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"A PROSPECTIVE STUDY TO EVALUATE THE ROLE OF STEREOTACTIC BIOPSY IN THE DIAGNOSIS OF BRAIN LESIONS"

Dr Amol Aaglave[1*], Dr Anand Sharma[2], Dr Deepak Jaiswal[3], Dr Avinash Sharma[4], Dr Vinaya Chaudhary[5], Dr Avdhesh Shukla[6]

[1*]MCh Neurosurgery Senior resident, Department of Neurosurgery, Gajra Raja Medical college, Gwalior, M.P., Email id : aaaglave1@gmail.com
[2]Associate Professor, Department of Neurosurgery, Gajra Raja medical college, Gwalior, M.P., Email id - dranandsharma100123@gmail.com
[3]MCh Neurosurgery, Senior resident, Department of Neurosurgery, Gajra Raja Medical college, Gwalior, M.P., Email id- deepakj038@gmail.com
[4]HOD and Professor, Dept of Neurosurgery, Gajra Raja medical college, Gwalior, M.P., Email id richavi.sharma@gmail.com
[5]Senior Resident, Mch neurosurgery, Gajra Raja medical college, Gwalior, M.P. Email - vinaya2310@gmail.com
[6]Professor, Department of Neurosurgery, Gajra Raja medical college, Gwalior, M.P. Email id : dravdhesh@gmail.com

Abstract

Background: Brain lesions, including neoplastic, inflammatory, infectious, and vascular pathologies, pose significant diagnostic challenges. Stereotactic biopsy has emerged as a valuable technique for diagnosing intracranial lesions that are inaccessible to conventional surgical approaches. Despite advances in imaging, histopathological confirmation remains crucial for determining appropriate management strategies. This study aims to evaluate the effectiveness, safety, and diagnostic yield of stereotactic brain biopsy in patients with suspected brain lesions.

Methods: A prospective observational study was conducted at the Department of Neurosurgery, J.A. Group of Hospitals and G.R. Medical College, Gwalior, India, between January 2023 and June 2025. Thirty patients with suspected brain lesions, identified through CT or MRI, underwent stereotactic biopsy. Preoperative neuroimaging was used to localize the lesions, and histopathological analysis was performed on biopsy samples. The diagnostic accuracy, post-operative complications, and impact on patient management were evaluated.

Results: Among the 30 patients, the most common histopathological diagnoses were tuberculoma (31%), astrocytoma (13.8%), and metastasis (13.8%). The overall diagnostic accuracy of stereotactic biopsy was 93.3%, with two non-diagnostic results. Post-operative complications were minimal, including new or worsened neurological deficits (13.3%), infections (6.7%), and seizures (10%). Notably, 60% of patients experienced improved functional status following the procedure.

Conclusion: Stereotactic biopsy is a safe, effective, and highly accurate diagnostic tool for brain lesions, especially in cases involving deep-seated, multifocal, or inaccessible lesions. The procedure is associated with a low risk of significant complications, and its high diagnostic yield significantly impacts patient management and treatment decisions.

Keywords: Stereotactic biopsy, brain lesions, diagnostic accuracy, post-operative complications, histopathology

Introduction

Brain lesions represent a diverse group of pathologies, including neoplastic, inflammatory, infectious, and vascular conditions. Accurate diagnosis of these lesions is crucial for determining appropriate management strategies and prognostication. While advances in neuroimaging modalities such as magnetic resonance imaging (MRI) and computed tomography (CT) have significantly improved the detection and characterization of brain lesions, imaging alone often fails to provide a definitive diagnosis, especially in cases of atypical, deep-seated, or multifocal lesions[1,2]. Consequently, histopathological confirmation remains the gold standard for diagnosis and guides therapeutic decisions.

Stereotactic biopsy has emerged as a minimally invasive, highly accurate technique for obtaining tissue samples from intracranial lesions. First conceptualized in the early 20th century, stereotactic methods have evolved with technological advances, enabling precise localization and targeting of lesions based on three-dimensional coordinates derived from neuroimaging[3]. The procedure can be performed using frame-based or frameless (neuronavigation or robotic-assisted) systems, each offering unique advantages in terms of accuracy, safety, and patient comfort [4,5]. Stereotactic biopsy is particularly valuable for lesions that are inaccessible or unsuitable for open surgical resection due to their size, location, or the patient's medical condition [1,3].

The diagnostic yield of stereotactic brain biopsy is reported to exceed 90–95% in experienced hands, with a low incidence of morbidity and mortality [5]. Studies have demonstrated its efficacy in diagnosing a wide range of intracranial pathologies, including high-grade gliomas, lymphomas, metastases, and infections. The technique is especially beneficial for lesions situated in eloquent or deep brain regions, where open surgery carries significant risk of neurological deficits[2,4]. Furthermore, stereotactic biopsy facilitates molecular and genetic analyses, which are increasingly important for personalized medicine in neuro-oncology[4].

Despite its widespread acceptance, stereotactic biopsy is not without limitations. Potential complications include hemorrhage, infection, and non-diagnostic sampling, although these are relatively infrequent with meticulous technique and preoperative planning[1,5]. The decision to perform a biopsy must be individualized, weighing the risks and benefits in the context of each patient's clinical presentation and imaging findings.

Because tissue diagnosis is so important for management, this prospective study will look at how well stereotactic biopsy can be used to find brain lesions. TThe study aims to evaluate the effectiveness, accuracy, safety, and impact of histopathological findings on patient management following stereotactic biopsy. The goal is to demonstrate that stereotactic biopsy is a crucial tool in contemporary neuro-oncological practice by systematically analyzing patient outcomes.

MATERIALS AND METHODS

Study Centre: This study was conducted at the Department of Neurosurgery, J.A. Group of Hospitals and G.R. Medical College, Gwalior, Madhya Pradesh, India.

Study Design: This was a prospective observational study aimed at evaluating the role of stereotactic biopsy in diagnosing brain lesions.

Study Duration: The study was conducted from January 2023 to June 2025.

Sample Size Calculation: A 50% complication rate was assumed for the stereotactic biopsy at a 5% level of significance and an 18% absolute error. The sample size was calculated using the formula:

$$n = z^2 * p * (1 - p) / e^2$$

Thirty patients were taken as the required sample size for the present study.

Inclusion Criteria:

1. Patients with suspected brain lesions, as identified by neuroimaging studies (CT or MRI).
2. Lesions located in deep areas of the brain.
3. Biopsy results crucial for clinical decision-making, including but not limited to the differential diagnosis of tumors, inflammation, degenerative lesions, postoperative recurrence of tumors, or necrosis.
4. Small, multiple, or diffuse lesions that were difficult to access through craniotomy.
5. Age above 18 years.
6. Patients who provided informed consent for participation.

Exclusion Criteria:

1. Patients with surgical contraindications, including vascular lesions, coagulopathy, or local/systemic infections.
2. Patients with severe co-morbidities that might interfere with the assessment of outcomes.
3. Patients who did not consent to the procedure.

Methodology:

1. **Patient Selection:** Patients presenting with suspected brain lesions who met the inclusion criteria were enrolled. The patients were screened based on factors such as age, lesion characteristics (size, location), and medical history to ensure safety for the stereotactic biopsy.
2. **Pre-procedure Evaluation:** Prior to the biopsy, detailed neuroimaging (MRI or CT scan) was reviewed to localize and assess the lesion. A pre-operative assessment was conducted to evaluate the patient's medical fitness for surgery and anesthesia.
3. **Stereotactic Biopsy Procedure:** Stereotactic biopsy was performed using a stereotactic frame system. Imaging guidance (MRI/CT) was employed to precisely target the brain lesion. The biopsy needle was directed to the lesion site, and tissue samples were collected for histopathological analysis.
4. **Post-procedure Care:** Following the procedure, patients were monitored for immediate complications, such as bleeding, infection, or neurological deterioration. Post-operative imaging was performed to evaluate the procedure's safety and assess for any immediate complications.
5. **Follow-up:** Patients underwent clinical and radiological follow-up after the biopsy. Follow-up assessments included monitoring for adverse events related to the biopsy, including infections, hematomas, or neurological deficits. Furthermore, follow-up neuroimaging was performed to assess lesion progression or resolution.
6. **Statistical Analysis:** Data collected during the study were analyzed using descriptive and inferential statistical methods. The diagnostic accuracy of stereotactic biopsy was evaluated by comparing biopsy results with the final clinical diagnosis (histopathological findings). Adverse events were analyzed for their incidence and severity. The statistical analysis was performed using SPSS or similar software, and significance was set at a p-value of <0.05.

Ethical Considerations: The study adhered to ethical guidelines, including obtaining informed consent from all participants and ensuring their confidentiality. The study was approved by the Institutional Ethical Committee of J.A. Group of Hospitals and G.R. Medical College, Gwalior.

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Results-

Table 1: Baseline Demographics (n = 30)

Variable	n	Percentage
Gender - Male	18	60%
Gender - Female	12	40%
Mean Age (years)	54.0	—
Age 21-40 years	5	16.7%

Age 41-60 years	18	60%
Age > 60 years	7	23.3%
Right-handed	27	90%
Left-handed	3	10%
Median Symptom Duration (weeks)	6.2	—

Baseline demographics such as sex, age distribution, handedness, and symptom duration are listed. These factors help contextualize the population studied and may guide surgical decisions based on demographic patterns.

Table 2: Distribution of Patients Based on Location, Histopathology, and Radiological Diagnosis (n = 30)

Category	Diagnosis	No. of Patients	Percentage
Location	Frontal	13	43.3%
	Parietal	9	30.0%
	Temporal	0	0.0%
	Occipital	0	0.0%
	Basal ganglia / thalamus	0	0.0%
	Multiple (more than 2 locations)	8	26.7%
Histopathology	Astrocytoma	4	13.8%
	Glioblastoma	2	6.9%
	Tuberculoma	9	31.0%
	Infective (Fungal/Bacterial)	4	13.8%
	Demyelinating Disease	2	6.9%
	Inconclusive	2	6.9%
	Lymphoma	2	6.9%
	Metastasis	4	13.8%
Radiological Diagnosis	NCC/Tuberculoma	5	16.7%
	CNS Lymphoma	5	16.7%
	Brain Abscess (Fungal)	4	13.3%
	Low Grade Glioma	5	16.7%
	High Grade Glioma	2	6.7%
	Metastasis	4	13.3%
	Tuberculoma	5	16.7%

The distribution of patients based on the location, histopathology, and radiological diagnosis of their brain lesions. In terms of lesion location, the majority of patients had lesions in the frontal lobe (43.3%), followed by the parietal lobe (30.0%). A smaller proportion of patients had lesions in multiple locations (26.7%), while no lesions were identified in the temporal, occipital, or basal ganglia/thalamus regions.

Histopathologically, the most common diagnosis was tuberculoma, found in 31.0% of patients. Other diagnoses included astrocytoma (13.8%), glioblastoma (6.9%), and metastasis (13.8%). Additionally, there were cases of fungal or bacterial infections (13.8%), demyelinating disease (6.9%), lymphoma (6.9%), and two inconclusive results (6.9%).

Regarding radiological diagnoses, neurocysticercosis (NCC) or tuberculoma was the most frequent (16.7%), followed by CNS lymphoma (16.7%) and low-grade glioma (16.7%). Brain abscesses, often fungal in nature, were identified in 13.3% of patients, while high-grade gliomas and metastasis were diagnosed in 6.7% and 13.3% of patients, respectively. Notably, tuberculoma was also frequently diagnosed radiologically in 16.7% of patients, which corresponds to the histopathological findings.

Table 3: Post-operative Complications (30-day) (n = 30)

Complication	**n**	**Percentage**
New/Worsened Neurological Deficit	4	13.3%
Wound Infection	2	6.7%
Seizures	3	10%
Venous Thrombo-embolism	1	3.3%
Mortality	1	3.3%
CSF Leak	0	0%
Histology	**n**	**Percentage**
Astrocytoma	4	13.8%
Glioblastoma	2	6.9%
Tuberculoma	9	31.0%
Infective (Fungal/Bacterial)	4	13.8%
Lymphoma	2	6.9%
Metastasis	4	13.8%
Demyelinating Disease	0	0%
Inconclusive	2	6.9%

Post-operative complications capture the outcomes from the biopsy procedure, showing the rates of neurological deficit, infections, and mortality, which are key in evaluating the safety of stereotactic biopsies.

Table 4: Stereotactic Biopsy Outcomes

Outcome	**n**	**Percentage**
Diagnostic Accuracy (Correct Diagnosis)	28	93.3%
Non-diagnostic/False Negative	2	6.7%
Improved Functional Status (Karnofsky ≥ 10)	18	60%
No Change in Functional Status	7	23.3%
Worsened Functional Status	5	16.7%

The diagnostic yield of stereotactic biopsy and its impact on patient outcomes is summarized, including both successful diagnoses and functional status changes post-biopsy.

Discussion

The present study provides an in-depth analysis of demographics, diagnostic distributions, post-operative complications, and outcomes of stereotactic brain biopsies in a cohort of 30 patients. Predominantly male with a mean age of 54 years, most patients fell within the 41–60 years age range, consistent with Mohamed et al.[6] who noted a higher incidence of stereotactic biopsies in middle-aged adults. Right-handedness in 90% of patients indicated typical cerebral dominance patterns. The median symptom duration of 6.2 weeks before biopsy aligns well with similar studies emphasizing the importance of timely intervention for accurate diagnosis and management.

Frontal and parietal lobe lesions were the most common pathological sites, with tuberculoma identified as the leading histopathological diagnosis, corroborating the findings by Bouchama et al. [7]who reported tuberculoma as a frequent cause of space-occupying brain lesions in endemic areas. Other diagnoses such as astrocytoma, glioblastoma, and metastasis were consistent with expected diverse etiologies in brain biopsies. Radiological diagnoses similarly mirrored histopathology, with tuberculoma and neurocysticercosis being prominent, reflecting the complexity of differential diagnosis in tropical regions.

Post-operative complications were infrequent but clinically significant. New or worsened neurological deficits affected approximately 13% of patients, echoing findings by Lavé et al.[8] which highlighted symptomatic complications typically under 5%, with neurological deficits as the most common adverse event. Infections, seizures, and venous thromboembolism were less common, with mortality rare and occurring in only one patient, consistent with Malone et al.'s[9] population study reporting morbidity rates between 3–13% and mortality less than 2%. The absence of cerebrospinal fluid leaks, a feared complication, aligns with broader literature emphasizing the relative safety of stereotactic procedures when properly executed.

Regarding diagnostic yield, this study observed high accuracy with definitive diagnoses obtained in the majority of cases, consistent with Katzendobler et al.[10] who demonstrated diagnostic yields of 81–99% depending on technique and expertise. Though a small percentage had non-diagnostic results, this is typical given the technical challenges of small samples and lesion heterogeneity described by Ogiwara et al..[11] Functional outcomes were largely positive, with most patients experiencing neurological and functional improvements post-biopsy, paralleling the findings of Schwendner et al. [12]who emphasized the clinical impact of accurate lesion targeting on patient recovery.

Conclusion

This cohort's experience reinforces stereotactic biopsy as a vital diagnostic tool with high accuracy and manageable risk profiles, supporting its role in guiding tailored therapies for complex brain lesions. Careful perioperative management and expertise are crucial in minimizing complications and optimizing functional recovery post-procedure.

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