Unveiling the potential application of intraoperative brain smear for brain tumor diagnosis in low-middle-income countries: A comprehensive systematic review

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Review Article

Unveiling the potential application of intraoperative brain smear for brain tumor diagnosis in low-middle-income countries: A comprehensive systematic review

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ABSTRACT

Background: Immediate intraoperative histopathological examination of tumor tissue is indispensable for a neurosurgeon to track surgical resection. A brain smear is a simple, rapid, and cost-effective technique, particularly important in the diagnosis of brain tumors. The study aims to determine the effectiveness of intraoperative brain smear in the diagnosis of brain tumors in low- and middle-income countries (LMICs), while also evaluating its sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy.

Methods: A comprehensive search of the literature was conducted using PubMed, Scopus, and Google Scholar. The retrieved articles were independently screened by two reviewers. The data was extracted, processed, and organized using Microsoft Excel.

Results: A total of 59 out of 553 articles screened were included in the final analysis. The sensitivity and specificity of the intraoperative smear of brain tumors were found to be over 90% in most studies. The PPV was consistently above 90% in 11 studies, reaching 100% in one study and the NPV varied, ranging from 63% to 100%, and the accuracy was found to be >80% in most studies. One recurrent theme in the majority of the included studies was that an intraoperative brain smear is a cost-effective, quick, accessible, and accurate method of diagnosing brain tumors, requiring minimal training and infrastructure.

Conclusion: Intraoperative brain smear is a simple, rapid, cost-effective, and highly sensitive diagnostic modality for brain tumors. It can be a viable and accessible alternative to more traditional methods such as frozen sections and can be incorporated into neurosurgical practice in LMICs as a reliable and efficient diagnostic tool.

Keywords: Brain tumors, Intraoperative brain smear, Low- and middle-income countries

INTRODUCTION

Brain tumors are a group of malignancies that can originate from cells within the brain (primary tumors) or from systemic tumors that have spread to the brain (secondary tumors). A global
age-standardized incidence of primary malignant brain tumors is 2.6 per 100,000 for females and 3.7 per 100,000 for males annually. Between 1990 and 2016, the rate of central nervous system (CNS) cancer increased by 9.3% in countries with a low sociodemographic index, 7.0% in countries with a low-middle sociodemographic index, 26.1% in countries with a middle sociodemographic index, and 22.0% in countries with a high sociodemographic index.

For a neurosurgeon, an instant intraoperative histopathological examination of tumor tissue is a critical tool to monitor surgical resection by differentiating normal brain histology from a tumor. An early diagnosis can potentially help the neurosurgeon determine the scope of the operation. The current modalities available for intraoperative brain tumor examination include stimulated Raman histology, frozen sections (hematoxylin and eosin-stain), and cytological methods.

The process of obtaining a frozen section, the gold standard for intraoperative histopathological examination, is time-consuming and can delay surgical treatment. It involves delivering tissue to a laboratory, processing the specimen, preparing slides by technicians, and interpreting the slides by a pathologist. Frozen section results can take 20–23 min compared to histopathology, which takes 2–3 days. The propensity of brain tissue to form ice-crystal artifacts makes frozen slices difficult to analyze, and the interpretation of frozen sections can have a high error rate due to factors such as tumor heterogeneity, surgeon error, pathologist interpretation error, and technical artifacts. In addition, the process is labor-intensive, expensive, and requires specialized personnel, making it less financially feasible for patients in resource-limited countries. However, an intraoperative brain smear is another diagnostic option and can be performed within 10–20 min.

Since 1930, when Eisenhardt and Cushing proposed the use of a touch imprint for rapid tumor identification, cytological methods have been utilized to diagnose brain tumors. The available brain smear techniques are touch or imprint smear and squash or crush smear. Brain smear is a simple and quick process. The nature of CNS tumors is particularly soft and gel-like; squash smears are particularly advantageous, as it uses this property to cause cytological features to be clearly observed in smears. The precise location, radiological results, and clinical presentation of the patient aid the pathologist in determining the cytological diagnosis.

The main goals of intraoperative neuropathologic consultation for neurosurgeons are to guarantee that the diagnostic specimen was collected with the least amount of trauma and to ensure an immediate and appropriate treatment. The smear preparation technique has been proven to be helpful as a supplement to imprint cytology for better diagnostic accuracy. Brain smears consider both cytological and architectural aspects of CNS tumors, in addition to background matrix and necrosis.

Brain smear techniques are relatively cheap compared to other modalities available and can be conducted within the operating room without any specialized equipment or specialized technicians being involved, which holds advantages for low- and middle-income countries (LMICs).

The objective of this study is to determine the usefulness of intraoperative brain smears in the diagnosis of brain tumors in LMICs through a systematic review of the existing literature. The review aims to evaluate the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy of intraoperative brain smears as a diagnostic tool in LMICs.

MATERIALS AND METHODS

This systematic review was conducted following our research protocol, which was based on the research question using population, intervention, control, and outcome. The preferred reporting items for systematic reviews and meta-analyses reporting standards were followed.

Eligibility criteria

This review analyzes the use of intraoperative brain smears during surgical procedures of brain tumors, both primary and metastatic. Studies eligible for inclusion were observational studies, including cohort studies, and randomized and nonrandomized controlled trials. The literature searched included articles that presented epidemiological, clinical, and laboratory aspects of the use of brain smears during tumor procedures. All age groups were included in this review. Studies were excluded from the study: editorials, case reports, case series (n < 10), studies published as abstracts only, letters to the editor, book chapters, and theses, as well as articles on spine tumors or other brain pathologies.

Final histopathology served as the gold standard test for evaluating diagnostic accuracy. This provided a definitive diagnosis based on tissue examination and has been widely recognized for its reliability and validity. Only studies utilizing the final histopathology report as the reference standard were included in our analysis.

Search strategy

A comprehensive search was conducted across multiple electronic databases, including PubMed, Scopus, and Google Scholar, with no language restrictions. The search encompassed articles from inception to December 25, 2022, and all searches were performed on the same date. We searched for relevant phrases in the Medical Subject...
Headings database and selected the following free-text terms as keywords: “brain neoplasms” OR “brain tumor” AND “brain smear” OR “intraoperative cytology” OR “intraoperative squash cytology” OR “imprint cytology” OR “touch cytology” to yield a comprehensive and inclusive dataset. The included studies were searched for forward citations to ensure that all the relevant literature are included in the study. The detailed search strategy for each database is available in the supplementary document.

**Study selection**

All retrieved studies’ titles and abstracts were initially screened by two reviewers (SAA and HH) for duplication and relevancy according to our research question. The final study selection was made after an independent review by two reviewers (SAA and HH) of the full texts of all possibly pertinent studies. A consensus was reached by a third author (MS) to settle conflicts.

**Data extraction**

Study characteristics (study title, authors, date of publication, publication type, study location, and sample size), population characteristics, study objective, advantages of the mentioned brain smear techniques, test characteristics (accuracy, sensitivity, specificity, PPV, and NPV), and study outcomes were extracted from eligible articles. Two authors independently extracted the data (SAA, HH). A third author (MS) corrected errors in data extraction and double-checked the information collected. Two authors (SAA and AA) independently evaluated each study’s quality using the Newcastle–Ottawa scale quality assessment.

The review underwent rigorous data validation, involving cross-referencing data from multiple sources, applying validation criteria, and resolving discrepancies through reviewer consensus. Data cleaning removed errors and inconsistencies while missing data were managed using the method of exclusion.

**Data analysis**

The data were processed and analyzed using Microsoft Excel. For ease of reporting and comprehension, the extracted data were cleaned and organized into tables.

**RESULTS**

Our initial search for relevant studies identified a total of 553 articles. After removing duplicates and reviewing the titles and abstracts, 88 studies were reviewed in full text. A total of 59 articles were included in the final analysis.

The majority of studies included in this review were conducted in LMICs, with single-center retrospective or prospective designs. Many of these studies were conducted in India. Out of the 59 studies, 52 were conducted in LMIC settings, of which 39 were conducted in India, as shown in Table 1. The most common brain tumors evaluated using this technique were gliomas, meningiomas, pituitary adenomas, and schwannomas. The majority of the articles compared the squash smear diagnostic technique with final histopathology or frozen sections, while in a few studies, imprint cytology was also considered.

The process of screening and selecting these studies, including the removal of duplicates and review of titles and abstracts, is shown in Figure 1. The kappa score, a measure of inter-rater reliability, between the two reviewers (HH and SAA) was high at both the title and abstract screening stage (Cohen’s $k = 0.81$) and the full-text review stage (Cohen’s $k = 0.83$).

The majority of the studies demonstrated high quality, with only six studies classified as having moderate quality. The detailed quality assessment is shown in Table 2.

The results of the analysis indicate that the sensitivity of intraoperative smear in detecting brain tumors was found to be more than 90% in the majority of cases (12 studies) and 100% in two studies. However, it should be noted that one study reported a sensitivity of 56%. In terms of specificity, the findings showed greater variability, with six studies reporting a specificity of >90%, while one study reported a specificity of 100%. The lowest reported specificity was observed in the range of 75–76%.

The PPV was reported above 90% in the majority of the studies (11 studies) and in one study, it was 100%. However, the lowest value reported was 75%. The NPV demonstrated a wide range, with the lowest value reported being 63% and the highest being 100%, as documented in three studies. However, the majority of studies (seven in total) that reported NPV fell within the range of 80–100%.

Overall, the accuracy of intraoperative smears for detecting brain tumors was reported >80% in the majority of studies (47 studies). It is important to note that the accuracy of any diagnostic test can be influenced by various factors, including the specific technique used and the characteristics of the population being tested. The detailed results of the studies on sensitivity, specificity, PPV, NPV, and accuracy are shown in Table 3 and Figure 2.

Articles in this review also discussed numerous advantages of intraoperative smear including cost-effectiveness, minimal infrastructure requirements, rapid (10–15 min), accessibility, and accuracy in diagnosis. Intraoperative smear was reported to be relatively inexpensive compared to more complex tests, and it can be performed using basic equipment and facilities.

**DISCUSSION**

This is the first comprehensive review that evaluates the sensitivity, specificity, positive and NPVs, and accuracy of an
Table 1: Baseline characteristics of included studies.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Study name</th>
<th>Country</th>
<th>Study design</th>
<th>Sample size</th>
<th>Pediatric and/or adult</th>
<th>Squash and/or imprint smear cytology</th>
</tr>
</thead>
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<td>Tele 2006[70]</td>
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<td>Prospective</td>
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<td>Adult</td>
<td>Squash</td>
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<td>5.</td>
<td>Hiryur et al. 2019[90]</td>
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<td>Cross-sectional</td>
<td>65</td>
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<td>Squash</td>
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<td>6.</td>
<td>Jain K et al. 2022[13]</td>
<td>India</td>
<td>Prospective</td>
<td>55</td>
<td>Pediatric</td>
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<td>8.</td>
<td>Kumarguru et al. 2021[36]</td>
<td>India</td>
<td>Retrospective</td>
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<td>Adult</td>
<td>Squash</td>
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<tr>
<td>9.</td>
<td>Maity et al. 2019[39]</td>
<td>India</td>
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<td>42</td>
<td>Pediatric</td>
<td>Squash</td>
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<td>10.</td>
<td>Ud Din et al. 2011[79]</td>
<td>Pakistan</td>
<td>Prospective</td>
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<td>Squash</td>
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<td>11.</td>
<td>Nasreen et al. 2015[46]</td>
<td>Bangladesh</td>
<td>Cross-sectional</td>
<td>64</td>
<td>Both</td>
<td>Squash</td>
</tr>
<tr>
<td>13.</td>
<td>Savargaonkar et al. 2001[69]</td>
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<td>Squash</td>
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<td>Acharya et al. 2016[41]</td>
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<td>Squash</td>
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<td>15.</td>
<td>Samal et al. 2017[61]</td>
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<td>63</td>
<td>Adult</td>
<td>Squash</td>
</tr>
<tr>
<td>17.</td>
<td>Govindaraman et al. 2017[18]</td>
<td>India</td>
<td>Prospective</td>
<td>75</td>
<td>Adult</td>
<td>Squash</td>
</tr>
<tr>
<td>18.</td>
<td>Kishore et al. 2018[43]</td>
<td>India</td>
<td>Prospective</td>
<td>127</td>
<td>Both</td>
<td>Squash</td>
</tr>
<tr>
<td>20.</td>
<td>Sarkar et al. 2017[62]</td>
<td>India</td>
<td>Prospective</td>
<td>107</td>
<td>Both</td>
<td>Squash</td>
</tr>
<tr>
<td>21.</td>
<td>Salami et al. 2015[60]</td>
<td>Nigeria</td>
<td>Retrospective</td>
<td>69</td>
<td>Both</td>
<td>Squash</td>
</tr>
<tr>
<td>22.</td>
<td>Sharma et al. 2011[65]</td>
<td>Nigeria</td>
<td>Retrospective</td>
<td>149</td>
<td>Adult</td>
<td>Both</td>
</tr>
<tr>
<td>24.</td>
<td>Agrawal et al. 2014[42]</td>
<td>India</td>
<td>Retrospective</td>
<td>41</td>
<td>Adult</td>
<td>Squash</td>
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<td>Adult</td>
<td>Squash</td>
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<td>India</td>
<td>Retrospective</td>
<td>326</td>
<td>Adult</td>
<td>Squash</td>
</tr>
<tr>
<td>28.</td>
<td>Jindal et al. 2017[27]</td>
<td>India</td>
<td>Retrospective</td>
<td>150</td>
<td>Pediatric</td>
<td>Squash</td>
</tr>
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<td>29.</td>
<td>Jindal et al. 2017[28]</td>
<td>India</td>
<td>Prospective</td>
<td>150</td>
<td>Both</td>
<td>Squash</td>
</tr>
<tr>
<td>30.</td>
<td>Lone et al. 2018[37]</td>
<td>Indian-occupied Kashmir</td>
<td>Retrospective</td>
<td>550</td>
<td>Both</td>
<td>Squash</td>
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<td>31.</td>
<td>Nalinimohan et al. 2018[46]</td>
<td>India</td>
<td>Prospective</td>
<td>131</td>
<td>Adult</td>
<td>Squash</td>
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<tr>
<td>33.</td>
<td>Pala et al. 2022[90]</td>
<td>Turkey</td>
<td>Prospective</td>
<td>55</td>
<td>Adult</td>
<td>Squash</td>
</tr>
<tr>
<td>34.</td>
<td>Qiao et al. 2019[34]</td>
<td>USA/China</td>
<td>Retrospective</td>
<td>403</td>
<td>Adult</td>
<td>Squash</td>
</tr>
<tr>
<td>35.</td>
<td>Raju et al. 2018[86]</td>
<td>India</td>
<td>Prospective</td>
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<tr>
<td>36.</td>
<td>Rani et al. 2014[47]</td>
<td>India</td>
<td>Comparative</td>
<td>110</td>
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<td>37.</td>
<td>Roessler et al. 2002[59]</td>
<td>Austria</td>
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<td>Comparative</td>
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<td>Yadav et al. 2022[74]</td>
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<td>Retrospective</td>
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<td>Bhagyalakshmi et al. 2012[66]</td>
<td>India</td>
<td>Prospective</td>
<td>81</td>
<td>NR (Mean Age - 35)</td>
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<td>Nigam et al. 2012[47]</td>
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<td>48.</td>
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<td>India</td>
<td>Prospective</td>
<td>100</td>
<td>NR</td>
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</table>

(Contd...)
Table 1: (Continued).

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<thead>
<tr>
<th>S. No.</th>
<th>Study name</th>
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<th>Study design</th>
<th>Sample size</th>
<th>Pediatric and/or adult</th>
<th>Squash and/or imprint smear cytology</th>
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<td>Jha et al. 2013[26]</td>
<td>India</td>
<td>Prospective</td>
<td>35</td>
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<tr>
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<td>Tena-Suck et al. 2015[22]</td>
<td>Mexico</td>
<td>Retrospective</td>
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<td>Adult</td>
<td>Squash</td>
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<td>Chaturvedi et al. 2013[12]</td>
<td>India</td>
<td>Retrospective</td>
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<td>Squash</td>
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<td>53.</td>
<td>Deshpande et al. 2010[14]</td>
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<td>Prospective</td>
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<td>54.</td>
<td>Ramana et al. 2018[15]</td>
<td>India</td>
<td>Prospective</td>
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<td>56.</td>
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<td>Both</td>
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<td>Khamechian et al. 2012[18]</td>
<td>Iran</td>
<td>Prospective</td>
<td>139</td>
<td>Adult</td>
<td>Imprint</td>
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</table>

NR: Not reported

Figure 1: Preferred reporting items for systematic reviews and meta-analyses flow diagram. Number (n).
Table 2: Quality assessment of the included studies.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Study name</th>
<th>Selection (4)</th>
<th>Comparability (2)</th>
<th>Exposure/outcome (3)</th>
<th>Overall star rating (9)</th>
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<td>8.</td>
<td>Kumarguru et al. 2021[38]</td>
<td>⭐⭐⭐</td>
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<td>Ud Din et al. 2011[29]</td>
<td>⭐⭐⭐⭐</td>
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<td>Nasreen et al. 2015[36]</td>
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<td>15.</td>
<td>Samal et al. 2017[61]</td>
<td>⭐⭐⭐</td>
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<tr>
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(Contd...)
Intraoperative brain smear. It also highlights its advantages for resource-limited settings where there is a shortage of trained histopathologists and histopathology facilities.

This review reported the diagnostic accuracy of the intraoperative brain smear as >80%, as reported in the majority of studies. Sensitivity and specificity values were similarly high, with more than 90% reported in most studies. In addition, most studies reported positive and NPVs >90%. The main advantages reported include its being a rapid, simple, reliable, and cost-effective tool for diagnosis. Other advantages include high accuracy, ease of smear given the friable quality of brain tumors, and use of minimal brain tissue. Thus, the use of intraoperative brain smear techniques has proven to be an effective tool in the diagnosis of brain tumors in patients undergoing surgery. This approach can efficiently reduce and potentially eliminate the need for additional surgeries to achieve negative margins in such patient populations.

A frequently cited benefit of intraoperative brain smears, as noted in many of the studies, is the considerably shorter time required for diagnosis compared to conventional techniques. As per the study by Jaiswal et al., the time required for reporting the results of intraoperative brain smears is approximately 10–20 min from the point of receipt. This stands in stark contrast to the duration of at least 2–3 working days required for final histopathology, making intraoperative brain smear a much swifter alternative. In comparison to histopathology, frozen section – another frequently utilized technique for intraoperative diagnosis of brain tumors – also represents a time-saving method, with the diagnosis being made within 20–23 min. However, this method requires the availability of a cryostat machine and various laboratory equipment – which is often not available in LMIC settings. While the advantages of intraoperative brain smears are numerous, it also does not compromise on accuracy, sensitivity, and specificity of the diagnosis. Histopathological diagnosis is typically considered the gold standard of diagnosis, and squash smear diagnosis has proven to have comparable high accuracy rates, ranging from 85% and above in our review. One study found the sensitivity and specificity of frozen sections to be slightly higher than squash smear (86.67% vs. 91.67%); however, this study did not find any significant difference in their accuracy levels, indicating the techniques are complementary procedures.

False positives and false negatives were reported in a few of the studies, as a small minority of the total sample size. One reason for this misdiagnosis through a squash smear was due to specific tumors such as ependymomas and meningiomas not being able to smear due to their firm nature. Other reasons include distortion of histological detail on the smear and sampling errors. Lymphomas, in particular, were misdiagnosed due to lymphogranuloma bodies being appreciated better on histopathological diagnosis than smears. Trouble was also faced by multiple authors during the grading of astrocytomas, mainly due to their heterogeneity.

Intraoperative brain smears are highly accurate (95.3%) and reliable as a primary diagnostic tool for planning treatment. The accuracy of this tool for detecting brain tumors is reported to be 80% or above in the majority of our studies. However, few studies in this review assessed the diagnostic accuracy of intraoperative squash smears using only specific kinds of tumors. For example, Qiao et al. studied the accuracy of squash smear on pituitary microadenomas. They reported an accuracy rate of 80.9% and commented...
Table 3: Characteristics of Intra-operative brain smear.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Study name</th>
<th>Sample size</th>
<th>Country</th>
<th>Study design</th>
<th>Pediatric and/or adult</th>
<th>Squash and/or imprint smear cytolgy</th>
<th>Sensitivity %</th>
<th>Specificity %</th>
<th>PPV %</th>
<th>NPV %</th>
<th>Accuracy %</th>
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Table 3: (Continued).

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NR: Not reported. *Low-grade-high-grade neoplasm. PPV: Positive predictive value, NPV: Negative predictive value
on how the decreased quantity of tissue available for diagnosis was best used by squash smear diagnosis. The few false-positive cases they encountered were due to misinterpretation of histology. Tena-Suck et al. did a study on craniopharyngiomas, reporting an accuracy rate of 83.33%.\textsuperscript{[71]} Another study was conducted, testing the smear technique on just chordomas; the reported accuracy was 70%, which may be due to the small sample size (n = 22) and insufficient sample tissue. The accuracy of brain smears increased in correlation with clinical details and radiological findings.\textsuperscript{[72]}

This review highlighted some of the limitations of squash smears in the diagnosis of certain brain tumors. One is the misrepresentation of tumor tissue due to absent histological artifacts, which leads to inaccurate diagnoses being made.\textsuperscript{[28]} This may be the case due to inadequate tissue being present on the smear slide. Another limitation is that not all brain tumors are soft enough to undergo the squash smear. Tumor types such as meningiomas and ependymomas are firmer in nature and, hence, can be better diagnosed through frozen sections rather than squash smears.\textsuperscript{[23]} To avoid such issues, squash smear techniques could be used exclusively on soft, friable brain tumors, and frozen section diagnosis could be reserved for firmer tumors – where the equipment is available. To tackle the misrepresentation of tumors, using an adequate tissue sample while preparing smear slides is important. This could ensure enough cytological features are represented on the slide to make an accurate diagnosis.

This study is the first systematic review, to the best of our knowledge, conducted on the utility of intraoperative brain smears in brain tumor diagnosis. Overall, the results show that intraoperative brain smear is a rapid, simple, safe, cost-effective, and fairly accurate method of diagnosis of brain tumors which can improve service delivery efficiency and reduce the burden on healthcare systems in LMICs. This method could be especially beneficial in resource-limited settings, where the equipment for frozen sections is not often available and histopathological diagnosis also faces obstacles. There is a lack of trained histopathologists, limited availability of laboratory infrastructure, and limited advanced equipment to support the high demand for histopathological diagnosis. Our study reports the advantages of brain smear specifically for resource-limited settings, where other modalities of diagnosis are often not available.

Future direction

Further research is necessary to fully explore and understand the feasibility and implementation of intraoperative brain smears as a diagnostic modality for brain tumors in LMICs. Conducting further controlled studies, especially those that gather data from a larger range of countries, will provide better insight into the utility of the brain smear. Further, a comparison of the brain smear technique with other diagnostic modalities available will also provide valuable insight. Finally, guideline development regarding the use of brain smears in brain tumor diagnosis will be necessary for regulating the approach and improving the quality of care given worldwide.

CONCLUSION

Our systematic review revealed that intraoperative brain smear is a simple, rapid, cost-effective, and highly sensitive diagnostic modality for brain tumors in LMICs. It appears from the included literature that brain smears in settings with limited resources can be a viable and accessible alternative to more traditional methods such as frozen sections. Furthermore, the results of the studies reviewed suggest that brain smears could be incorporated into neurosurgical practice in LMICs as a reliable and efficient diagnostic tool.

Declaration of patient consent

Patients’ consent not required as patients’ identities were not disclosed or compromised.

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Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

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SEARCH STRATEGY

Concept#1: (Intraoperative)
“Intraoperative Period”[Mesh] OR “Intraoperative Care”[Mesh]

Concept#2: (Brain Smear)
(“Brain Smear” OR “Intraoperative cytology” OR “Intraoperative squash cytology” OR “Intraoperative squash smear” OR “Squash Smear” OR “Imprint cytology” OR “touch cytology”)

Concept#3 (Brain Tumor)
“Brain Neoplasms”[Mesh] OR “Central Nervous System Neoplasms”[Mesh] OR “Brain tumor” OR “brain cancer” OR “CNS tumor” OR “Nervous system tumor” OR “Neuro-Oncology” OR “Intracranial neoplasm” OR “Primary brain tumor”

PubMed
(“Brain Neoplasms”[Mesh] OR “Central Nervous System Neoplasms”[Mesh] OR “Brain tumor” OR “brain cancer” OR “CNS tumor” OR “Nervous system tumor” OR “Neuro-Oncology” OR “Intracranial neoplasm” OR “Primary brain tumor”)

Scopus
(“Brain Neoplasms” OR “Central Nervous System Neoplasms” OR “Brain tumor” OR “brain cancer” OR “CNS tumor” OR “Nervous system tumor” OR “Neuro-Oncology” OR “Intracranial neoplasm” OR “Primary brain tumor”) AND (“Brain Smear” OR “Intraoperative cytology” OR “Intraoperative squash cytology” OR “Intraoperative squash smear” OR “Squash Smear” OR “Imprint cytology” OR “touch cytology”)

Google Scholar: (Using Publish or Perish)