young, J. S., Hervey-Jumper, S. L., & Berger, M. S. (2019). The management of low-grade gliomas in adults. *Journal of Neurosurgical Sciences*, *63*(4). https://doi.org/10.23736/s0390-5616.19.04701-5
4. Garrett, M. C., Pouratian, N., & Liau, L. M. (2012). Use of language mapping to aid in resection of gliomas in eloquent brain regions. *Neurosurgery Clinics of North America*, *23*(3), 497-506. https://doi.org/10.1016/j.nec.2012.05.003
5. Gore, J. C. (2003). Principles and practice of functional MRI of the human brain. *Journal of Clinical Investigation*, *112*(1), 4-9. https://doi.org/10.1172/jci200319010
6. Schlosser, M. J., Aoyagi, N., Fulbright, R. K., Gore, J. C., & McCarthy, G. (1998). Functional MRI studies of auditory comprehension. *Human Brain Mapping*, *6*(1), 1-13. https://doi.org/10.1002/(sici)1097-0193(1998)6:1<1::aid-hbm1>3.0.co;2-7
7. Wilden, J. A., Voorhies, J., Mosier, K. M., O'Neill, D. P., & Cohen-Gadol, A. A. (2013). Strategies to maximize resection of complex, or high surgical risk, low-grade gliomas. *Neurosurgical Focus*, *34*(2), E5. https://doi.org/10.3171/2012.12.focus12338
8. Coenen, V. A., Krings, T., Axer, H., Weidemann, J., Kränzlein, H., Hans, F., Thron, A., Gilsbach, J. M., & Rohde, V. (2003). Intraoperative three-dimensional visualization of the pyramidal tract in a neuronavigation system (PTV) reliably predicts true position of principal motor pathways. *Surgical Neurology*, *60*(5), 381-390. https://doi.org/10.1016/s0090-3019(03)00392-6
9. Holodny, A. I., Schwartz, T. H., Ollenschleger, M., Liu, W., & Schulder, M. (2001). Tumor involvement of the corticospinal tract: Diffusion magnetic resonance tractography with intraoperative correlation. *Journal of Neurosurgery*, *95*(6), 1082. https://doi.org/10.3171/jns.2001.95.6.1082
10. Wirtz, C. R., Tronnier, V. M., Bonsanto, M. M., Haßfeld, S., Knauth, M., & Kunze, S. (1998). Neuronavigation. *Der Nervenarzt*, *69*(12), 1029-1036. https://doi.org/10.1007/s001150050380
11. Spetzger, U., Laborde, G., & Gilsbach, J. (1995). Frameless Neuronavigation in modern neurosurgery. *min - Minimally Invasive Neurosurgery*, *38*(04), 163-166. https://doi.org/10.1055/s-2008-1053478
12. Wilson, S. M., Eriksson, D. K., Schneck, S. M., & Lucanie, J. M. (2018). Correction: A quick aphasia battery for efficient, reliable, and multidimensional assessment of language function. *PLOS ONE*, *13*(6), e0199469. https://doi.org/10.1371/journal.pone.0199469
13. Bajwa, M. H., Khalid, M. U., Shah, M., Shamim, M. S., Laghari, A. A., Akhunzada, N. Z., Anis, S. B., Raghib, M. F., Siddiqi, S., & Enam, S. A. (2022). Treatment patterns of glioma in Pakistan: An epidemiological perspective. *Journal of the Pakistan Medical Association*, *72*(11), S34-S39. https://doi.org/10.47391/jpma.11-s4-akub05
14. Antonsson, M., Jakola, A., Longoni, F., Carstam, L., Hartelius, L., Thordstein, M., & Tisell, M. (2017). Post-surgical effects on language in patients with presumed low-grade glioma. *Acta Neurologica Scandinavica*, *137*(5), 469-480. https://doi.org/10.1111/ane.12887
15. Bello, L., Gallucci, M., Fava, M., Carrabba, G., Giussani, C., Acerbi, F., Baratta, P., Songa, V., Conte, V., Branca, V., Stocchetti, N., Papagno, C., & Gaini, S. M. (2007). Intraoperative subcortical languagetract mapping guides surgical removalof gliomas involving speech areas. *Neurosurgery*, *60*(1), 67-82. https://doi.org/10.1227/01.neu.0000249206.58601.de
16. Sanai, N., Mirzadeh, Z., & Berger, M. S. (2008). Functional outcome after language mapping for glioma resection. *New England Journal of Medicine*, *358*(1), 18-27. https://doi.org/10.1056/nejmoa067819
17. Yordanova, Y. N., Moritz-Gasser, S., & Duffau, H. (2011). Awake surgery for WHO grade II gliomas within "noneloquent" areas in the left dominant hemisphere: Toward a "supratotal" resection. *Journal of Neurosurgery*, *115*(2), 232-239. https://doi.org/10.3171/2011.3.jns101333
18. Teixidor, P., Gatignol, P., Leroy, M., Masuet-Aumatell, C., Capelle, L., & Duffau, H. (2006). Assessment of verbal working memory before and after surgery for low-grade glioma. *Journal of Neuro-Oncology*, *81*(3), 305-313. https://doi.org/10.1007/s11060-006-9233-y

Copyright © 2025. IJBR Published by Indus Publishers
This work is licensed under a Creative Commons Attribution 4.0 International License.