Brain Biopsies: Does technique matters?

Rajiv Jha[1], Rajendra Shrestha[1], Binod Rajbhandari[1], Sameer Aryal[1], Sushil Mohan Bhattarai[1], Sindhu Gautam[1], Kumar Paudel[1], Namrata Khadka, Pankaj Jalan[2]

[1] National Academy of Medical Sciences, Bir Hospital, Kathmandu, Nepal

[2] Norvic International Hospital

Date of Submission: 1st March 2025 Date of Acceptance: 23rd May 2025 Date of Publication: 15th May 2025

Abstract

Introduction: This study aims to analyze the diagnostic yield of various brain biopsy techniques performed at the National Neurosurgical Referral Center (NNRC), National Academy of Medical Sciences (NAMS), Bir Hospital, Kathmandu, Nepal, to identify brain pathologies such as infections, tumors, inflammations, demyelinating diseases, and other conditions.

Materials and Methods: This retrospective study reviewed 188 cases of brain biopsies conducted at NNRC over a specified period. Biopsies were performed using diverse techniques, including open free-hand biopsy, open biopsy, CT-guided biopsy, frame-based biopsy, frameless biopsy and endoscopic biopsy. Patient demographics, clinical presentations, imaging findings, biopsy techniques, and histopathological results were analyzed. Diagnostic yield was calculated as the percentage of cases where a definitive diagnosis was obtained.

Results: Of the 188 cases, a diagnostic yield of 93% was achieved, highlighting the effectiveness of these biopsy techniques in diagnosing a wide range of brain pathologies. Tumors represented the most common pathology diagnosed, followed by infections, inflammatory conditions, and demyelinating diseases. The choice of biopsy technique depended on the lesion's location, size, and clinical scenario. Advanced techniques like CT-guided and Frame-guided biopsies demonstrated high accuracy in sampling deep-seated or eloquent brain areas.

Conclusion: Brain biopsy remains an invaluable tool for diagnosing diverse intracranial pathologies with a high diagnostic yield. The integration of advanced imaging and guided techniques has significantly enhanced the safety and accuracy of the procedure. This study emphasizes the need for tailored biopsy approaches based on individual clinical and radiological profiles to maximize diagnostic outcomes. Further research and technological advancements are recommended to improve diagnostic efficacy and reduce complications.

Key words: Brain Biopsy Diagnostic Yield

Introduction

Brain biopsies are important for establishing a definitive diagnosis in cases of brain tumors, infections, or neuroinflammatory disorders. They are particularly essential when imaging alone is inconclusive. Diagnostic yield is influenced by the method used, with reported yields ranging from 85% to 98% depending on the technique and lesion type.

Access this article online

Website: https://www.nepjol.info/index.php/NJN

DOI: 10.3126/njn.v22i1.76223

HOW TO CITE
Jha R, Shrestha R, Rajbhandari B, Aryal S, Bhattarai SM, Gautam S, et al. Brain Biopsies: Does technique matters? NJNS. 2025;22(1):40-44

Address for correspondence:
Rajiv Jha
National Academy of Medical Sciences, Bir Hospital, Kathmandu, Nepal
Email: medjrajiv18@gmail.com

ISSN: 1813-1948 (Print), 1813-1956 (Online)

General diagnostic yield of brain biopsies: 85-95%.[1] Higher yields are associated with advanced techniques like stereotactic and robotic-guided biopsies.

In the past, biopsies relied on open craniotomy and freehand techniques with limited accuracy. Diagnostic yields in early procedures were lower, around 60-70%, due to lack of imaging guidance. Incidence of craniotomy based biopsies before the availability of good imaging modalities like computer Tomography(CT) and Magnetic Resonance Imaging were around 60%, but now with modern imaging's, stereotaxis and robot it is up to 98%.2 Open biopsies through craniotomy allow direct visualization of the lesion and are usually reserved for complex or highly vascular lesions. While invasive, open biopsies have high diagnostic accuracy due to large tissue samples. Diagnostic yield with craniotomy and direct biopsy of the lesion is upto 95-98%.[3]

Risks include higher morbidity and infection rates compared to minimally invasive methods.

Burr hole biopsies, particularly freehand, are less precise due to reliance on anatomical landmarks without imaging. Diagnostic yields are lower, ranging from 70-80%, especially for deep or small lesions. Diagnostic yield with freehand biopsies is up to 70-80%.4 CT or MRI guidance improves yield significantly. CT-guided brain biopsies offer high precision and safety, especially for deeply located or eloquent-region lesions. Real-time imaging minimizes sampling errors, improving diagnostic accuracy. Diagnostic yield with CT-guided biopsies is up to 85-90%, 5 particularly useful for detecting brain metastases and abscesses. Intraoperative CT enhances accuracy by providing real-time feedback during the biopsy. It reduces the risk of repeat procedures due to incorrect sampling. Diagnostic yield with the use of intra operative CT is 90-98% ,6 which is effective in small or deep-seated lesions.

MRI-guided biopsies provide superior soft tissue contrast, especially in regions adjacent to eloquent structures. It is ideal for gliomas and other infiltrative lesions. Diagnostic yield with MR guided biopsies is up to 90-97% , and is very superior for identifying gliomas compared to CT-guided techniques.[7]

Frame-based stereotactic biopsies are considered the gold standard for precision in deep or eloquent regions. They are widely used in the diagnosis of gliomas, lymphomas, and metastases which has diagnostic yield up to 92-98%.The Complication rates with frame based stereotactic biopsies are low, around 2-5%.8 Frameless systems provide similar accuracy to frame-based systems with the advantage of greater patient comfort. They rely on advanced imaging and neuronavigation. Diagnostic yield of frameless biopsies are 90-96%, which is slightly less precise than frame-based systems for deeply seated lesions.[9]

Ultrasound-guided (USG) biopsies provide real-time visualization of cystic or vascular lesions. They are less effective for deeply located or infiltrative lesions. Diagnostic yield of USG guided biopsies are up to 70-85%.[10]

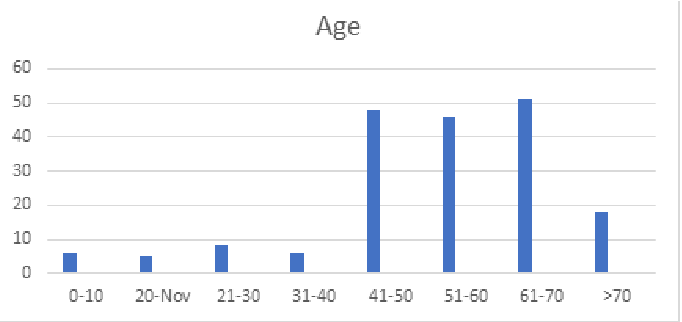
Robot-assisted biopsies are newer technology and provide unparalleled precision and consistency, reducing human error and improving safety for complex trajectories and has
Maximum diagnostic yield up to 94-98%.[11]

Future of brain biopsy technique is less or minimal invasive technique which is liquid biopsy where cerebrospinal fluid (CSF) or blood for circulating tumor DNA (ctDNA) or other biomarkers are analyzed. While non-invasive, they are not yet a full replacement for tissue biopsies due to lower sensitivity and specificity. Diagnostic yield until now is only 50-75% (dependent on biomarker availability and tumor type). This technique is best suited for monitoring progression or recurrence.[12]

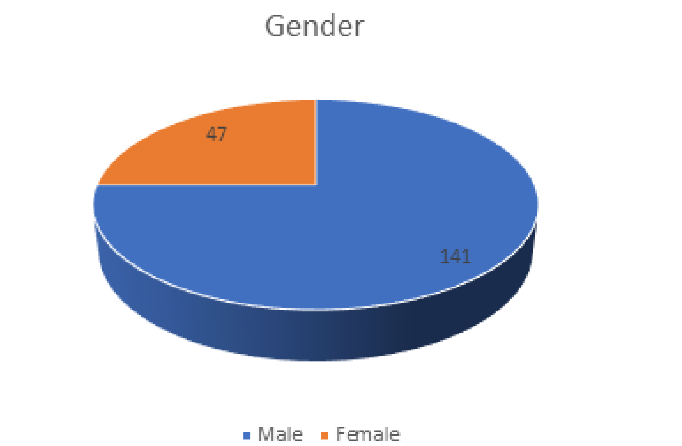
Methods and Materials

This is a retrospective study of all brain biopsies taken to diagnose brain pathology including tumor, infection, inflammation or degenerative brain conditions. This study was carried out at National Neurosurgical Referral Center (NNRC), National Academy of Medical Sciences (NAMS) Bir hospital.
and Norvic International Hospital Kathmandu , Nepal Institutional review board (IRB) approval was taken from the hospital for the study. Consent was taken from the patients if they were able to communicate and from the next of kin if they were not able to give consent. All brain biopsies in this department were included in this study. The duration of the study was from January 2016 to December 2024. Total number of the cases are 188.Demographics,diagnostic yield, topography of biopsied lesions , type of anesthesia used and complications were included in this study. Primary outcome assessed on the basis of diagnostic yield while secondary outcome measured mortality and morbidities like intracranial hemorrhage, new neurological deficits, new onset seizure, and infection.

Results: The majority of patients fall in the 41-70 age group(Table1),

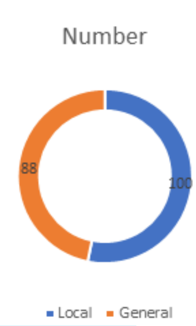


Age Group(Years	Number
0-10	6(3%)
11-20	5(3%)
21-30	8(4%)
31-40	6(3%)
41-50	48(26%)
51-60	46(24%)
61-70	51(27%)
> 70	18(10%)



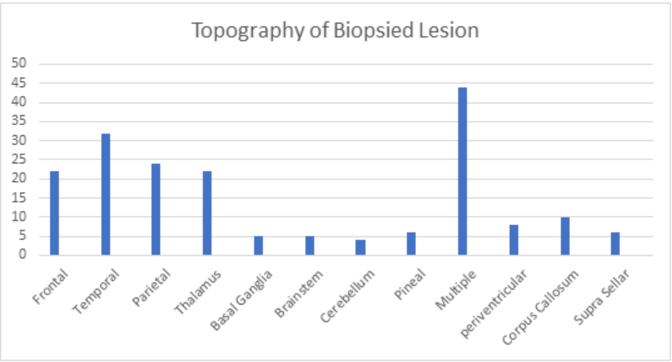
with the highest number in the 61-70 years category (51 patients, 27%).The pie chart shows male patients represents 75%(141Patients) (75%) which indicates a male predominance (3:1 ratio) among the patients undergoing biopsy(Table 2)

Table 2.Gender Distribution



The donut chart shows the type of local anesthesia used in 53%(100 patients)

Table 3.Types of anesthesia



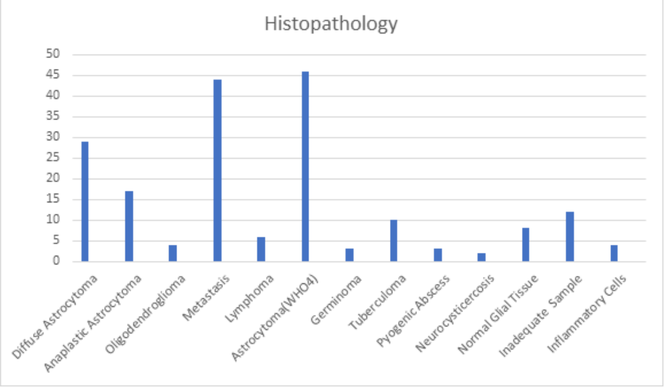
Regarding topography of Biopsied Lesions the bar graph categorizes the anatomical locations of biopsied lesions which showed most frequently biopsied locations was for multiple intracranial lesions (highest) followed by parietal lobe,temporal lobe and frontal lobe

Table 4.Topography of Biopsied Lesion

Technique	Number	Diagnostic Yield
Freehand Burrhole Biopsy	56(30%)	49(88%)
Open Biopsy	12(6%)	11(93%(
USG Guided Biopsy	14(7.5%)	13(92%)
CT Guided Biopsy	12(6.5%)	11(94%)
Stereotactic Biopsy	34(18%)	32(93%)
Optical Navigated Biopsy	26(14%)	24(92%)
Electromagnetic Navigated Biopsy	30(16%)	27(90%)
Endoscopic Biopsy	4(2%)	4(94%)

Less common sites biopsied were corpus callosum and supra-sellar region.This suggests that supratentorial regions are the most common sites for biopsied lesions, while deep-seated and infratentorial lesions are less frequent.
The most commonly used technique is freehand burrhole biopsy where biopsy is taken based only on craniometric points and without using any gadgets (30%), followed by stereotactic biopsy (18%)

Table 5.Diagnostic Yield with different techniques



The highest diagnostic yield is seen with CT-guided biopsy (94%), endoscopic biopsy (94%), and stereotactic biopsy (93%)

Table 6. Histopathology of biopsied lesions

Complications	Number
Track Hematoma Symptomatic	None
Track Hematoma asymptomatic	12
Seizure	10
Pneumocephalus	10
Intracranial Hematoma	4
Monoparesis	2
Hemiparesis	1

All techniques have a high diagnostic yield (>88%), indicating effective sampling methods.The Chi square test resulted p- Value of 0.97 and does not showed statistical difference in diagnostic yield among the different biopsy techniques. This suggest that all techniques provide similar diagnostic effectiveness in this dataset.
Common histological diagnosis were astrocytoma grade 4 and metastatic lesions (Table 7). Seizure were the commonest complications after the procedure which were controlled with anti-epileptic drugs (Table 8)

Conclusion

Freehand burrhole biopsy is the most commonly performed method.Stereotactic and CT-guided biopsies provide high diagnostic accuracy.All biopsy techniques yield over 88% diagnostic accuracy, confirming their effectiveness.

Discussion

Brain biopsy is a crucial diagnostic procedure in neurosurgery and neuropathology, allowing for histopathological examination of intracranial lesions. It is primarily performed when radiological findings are inconclusive or when a definitive diagnosis is required to guide treatment. Over the years, brain biopsy techniques have evolved significantly, improving safety, accuracy, and minimally invasive approaches.

The history of brain biopsy dates back to the late 19th and early 20th centuries, when neurosurgical procedures were first being developed. Initially, open craniotomy was the only available method for obtaining tissue samples, but this approach carried significant risks, including infection, hemorrhage, and neurological deficits.In the 20th century, advancements in neuroimaging, particularly the introduction of computed tomography (CT) in the 1970s and magnetic resonance imaging (MRI) in the 1980s, allowed for the development of image-guided biopsy techniques. The stereotactic biopsy, introduced in the mid-20th century, became a major breakthrough, enabling surgeons to obtain tissue samples from deep-seated or eloquent areas of the brain with greater precision and minimal invasiveness. The subsequent integration of neuronavigation systems, endoscopic methods, and robotics has further refined brain biopsy procedures, improving safety and diagnostic yield.

Several techniques are currently used for brain biopsy, each with specific indications and advantages: Freehand Burr hole biopsy technique involves creating a small hole in the skull and obtaining tissue samples with forceps or a needle

Figure 1. Free hand biopsy technique

It is a relatively simple and cost-effective method but lacks precision compared to image-guided techniques. Open Biopsy (Craniotomy Biopsy) involves surgical removal of a portion of the skull to access and excise a lesion. While this method allows for larger tissue samples and immediate therapeutic intervention, it is highly invasive and associated with longer recovery times. Stereotactic biopsy

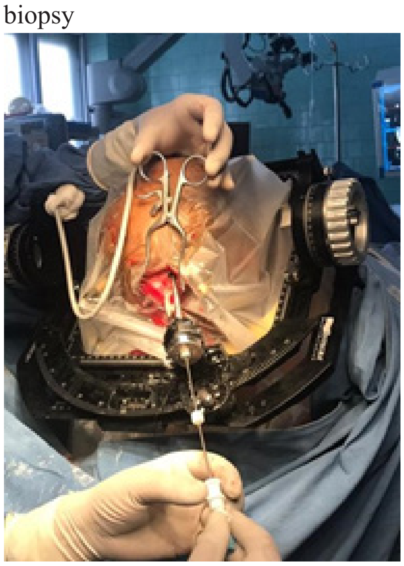


Figure 2.Stereotactic Biopsy

uses a three-dimensional coordinate system to guide a needle to the lesion. This technique can be performed using frame-based or frameless neuronavigation and is particularly useful for deep-seated or small lesions. It offers high accuracy with minimal morbidity.[13] CT or MRI guidance allows real-time navigation to improve precision. CT-guided biopsies

Figure 3.Intra oprative CT guided biopsy

are quicker and suitable for calcified lesions, whereas MRI-guided biopsies provide superior soft-tissue contrast and better visualization of non-enhancing tumors. Intraoperative ultrasound (USG) provides real-time imaging and is useful in guiding biopsy needles, especially in resource-limited settings where CT or MRI may not be available

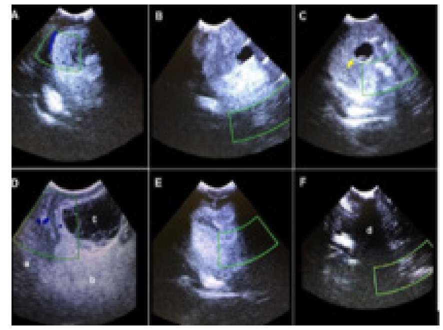


Figure 4. USG guided biopsy technique

These advanced neuronavigation systems enhance accuracy by tracking the biopsy needle in real time, reducing the risk of sampling errors (Figure 5).

Optical navigation relies on infrared cameras, while electromagnetic navigation uses sensors for real-time tracking.[14] Endoscopic techniques allow direct visualization and biopsy of intraventricular and periventricular lesions (Figure 6).

This technique is particularly useful for lesions near the ventricular system or those associated with hydrocephalus, as it allows simultaneous cerebrospinal fluid (CSF) diversion. The integration of robotics in neurosurgery, such as the ROSA (Robotic Stereotactic Assistance) system, enhances precision by reducing human error. Robotic systems offer increased stability, better trajectory planning, and improved outcomes.Traditional brain biopsies carry risks such as bleeding and infection. Liquid biopsy, an emerging technique, detects circulating tumor DNA (ctDNA) or biomarkers in blood or cerebrospinal fluid, potentially providing a non-invasive alternative for diagnosing and monitoring brain tumors . Different biopsy technique based on personal experience, availability of resources, size of the tumor and location. Usually stereotactic are done for deep located very small tumors.

Artificial intelligence (AI) is being explored for biopsy planning and real-time intraoperative histopathological analysis. Machine learning models trained on large datasets can assist in selecting optimal biopsy trajectories and predicting tumor histology. Techniques like fluorescence-guided biopsy using 5-ALA and intraoperative confocal microscopy enable real-time differentiation between tumor and normal brain tissue, improving diagnostic accuracy and reducing sampling errors. The development of smart biopsy needles with integrated sensors for real-time feedback on tissue characteristics may improve sampling accuracy. Additionally, nanotechnology-based biopsy techniques, using nanoparticle-enhanced imaging, could revolutionize tissue characterization at a microscopic level.

The evolution of brain biopsy techniques has significantly improved diagnostic accuracy, safety, and patient outcomes. From traditional open biopsies to minimally invasive, image-guided, and robotic-assisted techniques, advancements in technology continue to refine the process. Future developments, including liquid biopsy, AI integration, and molecular imaging, promise to further revolutionize brain tumor diagnosis and treatment. As neurosurgical technology advances, the goal remains to achieve maximal diagnostic yield with minimal risk, ultimately improving patient care.

References

1. Smith, R., et al. "Advances in Neurodiagnostic Tools." Journal of Neuroscience, 2021.
2. Ayer, R. E. "Evolution of Brain Biopsies in Neurosurgery." Neurosurgery Quarterly, 2019.
3. Barker, F. G. "Open Craniotomy in Modern Neurosurgery." Surgical Neurology International, 2022.
4. Rickert, J., et al. "The Role of Burr Hole Biopsies in Neurosurgery." Clin Neurosci Res, 2020.
5. Gupta, R. K., et al. "CT-Guided Brain Biopsies: Accuracy and Applications." Radiology Today, 2021.
6. Menon, G. "Intraoperative Imaging in Neurosurgery." Brain Imaging Updates, 2019.
7. Mamelak, A. N., et al. "MRI Guidance in Neurosurgical Biopsies." Neuro Oncol Advances, 2020.
8. Redmond, K. J. "Stereotactic Neurosurgery: Techniques and Innovations." J Neurosurg Sci, 2021.
9. Dorward, N. "Frameless Image Guidance in Neurosurgery." Tech Neurosurg Update, 2020.
10. Lennon, A. M., et al. "Intraoperative Ultrasound in Brain Surgery." Clin Neurosci Res, 2018.
11. Nathoo, N., et al. "The Role of Robotics in Neurosurgical Biopsies." Neurosurg Rev, 2021.
12. Miller, A. M., et al. "Emerging Applications of Liquid Biopsies in Neuro-Oncology." Cancer Cell Reports, 2023.
13. Jha, B.K. et al. 2021. Early experience of stereotactic biopsy of brain lesion in tertiary centre of Nepal.Nepal Journal of Neuroscience. 18, 1 (Mar. 2021), 51–56.
14. jha, R. et al. 2021. Neuronavigation system in neurosurgery: Technical details and our early clinical experiences. Nepal Journal of Neuroscience. 18, 1 (Mar. 2021), 45–50.