Ultrasonic Surgical Aspirator Based Histopathological Assessment in Neuro-Oncology: A Prospective Study at a Tertiary Care Hospital - Elevating Diagnostic Precision in Brain Tumor Specimens

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Abstract

Background: Ultrasonic surgical aspirators, powered by high-frequency sound waves, represent a cutting-edge tool in neurosurgery. The ongoing study endeavors to thoroughly assess the practicality and effectiveness of employing ultrasonic aspirators in the treatment of central nervous system tumors.

Objective: To assess the outcome of the Ultrasonic surgical aspirators in brain surgery tumors can be removed safely without harmful effects on brain parenchyma or the neurovascular structures.

Methods: It was a prospective study, we in our study had 64 patients in total that were part of the study; admitted between May 2019 and September 2023 with brain lesions, Department of Neurosurgery, Liaquat University of Medical and Health Sciences, Jamshoro among them males were 38 (59.3%) and females were 26 (40.6%), aged between 16 and 61 (mean 51.6±14.2). 32 patients were treated with Ultrasonic Surgical Aspirator, while in 32 patients the conventional method was adopted, and of them, it was not used. Patients undergoing Ultrasonic Surgical Aspirator had an age range of 16 to 57 years, with a mean age of 48.7±16.6 years. Meanwhile, those who did not undergo Ultrasonic Surgical Aspirator ranged from 30 to 61 years old, with a mean age of 51.1±10.4 years.

Results: No significant differences were observed between the two groups in terms of the variable used (p=0.087, p=0.6539 respectively). When comparing operative times, the group utilizing CUSA had an average surgery duration of 210 minutes (ranging from 90 to 260 minutes), while the group not using the ultrasonic aspirator had an average surgery duration of 160 minutes (ranging from 110 to 170 minutes). The mean time of surgery was marked longer in the Ultrasonic Surgical Aspirator was used (p=0.014). Apart that structural changes were found which can alter the grade of the tumor compared to the conventional biopsy.

Conclusion: Ultrasonic Surgical Aspirator serves as a valuable alternative in high-risk biopsy scenarios, it's vital to recognize its inherent limitations. With advancements such as digital histopathology and molecular analysis, ensuring the availability of the entire operative specimen for analysis becomes imperative due to the rapid processing capabilities associated with these methodologies.

Keywords: *Ultrasonic surgical aspirator, glioma, heterogeneity, meningioma, biopsy.*

INTRODUCTION

Since its introduction in the early 1980s, the Surgical Ultrasonic Aspirator has become a safe tool in the decompression of brain tumors. Surgical aspirators are a common tool used in many neurosurgical centers for the removal of brain tumor tissue. This technology allows surgeons to efficiently and precisely extract various types of tissue during brain tumor resection procedures. The aspirate typically contains a mixture of different types of tissue, including viable tumor tissue, normal or tumor-infiltrated brain tissue, and necrotic tissue, depending on the specific type of tumor being treated [1].

A surgical Ultrasonic Aspirator facilitates the excision of tumors, with minimized edema. Working within a confined area, it fragments tissue while irrigating and aspirating into a sterile waste bottle. Since the diagnosis of High-Grade Gliomas (HGG) hinges on histopathology and these tumors often exhibit heterogeneity, preserving unfragmented tissue becomes imperative for clinical pathology. However, this constraint leads to a diminished quantity of accessible tissue for research purposes [2].

It can have a safer approach even in cortical areas with the assistance of other tools, minimizing brain swelling [3].

Surgically removing lesions within or near brain tissue can increase morbidity risks due to surrounding tissue damage. While Surgical Ultrasonic Aspirator is acknowledged for selectively removing lesions without impacting surrounding tissues, debates persist regarding potential deleterious effects on neural tissue [4].

Combining functions such as bipolar, suctioning, and spraying of saline by a single handheld device can help the efficiency and simplicity of surgery, resulting in a cleaner surgical field. Evaluating Surgical Ultrasonic Aspirator in comparison to standard surgical instruments for compression and hemorrhage is crucial, and it should be done while considering the safety of Surgical Ultrasonic Aspirator on vessels and nerves. The robust

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intracellular bands are attributed to the protection of nerves and vessel walls [5].

Surgical ultrasonic Aspirator is extensively employed in diverse surgeries, but there remains a lack of consensus on its potential deleterious effects on neural tissue. Initially proposed as an instrument to enhance safety, reduce operating time, improve quality, and facilitate selective surgery, past reports indicate no known contraindications, with only a few limitations mentioned, primarily related to personal and financial aspects. However, recent studies have highlighted concerns about nerve injury, particularly in connection to the intensity and duration of application [6, 7].

Ultrasonic waves, the force of suction during tumor removal, and the compression of brain matter during the process of transfer to the biopsy jar can induce morphological changes. This assessment can impact the variables on the ultimate confirmation is essential [8].

Utilizing sophisticated ultrasonic surgical aspirators represents a significant advancement in neurosurgery, particularly in brain and spinal cord tumor resection. These instruments employ high-frequency sound waves to target and remove tumor tissue while minimizing damage to nearby neurovascular structures, thus improving patient safety and surgical outcomes.

The investigation into the use of ultrasonic surgical aspirators for treating central nervous system tumors is driven by several key factors. By utilizing tissue-selective ultrasonic aspirators, neurosurgeons can target and excise tumors while minimizing harm to surrounding neurovascular structure, minimally invasive approach enhances patient safety, reducing the risk and complications and shortening the duration of surgical procedures.

METHODOLOGY

The study, conducted at the Department of Neurosurgery, Liaquat University of Medical and Health Sciences, Jamshoro, involved 64 patients admitted between May 2019 and September 2023 with brain lesions. This prospective study obtained approval from the university's ethical department IRB # LUMHS/REC/256, with patients providing consent. Exclusions encompassed patients with advanced cardio-pulmonary insufficiency, those ineligible for anesthesia, and individuals with inoperable brain or spinal cord tumors.

The investigation centered on operation duration, post-operation vascular pathology presence, ultrasonic aspirator usage during tumor resection, and potential operation duration changes and surrounding tissue damage, particularly relevant to patients with comparable histopathology.

Patient selection was consistent across the study, regardless of age and sex, ensuring uniformity in categorizing individuals with and without Surgical Ultrasonic Aspirator. The investigation or the variables noted covered operation duration, post-operation vascular pathology, ultrasonic aspirator usage during tumor resection, and potential changes in operation duration alongside tissue damage in patients with comparable histopathology. This approach facilitated a comprehensive exploration of factors relevant to surgical outcomes, providing insights into the impact of Surgical Ultrasonic Aspirators and related variables on patient care and recovery.

A standardized policy guided the neurosurgical team's application of a Surgical Ultrasonic Aspirator, utilizing it for intra-axial tumor decompression, regardless of operative impressions, for both high-grade and low-grade tumors. Additionally, Surgical Ultrasonic Aspirator played a critical role in decompressing various extra-axial tumors, employing a combined approach for tumors like vestibular schwannoma and meningioma.

STATISTICAL ANALYSIS

In the study, the statistical analysis was tailored to match the characteristics of the data. The t-test was employed to compare outcomes between groups with and without an ultrasonic aspirator, ideal for normally distributed data as it provides a clear comparison of means. Conversely, the Mann-Whitney U test was utilized for data that did not conform to the normal distribution, offering reliable comparisons even without the typical bell curve. Descriptive statistics, presented as mean ± standard deviation, succinctly captured the central tendency and spread of the data, facilitating easy interpretation. Categorical data, such as gender, underwent scrutiny via the Chi-square test, enabling assessment of associations or differences in proportions between groups and uncovering potential relationships. Throughout these analyses, a standard threshold for statistical significance of $p < 0.05$ was applied, ensuring a rigorous evaluation of results. Lastly, SPSS v.24.0 was the chosen tool for conducting this analysis.

RESULTS

In our study, a total of 64 patients participated, comprising 38 (59.3%) males and 26 (40.6%) females, were between 16 to 61 years (mean 51.6±14.2) was age range. Among them, 32 patients underwent treatment with a Surgical Ultrasonic Aspirator, while conventional methods were employed for the remaining 32 patients. For those treated with the Surgical Ultrasonic Aspirator, aged between 16 to 57 years with a mean age of 48.7±16.6 years age range, while for those not treated with it, ages between 30 to 61 years, the mean was 51.1±10.4 years. In the Surgical Ultrasonic Aspirator group, we had 19 (59.37%) males and 13 (40.62%) females, while in the non-surgical ultrasonic aspirator group, there were 22 (68.75%) males and 8 (31.25%) females. No statistically marked changes were observed among the groups with age ($p=0.087$) or sex ($p=0.6539$).

Table 1: Variables used in the study.

	With Ultrasonic Surgical Aspirator	Without Ultrasonic Surgical Aspirator	p-value
Age	48.7±16.6 years	51.1±10.4 years	0.091
Operation time			
Average duration	210± 170 minutes	160±140 minutes	0.014

SD: Standard Deviation, Ultrasonic Surgical Aspirator
Among 32 patients, 15 were glioma, 7 were meningioma and 2 were metastasis.

Comparing operative times between the two groups, the average surgery duration in the Surgical Ultrasonic Aspirator group was 210 minutes (ranging from 90 to 260 minutes), whereas, in the non-surgical ultrasonic aspirator group, the median operation time was 160 minutes (ranging from 110 to 170 minutes). The average surgical duration was prolonged in the Surgical Ultrasonic Aspirator group (p=0.014), as indicated in Table **1**.

DISCUSSION

Glioma

In our recent procedures, we tackled fifteen patient cases presenting with gliomas, employing the Surgical Ultrasonic Aspirator technique for suctioning. Among these cases, we encountered a diverse array of glioma types: 7 high-grade gliomas, 4 astrocytomas, 3 oligodendrogliomas, and 1 pilocytic astrocytoma. Interestingly, our examination revealed that features such as calcification were discernible in the specimens obtained through the Surgical Ultrasonic Aspirator.

One notable observation was that the material of the tumor was notable in both the conventional sections. However, we did encounter a challenge with Surgical Ultrasonic Aspirator specimens, particularly regarding diagnosing the grade, especially when the lesion was extracted from the peripheral regions. This was a contrast to the conventional sections, which preserved these peripheral features more effectively. Moreover, we noted artefactual hemorrhage, necrosis, and fibrinous debris in the Surgical Ultrasonic Aspirator specimens, which posed a challenge to interpretation. These artifacts sometimes interfered with our ability to accurately assess the samples. Despite these challenges, when immunohistochemistry was performed, the results from the Surgical Ultrasonic Aspirator tissue were consistently optimal, showcasing the potential benefits of this technique in certain contexts.

Meningioma

In our recent cases involving brain meningiomas, we encountered a total of seven instances. Among these, four were classified as grade 2 meningiomas, while the remaining three were identified as atypical meningiomas. One particularly noteworthy case involved a rhabdoid meningioma, which was successfully diagnosed using both the Surgical Ultrasonic Aspirator technique and conventional biopsy sections.

However, we did face challenges with the accuracy of grading when relying solely on Surgical Ultrasonic Aspirator specimens. Specifically, we found it difficult to identify certain histological features such as mitotic activity or “patterns like sheets” in the samples obtained through the Surgical Ultrasonic Aspirator. This limitation underscored the importance of combining various diagnostic methods to ensure comprehensive and accurate assessments of meningioma cases. Despite these challenges, the ability to diagnose rhabdoid meningioma using a Surgical Ultrasonic Aspirator based on histopathology highlights the potential utility of this technique in certain instances.

Metastasis

In our recent cases, we encountered two instances of metastatic tumors that were successfully diagnosed using a Surgical Ultrasonic Aspirator. Upon examination, we observed tumor cells arranged in nests, showcasing a range of morphologies from round to polygonal shapes, accompanied by noticeable pleomorphism. Furthermore, the presence of mitotic activity provided additional evidence for the malignant nature of these tumors.

However, despite these findings, subtyping proved to be challenging with the Ultrasonic Surgical Aspirator specimens. While the general characteristics of the tumors were apparent, distinguishing between specific subtypes was not as straightforward. This highlights the limitation of relying solely on an Ultrasonic Surgical Aspirator for detailed tumor classification and underscores the importance of integrating multiple diagnostic techniques to achieve a comprehensive understanding of metastatic tumors.

Using ultrasonic aspiration for tissue improvisation in resected tumors indeed appears to be helpful in diagnostic accuracy based on histopathological analysis. In the contemporary landscape of neurosurgery, this technique can not only enhance safety but also improve diagnostic precision, marking a significant advancement in tumor resection procedures [9-11].

In one of the studies, the peripheral area, characterized by protein classes in the A− tumor and labeled the “healthy zone”, raises the possibility of tumor infiltration within the ostensibly healthy region, which surgery fluorescence fails to detect. This insight suggests a future avenue: utilizing single-cell proteomics as the optimal approach to validate and precisely locate tumor cell infiltration within the brain parenchyma [12].

Ultrasonic Surgical Aspirator fluid holds promise as a biological matrix for molecular characterization studies, revealing distinct molecular profiles in glioblastoma states and tumor zones. Shared protein elements suggest pathology beyond fluorescence-positive areas, supporting the cancer’s invasive nature. Newly diagnosed and recurrent glioblastoma display unique molecular features, indicating CUSA fluid’s potential as a biomarker source. However, validation through

individual specimen screening and comprehensive clinical exploration is needed [13].

In another study by Cadwell CR *et al.*, 54% of slides, each brain tumor specimen was resected using, a high-tech tool akin to a magnifying glass for surgeons. In this case, however, there's a twist. Despite the advanced digital imaging technology employed, there's a glaring loss of fidelity. Think of it as a puzzle with missing pieces, leaving gaps in the picture. Most of these missing fragments are tiny, smaller than a pinhead, hardly noticeable at first glance [14].

Subcortical stimulation utilizing an electrified Ultrasonic Surgical Aspirator during the resection of supratentorial lesions in children holds promise, yet its sensitivity, specificity, and overall efficacy necessitate further scrutiny in forthcoming studies [15].

The ultrasonic surgical aspiration apparatus requires careful handling to prevent damage to elastic structures such as blood vessels during operation, ensuring a wide operating field is crucial to mitigate the transmission of Surgical Ultrasonic Aspirator vibration to neighboring tissues. The study also states that a surgical Ultrasonic Aspirator, may not act as a good tool for biopsy [16].

Cavitron Ultrasonic Surgical Aspirator provides a means to obtain cell suspensions directly from the tumor site, offering a unique window into the tumor's composition. These specimens undergo meticulous analysis employing both flow cytometry and mass cytometry methodologies [17].

In the quest to understand glioma heterogeneity and explore high-grade glioma (HGG) markers, studies adopted a novel approach. Using a Surgical Ultrasonic Aspirator, extracted tissue with the potential to unravel glioma biology mysteries. This technique targets the tumor-healthy tissue interface, rich in migrating and proliferating cells, offering insight into the disease's dynamics. After extraction, the tissue undergoes meticulous processing. It's gently suspended in a specialized physiological electrolyte solution, acting as a protective barrier amidst biological complexities. This solution maintains cellular balance, shielding against oxidative stress and preserving their integrity for analysis. With this innovative method, we are poised to dissect glioma biology precisely, unveiling its heterogeneous nature and decoding HGG markers with unprecedented clarity [18].

The unique characteristics of brain tumors resected with Ultrasonic Surgical Aspirator necessitate their inclusion to ensure comprehensive validation of digital pathology systems. Such tumors may exhibit distinct histological features and tissue morphology compared to those resected using other surgical tools. Therefore, omitting or including these specimens in low numbers could compromise the accuracy and reliability of digital pathology algorithms designed to analyze brain tumor samples.

Moreover, the incorporation of brain tumor specimens resected with an Ultrasonic Surgical Aspirator can facilitate the development of tailored algorithms capable of accurately identifying and characterizing tissue structures specific to these samples. By including a diverse range of specimens in validation studies, researchers can enhance the robustness and generalizability of digital pathology systems, ultimately improving their diagnostic performance in clinical settings [19-21].

CONCLUSION

Histopathological examination of ultrasonic aspirator samples, compared to conventional samples, can enhance diagnostic accuracy. In glial tumors, the diagnostic utility of these samples may be similar to conventional samples; however, for accurate grading and characterization, evaluating both types of samples is essential. Technologies such as digital histopathology and molecular analysis are gradually improving diagnostic precision. With these advancements, it is crucial to have the complete operative specimen available for analysis, as these methods enable rapid processing and detailed examination.

ETHICAL APPROVAL

This prospective study obtained approval from the university's ethical department (IRB # LUMHS/REC/256). All procedures performed in studies involving human participants were following the ethical standards of the institutional and/ or national research committee and with the Helsinki Declaration.

CONSENT FOR PUBLICATION

Consent was obtained by all patients/participants in this study.

AVAILABILITY OF DATA

Not applicable.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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AUTHORS' CONTRIBUTION

All authors contributed equally.

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