Section: Pathology

Original Research Article

INTRAOPERATIVE SQUASH CYTOLOGY AND CLINICO-IMMUNOHISTOPATHOLOGICAL CORRELATION OF CNS TUMOR & TUMOR LIKE LESIONS

Vartika Dubey[1], Rani Bansal[2], Abhinav Bansal[3], Shubhangi Gupta[4], Anjali Khare[5]

[1]*Junior Resident, Department of Pathology, Subharti Medical College, Swami Vivekanand Subharti University, Meerut, India.*
[2]*Professor, Department of Pathology, Subharti Medical College, Swami Vivekanand Subharti University, Meerut, India.*
[3]*Associate Professor & Head, Department of Neurosurgery, Subharti Medical College, Swami Vivekanand Subharti University, Meerut, India.*
[4]*Associate Professor, Department of Pathology, Subharti Medical College, Swami Vivekanand Subharti University, Meerut, India.*
[5]*Professor & Head, Department of Pathology, Subharti Medical College, Swami Vivekanand Subharti University, Meerut, India.*

Received *: 05/09/2024*
Received in revised form *: 26/10/2024*
Accepted *: 09/11/2024*

Corresponding Author:
Dr. Shubhangi Gupta,
Associate Professor, Department of Pathology, Subharti Medical College, Swami Vivekanand Subharti University, Meerut, India.
Email: drshubhangigupta@gmail.com

DOI: 10.70034/ijmedph.2024.4.113

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2024; 14 (4); 597-603

ABSTRACT

Background: Intraoperative squash/crush cytology is an important tool for intraoperative diagnosis of CNS tumors. This is an easy, fast and cost-effective method that offers important information for diagnosis, prognosis, and subsequent management. The most common form of intracranial neoplasms are primary central nervous system (CNS) tumors, most commonly Meningioma. Histopathological examination remains the gold standard for tumor typing followed by immunohistochemistry. Intraoperative consultation by squash cytology helps in improving the quality of surgical procedures. **Aim and Objectives:** 1. To study the Intraoperative squash cytology and immunohistopathological correlation. 2. To study the relevance of squash cytology in diagnosis of CNS tumors and its immediate surgical management.

Material and Methods: The study was conducted in the Department of Pathology at Subharti Medical College, Chhatrapati Shivaji Subharti Hospital, Meerut, focusing on intraoperative squash cytology and immunohistopathological correlation of CNS tumors and tumor-like lesions. The study included 60 cases. Crush smears were prepared and stained using various staining methods. The study aimed to provide a diagnosis within half an hour, allowing the neurosurgeon to plan for immediate surgical intervention. Immunohistochemical markers like IDH 1 and p53 were used for further analysis.

Results: The study reveals high diagnostic accuracy for gliomas, meningiomas, and epidermoid tumors, indicating the effectiveness of current diagnostic practices. Variable concordance for hemangiomas and other less common tumors marks the complexity of CNS tumor pathology and the need for meticulous histopathological evaluation. The majority of cases fell into WHO Grade 1 (57.14%), with no significant association between age group and sex. The analysis of cyto-histopathological and clinico-pathological correlations revealed a high diagnostic accuracy for common CNS tumors like gliomas and meningiomas. 95 % of cases showed a positive correlation between cyto and histopathogical findings.

Conclusion: Intraoperative squash cytology is an effective tool in the diagnosis of CNS tumor & tumour like lesions. This diagnostic method can help neurosurgeons to optimize their surgical approach as it's a quick diagnostic method when compared with histopathological & IHC analysis. When compared with frozen technique it is relatively cheap & easy to perform. It can be an asset in outskirts & developing hospital setup for operating on CNS tumours.

Key Words: CNS tumours, Squash cytology, Meningioma, Glioma, IHC.

INTRODUCTION

Primary CNS tumors arise from the meninges, as well as intracranial tissues. Along with this, intraoperative squash cytology greatly helps in diagnosing these tumors rapidly, which is crucial for neurosurgeons to adjust surgical approach.[1] Eisenhardt and Cushing introduced the technique in 1930, allowing less tissue use and reducing damage to neighboring brain structures.[2] Squash cytology provides good cytomorphological detail and is associated with simplicity, speed, and cost efficiency.[3]

Primary CNS tumors make up only 0.6% of adult cancers and are the second most common solid tumor in children.[5] The most common types include gliomas, meningiomas, and metastatic lesions.[6] Immunohistochemistry aids in tumor typing, but histopathological examination remains the gold standard.[4] The use of stereotactic techniques enables accurate localization and differentiation of tumors, improving surgical outcome.[7]

In developing countries like India, where cryostat setups are limited, squash cytology is an economical and faster test compared to frozen section.[8] Biopsies are often necessary to verify if a tumor is benign or malignant. This study aims to evaluate the sensitivity and specificity of intraoperative squash cytology by highlighting its correlation with immuno-histopathological findings for optimal patient management.

Aim and Objectives

1. To study the Intraoperative squash cytology and immunohistopathological correlation.
2. To study the relevance of squash cytology in diagnosis of CNS tumors and its immediate surgical management.

MATERIALS AND METHODS

This was a prospective study conducted in the Department of Pathology, in association with the Department of Neurosurgery at our institute involving 60 cases of suspected CNS tumor patients requiring intraoperative procedures between February 2023 and August 2024. The focus was on intraoperative squash cytology and the immunohistopathological correlation of CNS tumors and tumor-like lesions.

In the operating theater, tissue samples (~1mm) were collected and gently crushed between slides to prepare crush smears. Various stains were used, including H&E, MGG, Leishman-Giemsa, Pap stain, and toluidine blue when required. Smears were quickly reviewed, and the results were communicated to the neurosurgeon for surgical planning. After surgery, biopsy samples were processed by routine paraffin-embedding, and analyzed histopathologically. Immunohistochemical markers like IDH 1 and p53 were applied when necessary.

RESULTS

The prospective study examined 60 cases of CNS tumors/tumor-like lesions using squash cytology and histopathological examination. The median age of the patients was 43 years, with an equal number of males and females. The chi-square value of 4.535 with a p-value of 0.475 indicates no significant association between age group and sex in the distribution of cases. Tumors were located in both cranial (45 cases) and spinal (15 cases) regions, primarily affecting the frontal and parietal areas.

Clinically seventeen different types of tumors were encountered in the study, with glioma and meningioma constituting the majority. Vascular tumors, benign neural tumors, and cranial bone tumors showed clinico-pathological discordance.

The study revealed a spectrum of cytological neurologic diagnosis, with meningiomas being the most common (30% of cases), followed closely by gliomas (26.6%). This included high-grade gliomas (15%), as well as lower-grade gliomas and specific grades like 2/3. The meningiomas constituted various grades with forms like angiomatous and psammomatous meningiomas. Other tumour spectrum included, Schwannoma 8.3 %, Epidermal inclusion cyst 8.3 %, Hemangioma 5%, Metastasis 3 % followed by other tumours constituting 1.7 % each. Less frequent diagnosis included pituitary adenomas, craniopharyngiomas, and metastatic tumors. Histopathological diagnosis were classified according to WHO guidelines, followed by immunohistochemistry wherever applicable.

This study demonstrated a high clinical-cytological correlation in 88.3% of cases, reinforcing the diagnostic value of these methods. 56 cases out of 60 showed complete cyto-histo concurrence. Squash cytology achieved a cyto-histopathological concordance of 95%. Clinico-pathological correlation was 88.3%. 7 out of 60 cases showed clinico-pathological discordance. (Table 1, 3) (chi-square= 41.29 p= 0.0001)

Minor deviations were seen in 2 out of 3 discordant cases, while major deviation was seen in 1 case. (Table 2)

For suspected high grade glioma/ glioblastoma (n=16) Immunohistochemistry for IDH1 and p53 were done and all of them came out to be positive for p53 and IDH1 except 1 case of low grade glioma which was negative for p53 (Table 4). Immunohistochemical markers like IDH1 and p53 were pivotal in managing gliomas, with high-grade gliomas mostly showing positive reactivity.

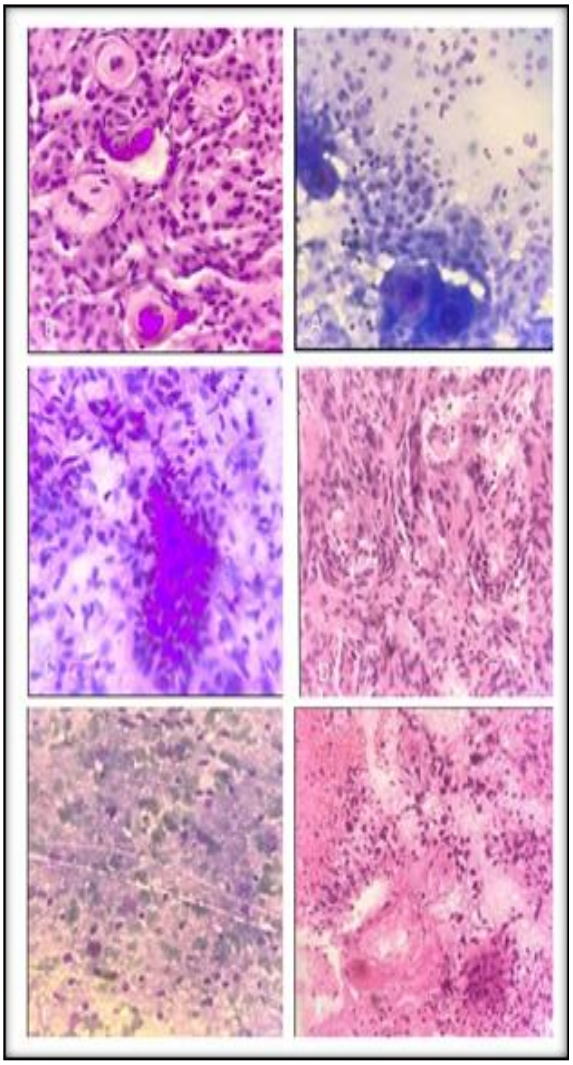

Figure 1: A & B- Psammomatous meningioma: Squash smears showing psammoma bodies. (MGG, 40x) & histopathology section showing syncytial clusters with psammoma bodies. (H&E, 40x) C &D- Meningioma: Squash smears with plump, polyhedral meningothelial cells & elongated cells having streak of bipolar cytoplasm, with crush artefact (MGG, 40x) Histopathology section of meningioma, showing tumor tissue arranged in syncytial pattern with cells exhibiting ill-defined border (H&E, 40x) E & F- High grade glioma, Squash smears showing pleomorphic cells with necrosis. (MGG, 40x) Histopathological section revealing cluster and nests of cells with hyperchromatic nuclei & necrosis (H&E,40x).

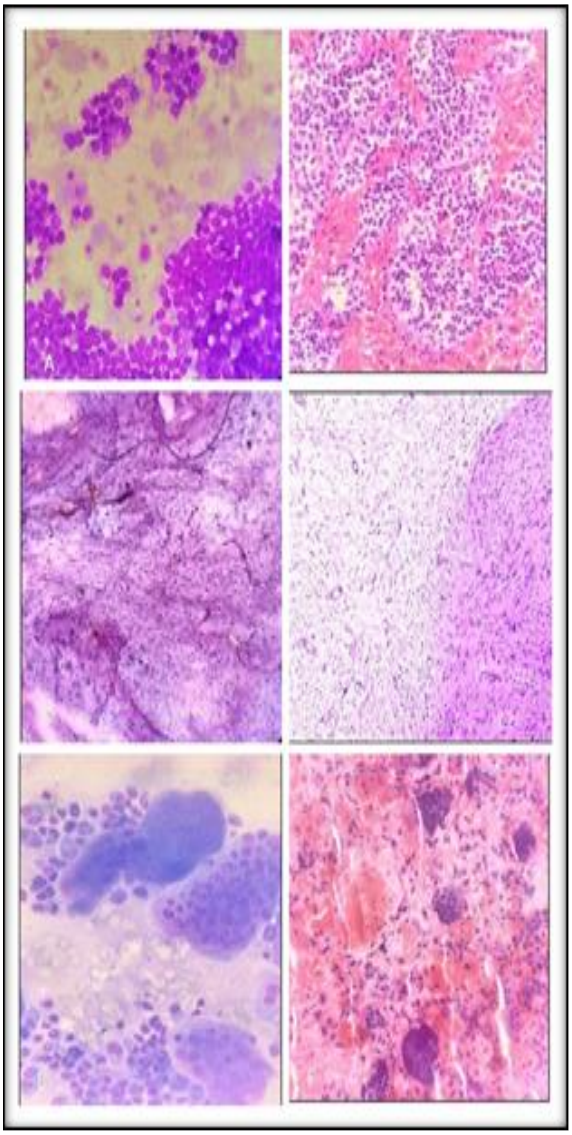

Figure 2: A & B -Pituitary Macroadenoma Squash smears revealing round cells with hyperchromatic nuclei with eosinophilic to amphophilic cytoplasm (MGG 40x) Histopathology sections revealing monomorphous population of cells in acinar pattern (H&E, 40x) C&D- Benign neural tumor, Squash smears revealing spindle & plump cells, along with pink stromal matrix. (H&E,40x) Schwannoma, histopathology section revealing spindle cells in hypocellular & hypercellular pattern (H& E,40x)

E&F- Giant cell tumor. Squash smears revealing osteoclastic giant cells. (MGG-40x)

Osteoclastoma. Histopathology section showing giant cells in a hemorrhagic background. (40x)

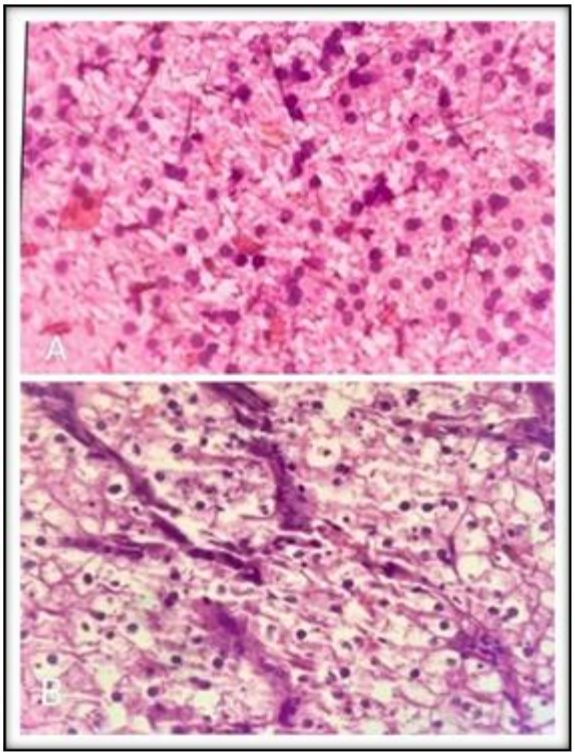

Figure 3:
Adnexal tumor

A. Squash smears from scalp region showing round to polyhedral cells with eosinophilic cytoplasm. (L&G-40x)

B. Metastatic tumor primary being renal cell carcinoma, clear cell type –scalp region (40 x- H & E)

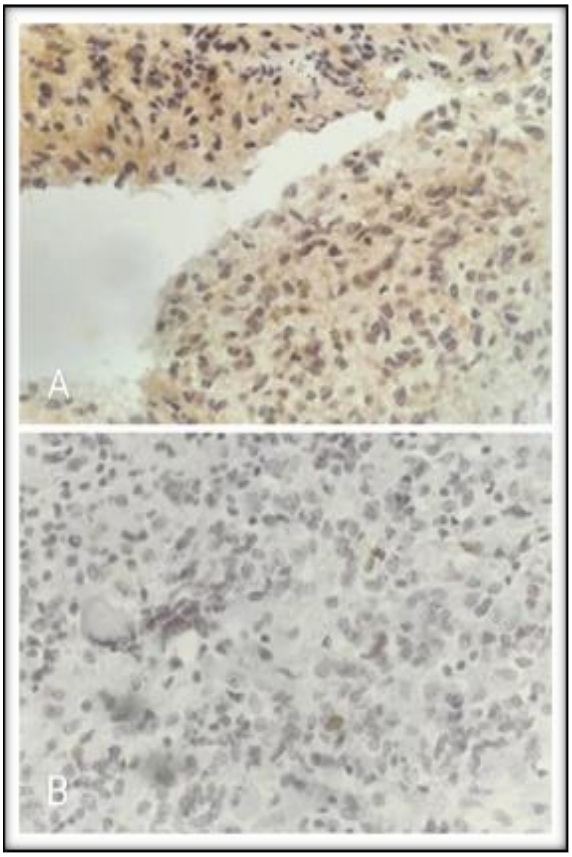

Figure 4: A. IDH 1 positivity in a case of High grade glioma (40x)
B. p53 positivity in a case of high grade glioma (40x)

Table 1: Clinico-Cyto- Histopathological correlation

Provisional clinical diagnosis	No. of cases	Squash smear diagnosis	Histopathological diagnosis	Clinico-pathological correlation	Cyto-histo pathological
Glioma	16	Glioma	Glioma	✓	✓
Medulloblastoma	1	Small round cell tumor	Medulloblastoma	✓	✓
Hemangioma	1	Meningioma	Meningioma	×	✓
Astrocytoma/Ependymoma	1	Ependymoma	Ependymoma	✓	✓
Meningioma	16	Meningioma	Meningioma	✓	✓
Lymphoma/Meningioma	1	Non hodgkins lymphoma	Non hodgkins lymphoma	✓	✓
Osteomyelitis	1	Squamous cell carcinoma	Squamous cell carcinoma	×	✓
Neurogenic tumor	1	Giant cell tumor	Giant cell tumor	×	✓
Neurofibroma	1	Cavernous hemangioma	Cavernous hemangioma	×	✓
Hemangiopericytoma	1	Vascular Tumour	Angiomatous meningioma	×	✓
Schwannoma	4	Schwannoma	Schwannoma	✓	✓
Craniopharyngioma	1	Craniopharyngioma	Craniopharyngioma	✓	✓
Tuberculoma	1	Tuberculoma	Tuberculoma	✓	✓
Benign Neural tumor	1	Inconclusive	Schwannoma	✓	×
Metastasis	1	Adnexal tumor	Metastasis	✓	×
Metastasis	1	Metastasis	Sarcoma	✓	✓
Epidermoid tumor	5	Epidermoid tumor	Epidermoid tumor	✓	✓
? Neurofibroma	1	Benign Neural tumor	Hemangioma	×	×
?Neurofibroma	1	Benign neural tumor	Neurofibroma	✓	✓
? Tumor	1	Intervertebral disc	Intervertebral disc	×	✓
? Tumor	1	Lymphoproliferative lesion	Lymphoproliferative lesion	✓	✓
Pituitary macroadenoma	1	Pituitary macroadenoma	Pituitary macroadenoma	✓	✓
Cavernous hemangioma	1	Vascular tumor	Cavernous hemangioma	✓	✓

Table 2: Cyto-histo discordant cases

SITE	SQUASH DIAGNOSIS	HISTOPATHOLOGICAL DIAGNOSIS
C5-C6	Inconclusive	Schwannoma
Intradural-extramedullary	Benign neural tumour	Hemangioma
Scalp	Adnexal tumour	Metastasis

Table 3: Clinico-Pathological Discordant Cases

Clinical Diagnosis	Histopathological diagnosis
Hemangioma	Meningioma
Osteomyelitis	Squamous cell carcinoma
Neurogenic tumour	Giant cell tumour
Neurofibroma-2 cases	Hemangioma
?Tumour	Intravertebral disc
Hemangiopericytoma	Angiomatous meningioma

Table 4: IDH1 and p53

Glioma	IDH 1	p 53
Glioma (n= 4)	Positive	Positive
High grade glioma (n=7)	Positive	Positive
Glioma with sarcomatous differentiation (n=3)	Positive	Positive>80%
Glioma grade 2 (n=1)	Positive	Positive< 10%
Low grade glioma (n= 1)	Diffusely strong positive	Negative

DISCUSSION

Intraoperative consultation (IOC) for central nervous system (CNS) tumors is an essential part of surgical determinations and patient management. Squash cytology has resulted in higher accuracy and faster intraoperative diagnosis. By providing feedback and information to the surgeons, these techniques enable them to perform in real time; thus benefiting the patients by improving their outcome. Khonglah et al,[1] examined the difficulties and pitfalls in intraoperative CNS tumor diagnosis, answering these challenges from a surgeon's viewpoint, emphasizing the importance of timely and accurate decision-making.

Yadav et al,[9] highlighted the significance of crush cytology in contemporary surgery and emphasized that with advancements in imaging and molecular diagnostics, intraoperative cytology is still pivotal. The Jaiswal and Gadkari,[3] study further attests to the value of intraoperative cytology with its high diagnostic accuracy. Jindal et al,[4] confirmed squash cytology's reliability in pediatric CNS cases, with 150 children undergoing analysis.

Comparative studies by Shah et al,[8] and Samal et al,[10] showed the advantages of squash cytology and frozen sections, respectively, in CNS tumor diagnosis. Frozen sections offer good architectural detail, but squash cytology provides superior cellular detail and rapid results, which is crucial during neurosurgery. Tumor classification—essential for triaging intraoperative care—relies on references like the 2021 WHO Classification of Tumors of the CNS,[11] and standard textbooks.[12-15]

Studies by Jaiswal et al,[16] Asha et al,[17] and Shah et al,[8] consistently report high diagnostic accuracy for squash cytology in CNS tumor surgeries, demonstrating its usefulness in practical intraoperative settings. Roessler et al,[18] and Iqbal et al,[1] rejected abandoning cytologic smears in neurosurgery, emphasizing their role in enhancing diagnostic accuracy and influencing surgical decisions.

Age of presentation for CNS lesions diagnosed by squash cytology varied across studies. Krishnani et al,[20] reported a mean age of 37 years (range 1–79 years), and Mitra et al,[21] reported an average age of 38 years (range 3–75 years). Our study's mean age of 42.3 years aligns with previous research. CNS tumors affect a wide age range, with tumors like pilocytic astrocytomas and medulloblastomas more common in younger patients, and glioblastomas and meningiomas in older adults.

CNS tumors span all age groups. The mean age of our study (42.3 years) reflects a balance between tumors common in adults and those more prevalent in children. Age-specific trends guide diagnostic evaluation, prognostic predictors, and follow-up plans.

Gender distribution of CNS tumors also varies. Krishnani et al,[20] reported a slight male predominance (53.3% male, 46.7% female), while Patil et al,[26] and Mitra et al,[21] reported 57% and 56% males, respectively. In contrast, our study showed equal incidence among males and females (50–50). This deviation could be due to regional demographics or sample sizes. Understanding gender patterns aids epidemiological studies and healthcare planning and encourages research into genetic or environmental factors.

Tumor location in our study also showed notable differences. We found 21% of tumors in the frontal and parietal regions, 17% in the temporal and occipital regions, 7% in the suprasellar and pineal regions, 11% in the cranial base and CP angle, 5% in the cerebellar and tentorial regions, 15% in the scalp and miscellaneous areas, and 25% in the spinal region. Krishnani et al,[20] reported a higher incidence of tumors in the cerebral hemispheres (45%).

The diagnostic accuracy of squash cytology in our study was 95%, with 57 cases showing cyto-histopathological concordance and only 3 discordant cases. This rate aligns with studies like Ramana et al,[22] (90.1% accuracy) and Krishnani et al,[20] (94.9%). Squash cytology remains a reliable intraoperative diagnostic tool, especially for gliomas, where we found 100% diagnostic concordance.

Gliomas constituted 26.6% of cases in our study which was fairly high. Ostrom et al,[23] and Dolecek et al,[24] identified gliomas as the most common malignant brain tumors and meningiomas as the most common non-malignant tumors. Squash cytology also identified less common tumors like neurofibromas (1.7%), epidermoid tumors (8.3%), and craniopharyngiomas, reflecting the diversity of CNS lesions diagnosed.

Morphological cellular details were studied keenly & reported. Squash smears of glioma showed glial cells ,epithelial – like neoplastic cells with oval nuclei, hyperchromatism & scanty cytoplasm. (Fig 1). All cases showed complete cyto-histo concordance. Gowri Prakasham et al,[6] also found similar cytological findings in glioma with only 1 case showing cyto-histo discordance.

Most of the cases of meningioma on squash smears showed plump to ovoid meningothelial cells arranged in whorled & syncytial pattern (Fig 1). Grading of meningioma required histopathological confirmation, though psammomatous meningioma was clearly diagnosed in squash smears. Benign neural tumors like schwannoma (neurilemmoma) & neurofibroma constituted 10% of the total cases. It was difficult to smear due to cohesiveness of cells which leaded to twisted rope appearance on cytology (Fig 2). Jindal et al,[4] also found this morphological feature of “twisted roap” appearance in squash smears. Hypercellular & hypocellular areas were noted in some smears. Diagnostic accuracy was high when correlated with the histopathological diagnosis.

Squash smears of pituitary adenoma were cellular & showed monotonous population of round cells resonating with clinical & histopathological diagnosis (Fig 2). Vikram Narang et al,[25] found papillary pattern of relatively monomorphic cells with nuclei having stippled chromatin in 3 cases of pituitary macroadenoma. 2 cases of lymphoproliferative lesions studied showed sheets of monotonous lymphoid cells in the squash smears clearly making the diagnosis of tumour being of lymphoid origin. Both the cases were concurrent with the clinical & histopathological diagnosis. Acharya et al found monomorphous population of atypical lymphoid cells on squash. Epidermoid tumors constituted 5 cases. Squash smears showed nucleated & anucleated squames along with cholesterol clefts. Diagnostic accuracy being 100% in all 5 cases. There were 2 cases of metastatic tumors. 1 of them was concurrent with histopathological diagnosis, showing neoplastic cells arranged in dyscohesive sheets, while other one was misdiagnosed as skin adnexal tumor as it was a scalp swelling, which later turned out to be a metastatic tumor, primary being of renal origin (Fig 3). Nanrang V et al,[24] found 5 cases of metastatic tumors which showed good diagnosis on cytology, smears being cellular. Though they found metastatic tumors were difficult to differentiate from glioblastoma multiforme.

IHC analysis plays an important role too as it differentiates gliosis from glioma, glioma from its mimickers. Also prognosis is determined by it, as IDH-mutant type has a better prognosis when compared with the IDH-wild type. So it plays a pivotal role in being therapeutic too. In our study IHC analysis was done in the cases of glioma which aided the neurosurgeon for further management.

Overall, our study supports the continued relevance of squash cytology in CNS tumor diagnosis, with high diagnostic accuracy and significant impact on surgical management. The technique's ability to provide real-time feedback during surgery makes it invaluable in neurosurgical practice. The age, gender, and tumor location distribution in our study offer insights into the epidemiology of CNS tumors, supporting the need for tailored diagnostic and therapeutic approaches based on demographic and anatomical factor.

CONCLUSION

Intraoperative squash cytology is an effective tool in the diagnosis of CNS tumor & tumour like lesions as it is simple, rapid & cost-effective technique. This diagnostic method can help neurosurgeons to optimize their surgical approach as it’s a quick diagnostic method when compared with histopathological & IHC analysis. When compared with frozen technique it is relatively cheap & easy to perform method. It can be an asset in outskirts & developing hospital setup for operating on CNS tumours.

REFERENCES

1. Khonglah Y, Lyngdoh B, KakatiA, etal Intraoperative diagnosis of Central Nervous System Tumors: Challenges, Errors, Lessons Learned, and the Surgeon’s Perspective. Cureus 2021 13(9): e17823.
2. Eisenhardt L, Cushing H. Diagnosis of intracranial tumors by supravital technique. Am J Pathol 1930; 6:541–552.
3. Jaiswal YP, Gadkari RU. Evaluation of Role of Intraoperative Cytology Technique in Diagnosis and Management of Cancer. J Cytol. 2020 Jul Sep;37(3):126-130
4. Jindal, Arpita; Kaur, Kanwalpreet; Mathur, Kusum; Kumari, Vinod; Diwan, Himanshi. Intraoperative Squash Smear Cytology in CNS
5. Lesions: A Study of 150 Pediatric Cases. Journal of Cytology 34(4):p 217-220
6. Stoyanov GS, Petkova L, Dzhenkov DL. A Practical Approach to the Differential Diagnosis of Intracranial Tumors: Gross, Histology, and Immunoprofile-based Algorithm. Cureus. 2019 Dec 15;11(12):e6384. doi: 10.7759/cureus.6384. PMID: 31938662; PMCID: PMC6957037
7. PRAKASAM G, KARKUZHALI K, GURUSAMY V. Role of Squash Cytology in Intraoperative Diagnosis of Meningioma. Journal of Clinical & Diagnostic Research. 2021 Aug 1;15(8).

8. Banerjee M,Chowdhury AR, Paul P, Correspondence: Anadi Roy Chowdhury, MD Pathology, FRCPath, Associate Professor and Consultant Pathologist, Department of Pathology, R G Kar Medical College, Kolkata, India
9. Shah AB, Muzumdar GA, Chitale AR, Bhagwati SN. Squash preparation and frozen section in intraoperative diagnosis of central nervous system tumors. Acta Cytol. 1998; 42:1149–54.
10. Yadav KK, Bhatti R, Moorchung N, Mutreja D, Carvalho AS. Is Crush Cytology of Central Nervous System Lesions Relevant in Surgical Practice Today? J Neurosci Rural Pract. 2019 Jan-Mar;10(1):34-38. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6337991/
11. Samal S, Kalra R, Sharma J, Singh I, Panda D, Ralli M. Comparison between crush/squash cytology and frozen section preparation in intraoperative diagnosis of central nervous system lesions. Oncol J India [serial online] 2017 [cited 2022 Aug 7];1:25-30. https://www.researchgate.net/publication/322595229_Comparison_between_crushsquash_cytology_and_frozen_section_preparation_in_intraoperative_diagnosis_of_central_nervous_system_lesions
12. Louis DN, Perry A, Wesseling P, et al. The 2021 WHO Classification of Tumors of the Central Nervous System: a summary. Neuro Oncol. 2021;23(8):1231- 1251. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8328013/
13. WHO Classification of Tumors Editorial board, Central Nervous system tumours. Lyon (France): International Agency for research on Cancer ; 2021.(WHO classification of tumour series, 5th ed ; Vol 6).
14. Kumar V Abbas A Aster J : Robbins & Cotran Pathologic Basis of Disease 10th ed- June15,2020
15. Longacre T Greenson J Hornick J Reuter V : MILLS AND STERNBERG'S DIAGNOSTIC SURGICAL PATHOLOGY May 3 2022; 7thEd Goldblum J, McKenney J, Lamps L, Myers J : Rosai and Ackerman's Surgical Pathology ; 2018 11th ed.
16. Jaiswal S, Vij M, Jaiswal AK, Behari S. Intraoperative squash cytology of central nervous system lesions: a single center study of 326 cases. Diagn Cytopathol. 2012 Feb;40(2):104-12. doi: 10.1002/dc.21506. Epub 2010 Nov 2. PMID: 22246925. https://pubmed.ncbi.nlm.nih.gov/22246925/
17. Asha T, Shankar SK, Rao TV, Das S. Role of squash-smear technique for rapid diagnosis of neurosurgical biopsies—A cytomorphological evaluation. Indian J Pathol Microbiol 1989;32: 152 160. https://pubmed.ncbi.nlm.nih.gov/2674004/
18. Roessler K, Dietrich W, Kitz K. High diagnostic accuracy of cytologic smears of central nervous system tumours. A 15-year experience based on 4172 patients. Acta Cytol 2002; 46:667–674. https://pubmed.ncbi.nlm.nih.gov/12146028/
19. Iqbal M, Shah A, Wani MA, Kirmani A, Ramzan A. Cytopathology of the central nervous system. I. Utility of crush smear cytology in intraoperative diagnosis of central nervous system lesions. Acta Cytol 2006; 50:608–616. https://pubmed.ncbi.nlm.nih.gov/17152270/
20. Krishnani N, Kumari N, Behari S, Gupta RK. Intraoperative squash cytology: Accuracy and impact on immediate surgical management of central nervous system tumours. Cytopathology. 2012;23(5):308-313. https://pubmed.ncbi.nlm.nih.gov/21838720/
21. Mitra S, Kumar M, Sharma V, Mukhopadhyay D. Squash preparation: A reliable diagnostic tool in the intraoperative diagnosis of central nervous system tumors. J Cytol. 2010;27(3):81-85. https://pubmed.ncbi.nlm.nih.gov/21187881/
22. Ramana PV, Vijaya Nirmala B, Srujana Shyamala. Diagnostic accuracy of central nervous system tumors by squash cytology. IAIM, 2018; 5(4): 29-35. https://www.semanticscholar.org/paper/Diagnostic-accuracy-of-central-nervous-system-by-Ramana-Nirmala/374773ab9f0e4b43db34fec8f201f1dffce16e26
23. Ostrom QT, Gittleman H, Liao P, Rouse C, Chen Y, Dowling J, et al. CBTRUS statistical report: Primary brain and central nervous system tumors diagnosed in the United States in 2007–2011. Neuro Oncol. 2014;16 Suppl 4:iv1-iv63.
24. Dolecek TA, Propp JM, Stroup NE, Kruchko C. CBTRUS statistical report: Primary brain and central nervous system tumors diagnosed in the United States in 2005-2009. Neuro Oncol. 2012;14 (5): 1-49. https://pubmed.ncbi.nlm.nih.gov/23095881/
25. Nanarng V, Jacob S, Mahapatra D, Mathew JE. Intraoperative diagnosis of central nervous system lesions: Comparison of squash smear, touch imprint, and frozen section. J Cytol. 2015 Jul-Sep;32(3):153-8. https://pubmed.ncbi.nlm.nih.gov/26729974