Gac Méd Caracas 2023;131(4):886-898
DOI: 10.47307/GMC.2023.131.4.11

Imaging and Pathological Features and Recurrence Causes of Cystic Meningioma

Imágenes y Características Patológicas y Causas de Recurrencia del Meningioma Quístico

Jiang Long[1*]

SUMMARY

Objective: *This study aims to establish preoperative imaging features, establish how they are correlating with post-operative pathological features, and discover the causes of recurrence.* **Results:** *Data on imaging procedures in the preoperative period, records of surgical operations, and reports from pathology conclusions were collected. Among 623 patients who were undergoing neurosurgery resection of intracranial meningioma, 24 cases of cystic meningioma were identified, corresponding to a world incidence of 3.8 %. The hemispheric convexity was the most frequent place of localization. The apparent diffusional coefficient was significantly lower in grade 2 and grade 3 tumors if compared to grade 1. Full resection of the cystic component was possible in 18/24 cases. Partial resection in 3/24 cases. In 2/24 cases, it was not possible to make total or partial resection, but multiple biopsies were performed from the cystic walls.* **Conclusion:** *Conclusion of the pathology examination of cells found neoplastic findings within the cyst's wall in 66.6 %. All patients were followed up for 24 months. Some of them were followed up for a long-term period. The long-term period was an average of 49 months (range 36-96 months). Cases of recurrences that needed surgery were not observed.*

Keywords: *Tumor, MRI, neurosurgery, histopathology, radiology.*

RESUMEN

Objetivo: *El objetivo de este estudio es establecer las características de las imágenes preoperatorias, establecer cómo se correlacionan con las características patológicas postoperatorias y descubrir las causas de la recurrencia.* **Resultados:** *Se recogieron datos de procedimientos de imagen en el período preoperatorio, registro de operaciones quirúrgicas e informes de conclusión de patología. Entre 623 pacientes que fueron sometidos a resección neuroquirúrgica de meningioma intracraneal, se identificaron 24 casos de meningioma quístico, lo que corresponde a una incidencia mundial del 3.8 %. La convexidad hemisférica fue el lugar de localización más frecuente. El coeficiente de difusión aparente fue significativamente menor en los tumores de grado 2 y grado 3 en comparación con el grado 1. La resección completa del componente quístico fue posible en 18/24 casos. Resección parcial en 3/24 casos. En 2/24 casos no fue posible realizar una resección total o parcial, pero se realizaron múltiples biopsias de las paredes quísticas.* **Conclusión:** *Al concluir el examen anatomopatológico de las células se encontró hallazgo neoplásico dentro de la pared de los quistes en el 66.6 %. Todos los pacientes fueron*

DOI: https://doi.org/10.47307/GMC.2023.131.4.11

ORCID: 0000-0003-1191-7079[1]

Romodanov Neurosurgery Institute of the National Academy of Medical Sciences of Ukraine, Ukraine, Kyiv 04050.
*Corresponding Author: Jiang Long, E-mail: lo.jiang45@gmail.com

Recibido: 21 de julio 2023
Aceptado: 12 de septiembre 2023

seguidos durante 24 meses. Algunos de ellos fueron seguidos durante un período prolongado. El período a largo plazo fue un promedio de 49 meses (rango 36-96 meses). No se observaron casos de recurrencias que necesitaran cirugía.

Palabras clave: *Tumor, resonancia magnética, neurocirugía, histopatología, radiología.*

INTRODUCTION

In the structure of all central nervous system tumors, meningioma is the most common case. The last research showed that 37.6 % of all central nervous system tumors consist of meningiomas and benign are about 50 % of them (1). Meningioma grows from the meningeal layers of the brain and spinal cord. Cystic meningioma represents the same meningioma that arises from the meningeal layer, but it has intra-tumoral or peritumoral cysts. It is quite a rare type of meningioma and comprises about 5.5 % of all meningiomas (2). The problem of cystic meningioma is the complexity of its differential diagnosis with other intra-axial glial or metastatic tumors. In fact, the clear understanding that results of the imaging show cystic meningioma has crucial decisions on tactics of surgical treatment. Usually, meningioma is diagnosed through its imaging features like well-circumscribed form, extra-axial localizations, adjacent to the dura and marked, homogeneously enhancing after intravenous contrast injection on computed tomography (CT) and magnetic resonance imaging (MRI) (3). The vast majority of meningiomas consist of solid, high cellular structures with good vascular supply, but in some cases, meningiomas may consist of (partly or most of its structure) cysts, which make their differentiation from other diagnosis and their definition with further management very difficult.

Most meningiomas' histological profiles are benign, but some of them can have malignant profiles. Salami et al. (4) to the World Health Organization (WHO) classification considered that cystic meningiomas have the same histological image as solid tumors. Preoperative diagnosis is challenging, and usually, the final diagnosis is established only after the histology of the tumor specimen. Zhao et al. (5) reported a case of valuable imaging evidence for the localizations and classifications of cystic meningiomas. The definition of cystic meningioma is associated with meningiomas macroscopical cysts. These macroscopical cysts can be described as intra-tumoral degenerative cysts, reactive intraparenchymal cysts, or peritumoral arachnoid cysts (6,7).

Researchers have no consensus about the nature of these cysts. Buerki et al. (1) consider that peritumoral cysts can originate from loculated widened subarachnoid spaces, surrounding edema, demyelination, or hemorrhage. Yamada et al. (8) think that intra-tumoral cysts can form as the result of active production of secret from tumor cells.

The gold standard for symptomatic meningioma management is surgery, even for cystic meningiomas and usually under general anesthesia. However, a few years ago, in the journal "Interdisciplinary Neurosurgery" Okunlola et al. (9) published an article about awake craniotomy and considered that it has its advantages to avoid future language or movement deficits. Because radiological appearance is mostly unusual – a tactic of surgery is based on the possibility of distinguishing cysts with gliomas, hemangiopericytomas, metastatic brain tumors as well as other focal cystic lesions of the brain.

Besides the complications in establishing the diagnosis, there are other questions still unsolved including the origins of associated cysts which are debated, the ideal surgical extent of resection weighing recurrence risk versus neurological function, the role of emerging tools like fluorescence for total removal, strategies for unusual cases like pineal cystic meningiomas, the need to correlate recurrence rates with tumor grade to refine prognosis and follow-up, and building consensus on whether total cyst wall resection is mandatory when tumor cells are absent or if partial excision is sufficient in some scenarios. The importance of removing the cystic wall underpins the risk reduction of recurrence. This research aims to create a single-institution retrospective cohort study of surgically treated meningioma patients between 2015 and 2021 to determine imaging and pathological features of cystic meningiomas and establish causes of recurrence.

The article argues that complete surgical resection of all components of cystic meningiomas, including the cyst walls, is critical to reducing the risk of tumor recurrence. This study provides useful clinical details on the imaging features, surgical approaches, pathological findings, and recurrence rates of cystic meningiomas, expanding knowledge that can directly improve diagnosis, treatment planning, surgical techniques to reduce recurrence risk, prognostic awareness, and management of patients with this subtype of meningioma. The data has clear practical applicability for surgeons, radiologists, and pathologists who diagnose and treat cystic meningiomas by elucidating best practices for achieving total resection and analyzing rates of neoplastic cyst wall involvement to guide biopsy and recurrence prevention when complete excision is not feasible.

MATERIALS AND METHODS

The research includes information about all patients with cystic meningioma, which were evaluated and managed over 6 years in local neurosurgical centers. The study included 24 cases of cystic meningioma, which were diagnosed among 623 surgeries for intracranial meningioma. It is corresponding to a world incidence of 3.8 % (2). CT and MRI were done in all cases before neurosurgical operations. CTs were conducted on a 64-slice multi-detector row computer tomography scan. For MRI, Siemens Symphony 1.5T was used, to complete the institutional protocol for visualizations of brain tumors: axial fluid-attenuated-inversion recovery (FLAIR); axial and sagittal T1; axial T2 Gradient-Echo; susceptibility-weighted images (SWI) after injection of intravenous contrast T1 sequence.

Surgical treatment was performed standard centered craniotomy on the place of localization of meningioma and next dissection of tumor and excision. In all operations performed, complete resection of cystic components, and remnants of the wall and dural tails were observed. If any of these components could not be removed, multiple biopsies from different sites were taken. Excision of meningioma was performed through standard microsurgical fashion. Depending on tumor consistency, location, and vascular net, was performed first debulking after suction, sharp excision, coagulation, or ultrasonic aspiration. After this, the separation of meningioma from the brain parenchyma along the arachnoid layer was conducted, and the same manipulations were done for the structures of cysts. To avoid the injury of vascular structures and successful preservation and dissection of all veins and perforator arteries, rigorous microsurgical dissection along this separated arachnoid plane was used.

In addition, patients, who were classified as third-grade meningiomas at pathological examination, were referred for postoperative radiotherapy. All dissected tumor components, including cystic walls and dural tail, were analyzed on the presence of neoplastic cells inside the cystic walls. Results of histological analysis were categorized, depending on the histological features of meningioma to the WHO classifications (Table 1).

Table 1

World Health Organization Meningioma Classifications

WHO Grade I Benign	WHO Grade II Atypical	WHO Grade III Malignant
Meningiothelial	Chordoid	Papillary
Fibrous (fibroblastic)	Clear Cell	Rhabdoid
Transitional (mixed)	Atypical	Anaplastic
Psammomatous		
Angiomatous		
Secretory		
Lymphoplasmacyte-rich		
Metaplastic		

Source: Ostrom et al. (1).

Grade 1 meningiomas are benign and account for 80 %-90 % of cases. They exhibit compact architecture and uniform nuclei with inconspicuous nucleoli. Grade 2 or atypical meningiomas demonstrate increased mitotic activity, patternless architecture, and nuclear atypia. Grade 3 or anaplastic meningiomas are malignant with overt anaplasia, high mitotic rate, spontaneous necrosis, and poor differentiation resembling carcinoma, melanoma, or high-grade sarcoma. Higher-grade lesions tend to be more aggressive and carry worse prognoses (1).

According to the Nauta classification, intracranial cystic meningiomas can be classified into four types (10). The Nauta classification categorizes cystic meningiomas based on their histopathological characteristics and the relationship between the cyst and the tumor. There are four recognized types: Type I, where the cyst is located outside the meningioma; Type II, in which the cyst is present within the tumor itself; Type III, characterized by a mixed pattern with both intratumoral and peritumoral cysts; and Type IV, where the meningioma itself arises from the wall of a pre-existing cyst, often described as a cystic degeneration within the tumor. Cystic meningiomas of A type contain cerebral spinal fluid and divide into A1 and A2, depending on their locations. Type B is characterized by cystic meningioma with xanthochromia fluid and divides into B1 and B2, depending on its locations. Meningioma in type C has yellow or dark fluid intratumurally. Type D contains clear fluid in peritumoral cysts, extratumoral cysts, and intratumoral cysts.

RESULTS

Research is based on the results of the treatment of 623 patients, who went through the neurosurgical operation, and in the postoperative period, on histological examination, meningioma was diagnosed. Among these 623 patients, 24 had cystic meningioma, which is related to the world incidence (3.8 %). A predominance of women (18 *vs*. 6) was noted.

The observed predominance of women over men in the case of cystic meningiomas aligns with general epidemiological trends seen with meningiomas. Multiple studies have pointed towards hormonal factors as a potential explanation (7,8). Estrogen and progesterone receptors are frequently found in meningioma cells, suggesting that these tumors might be influenced by sex hormones. The presence of these receptors, especially progesterone, could potentially drive a higher incidence in women. Additionally, fluctuations in hormone levels during events like menstruation, pregnancy, and menopause can influence tumor growth. Nevertheless, men tend to experience a more aggressive progression of the disease, with a higher likelihood of tumor recurrence post-surgery. This is contrasted with women, who frequently have a milder course and a more favorable prognosis, largely attributed to hormonal influences, particularly the protective role of progesterone. Furthermore, women often present with larger cystic components within tumors than men, yet despite the size, they often respond better to treatment (10).

The average age was 48.4 years. Symptoms included: headache (21/24 - 87.5 %), focal or/and progressive neurological deficit (16/24 - 66.6 %), dizziness (12/24 - 50 %), seizures (9/24 - 37.5 %), depression syndrome (4/24 - 16.6 %). The empiric diagnostic of cystic meningioma by preoperative imaging was only in half of the cases (12/12 – 50 %). The tumor location is described in Table 2.

Table 2

Location of Tumor

Tumor localization	Total
Frontoparietal convexity	6
Temporo-occipital convexity	2
Parasagittal and falx cerebri	6
Olfactory groove	4
Sphenoid ridge	1
Petrous ridge and Petro clival	5
Total	24

Source: the material based on results of MRI.

The medium size of cystic meningioma was about 43 mm (From 32 – 104 mm). Solid portion hypointense was observed in 11 cases of the T1 sequence. In 13 cases, iso-intense appeared. In one case, scattered hyper-intensities were observed, which were confirmed as intra-tumoral hemorrhagic components on T2 and SWI sequences.

FLAIR showed hyper-intensity components with solid structure in 14 cases. In 6 patients, FLAIR showed iso-intensity and hypo-intensity in 4 cases. Dural sinus invasion was present on post-contrast in 3 cases, and there were no signs of infarction. Diffusion-weighted image (DWI) was performed in 16 cases. DWI showed high signal intensity if compared with the adjacent parenchyma in 9 of 16 cases. The apparent diffusion coefficient was present only in 2/16 cases of grade 1 tumors in comparison with 7/7 grades 2-3. The average apparent diffusion coefficient value was much lower in grade 2 and 3 lesion zones.

Cystic component on T1, FLAIR, and DWI was hypointense, but only 2 cases with FLAIR had isosignal. In one case, a hemorrhagic component out of the tumor tissue was present. Multi-cystic mass was present in half of the meningiomas (12/24). More than two same cysts were found in 8 cases, and in 4 cases, different cyst types for the same type of meningioma were present. Enhancement of cyst wall observed in all types of cysts: 1, 2, and 3, and only in 4 grade of meningioma enhancement of cyst wall was absent. In one case, clear thickening of wall enhancement was observed (Figure 1). Post-contrast T1 sequence shows midline tumor of large size with mass effect around. Intense homogeneous enhancement is shown by the component with a solid structure and the thick wall of large cysts on the periphery. On the FLAIR sequence, marked edema in the surroundings and mass effect was observed. Low-intensity area reveals in susceptibility weighted sequence in relation with hemorrhagic foci inside solid tumor component.

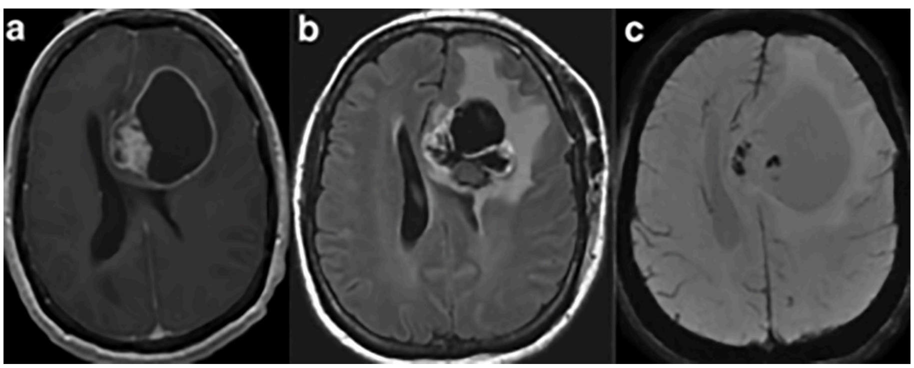

Figure 1. Cystic Meningioma of Falx Cerebri (Grade 3 According to WHO Classification): a) T1; b) FLAIR; c) Susceptibility Weighted Sequence Revealing.

The large size of cysts (more than 30 mm) was found in 6/24 cases with an average size of about 70 mm (range 32-128). In most cases (4/6) localization of such large cysts was on the convexity of hemispheres. In three of these six cases, large cysts contained structures of septum. In one case, an enhanced area inside the solid portion of the mural nodule of a large cyst was present (Figure 2). This meningioma can be characterized as 1 grade according to the WHO classification. On frontal convexity, there is a large cystic mass with a mural nodule of a small size. On T1 and T2 sequences, it is isointense compared with the cortex. The cystic component is the same by its signal intensity to the cerebrospinal fluid. Post-contrast MRI shows mild and homogeneous enhancement of mural nodule. Also observed was no enhancement of cystic wall and cystic content.

Edema of vasogenic mechanism in nearby brain tissue was observed in 15/24 cases. In five cases, edema around peripheral cysts of a big size was observed. Vascular entrapment was observed in 6 cases. In these patients, big-size peripheral cysts with lobulated components were found.

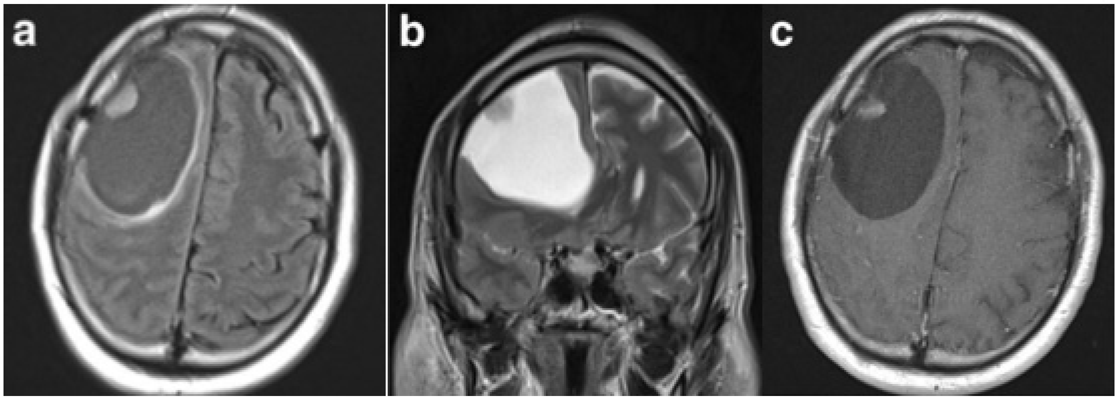

Figure 2. Picture of a Cystic Mural Nodule Inside Meningothelial-Microcystic Meningioma (Grade 1, According to WHO Classification).

Lobulated structures consisted of septum-like findings (Figure 3). Inside the peripheral cyst, structures of vascular nature were present, which were observed on axial and coronal planes during the T1 post-contrast sequence. The tail of the dural layer was also noted. In the structure of the solid component, a lot of small cysts were observed. The conclusion of radiological examinations assumes microcystic meningioma. The conclusion of pathology examinations classified this finding as meningothelial meningioma.

Calcifications of the tumor were present in 3/24 cases on CT. Hyperostosis of bone was observed in 18/24 lesions (all of them were located on convexity), including a patient with diagnosed meningioma, which was located intraosseous outside the dural layer. Full surgical resection of meningioma and structure components of the cysts was potentially possible in 18/24 cases. Partial resection was done in 3/24 patients.

In 2/24 of the patients, it was not possible to make total or partial resections, but multiple biopsies from cystic walls were done. In one case, during the surgery, it was not possible to identify the cyst wall. After comparing the imaging aspects of the microcystic meningothelial forms, it was considered that the edema was more marked in the pure meningothelial form. Changes in the microcystic types of meningiomas were observed in a single case (Figure 3).

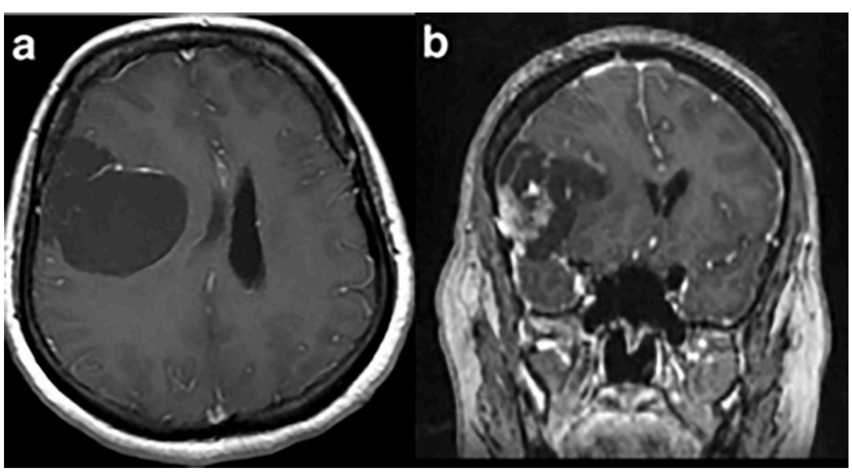

Figure 3. Meningothelial Meningioma with Peripheral Cysts and Septum-Like Components Inside.

Some of the most common and challenging surgical complications that can occur with resection of cystic meningiomas include:

- Bleeding - These tumors are often highly vascular with abnormal fragile vessels. Hemorrhage during surgery can be difficult to control.
- Cyst rupture - Accidental intraoperative rupture of the cyst capsule can lead to leakage of fluid and dissemination of tumor cells.
- Cranial nerve deficits - Cystic meningiomas near the skull base put cranial nerves at risk during dissection. This can cause postoperative neuropathies.
- Brain edema - Disrupting cyst architecture and fluid balances can exacerbate vasogenic cerebral edema. This may require urgent management.
- Infection - Cyst contents may become contaminated leading to meningitis, encephalitis, abscess, or wound infection postoperatively.
- Seizures - Cystic meningiomas have high epileptogenic potential that can cause seizures, especially with subtotal resection.
- Residual tumor - Partial or incomplete resection leaves behind tumor tissue likely to recur. Extensive invasion can prevent total removal.
- Recurrence - Even with apparent total excision, cystic meningiomas have higher recurrence rates likely due to occult spread.

Careful presurgical planning, meticulous dissection techniques preserving neurovascular structures, watertight dural closure, antibiotics, anticonvulsants, corticosteroids, and close postoperative monitoring can help minimize risks and complications following cystic meningioma surgery.

Vascular entrapment was diagnosed intraoperatively in 7 cases. Three patients had small arterial branches adherent to the cyst's wall. In one case, between the cystic part of the tumor and the solid part of the tumor, the vessel was stuck. In two cases, the opercular branch of the middle cerebral artery which was going through the cyst and arriving in contact with the brain parenchyma was observed.

The pathological finding was summarized according to WHO classification. Grade 2 and 3 meningiomas were diagnosed in 7/24 cases. The angiomatous variant was present in one patient, and they had had radiotherapy for facial angioma 50 years before. Inside the cyst's wall, neoplastic cells in 9/24 cases were identified. Also in three cases, meningotheliomatous cells were present. In this research, all patients' post-operative follow-ups for 36 months were done. The postoperative follow-up period of a long term was conducted in 14/24 patients for 52 months on average. Recurrence of the tumor, which requires surgery, was not observed. Three patients with grade 3 meningioma at pathology: one of them was lately diagnosed with meningeal dissemination, which resulted in hydrocephalus, and another two with papillary meningioma that disappeared.

In this research, one case of unusual location was presented. Meningioma was located in the pineal region (Figure 4). The pineal region presented a tumor, which consisted of a structure of a solid par and structure with a cystic component. This tumor is isotone compared with the cortex on the T1 sequence in the median sagittal. This tumor compresses the superior colliculi. If compared with a cerebrospinal fluid component of this cyst, it isointense on FLAIR and T2 spin-echo. The solid part of this tumor showed hyperintensity on T2 spin-echo and FLAIR and diffusion. The solid component of the structure was smaller than the cyst part. On T1 sequences in sagittal and axial projection was observed round mass lesion and quadrigeminal hollow structure, which took up the contrast intense and homogeneous. Clear attachment to the dural layer was absent, and the was no enhancement of the cyst wall. Identification of the pineal gland was not possible.

Tumoral cysts in the context of previous malignant breast carcinoma made it hard to distinguish from the raising the suspicion of metastasis. Tumor volume gradually increased over 4 years and then was made neurosurgical operation for tumor resection. After that, pathology examinations of the resected samples and a conclusion were established.

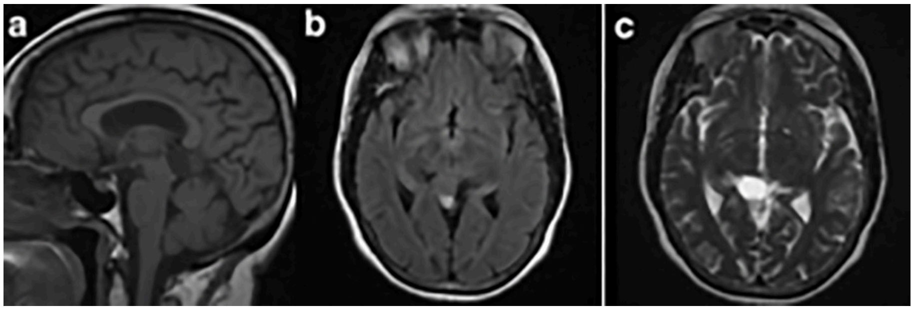

Figure 4. Meningothelial Cystic Meningioma of the Pineal Region

From 1 % to 4 % of all intracranial tumors consist of neoplasms, which grow from the region of the pineal gland. Among them, meningiomas account for about 6-8 % (11). Most reported diagnoses are benign nature meningiomas, and the two predominant histological patterns are fibrous and meningothelial. In this research, meningioma is considered to be of meningothelial type.

The typical localization of meningiomas that are aroused from the pineal gland is a falcotentorial junction in the area of the velum interpostium or zone of the arachnoid envelope of the pineal gland. In some cases, they can arise from the arachnoid envelope of the pineal gland. In this research, pineal meningioma is aroused from the pineal gland. Multiplane rebuilding of 3D postcontrast T1 image can be helpful in imaging the ration with Galen vein and attachment with falcotentoria. The cystic nature of the meningiomas no one can consider, except Li et al. (12). In that research, a database of 10 papillary meningiomas was contacted. One of these cases was the multiple cysts, which were located intra-tumoral and in the pineal region.

In this research, features of neoplastic nature in the structure of the cyst wall in 66.6 % of cases were observed (Figure 5). Due to this information, the surgical strategy was changed. It was adapted to full resection whenever it was technically possible. The technically impossible situation when performing total resection of all cystic meningioma components occurred when a suspected risk was to damage both critical structures, functional nervous area, and vascular structures of nerves.

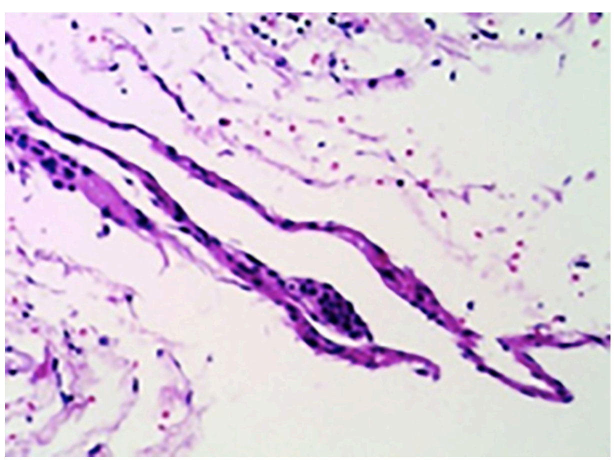

Figure 5. Wall of Cystic Component Containing Meningioma Cells. Pathology with Hematoxylin and Eosin, Magnification X200.

Recurrence in time of average following up (ratio, 36-96 month) were not observed. Special attention was paid to the segments with contrast enhancement on the image in the preoperative period. If after neurosurgical manipulations surgical remnants were still observed, (4/24 – 16.6 %) multiple biopsies of the remaining cystic wall were performed. Examination of experiences if this research concluded that full removal of meningioma with its cystic structures is primary to make recurrence rates lower.

DISCUSSION

In the past few years, the use of the new fluorescent agent 5-aminolevulinic acid (5-ALA) has shown promising results in meningioma surgery, especially in cases of bone infiltration, skull base localization, and atypical meningiomas (13). The use of 5-aminolevulinic acid (5-ALA) fluorescence imaging presents a significant advancement in treating cystic meningiomas. 5-ALA is a fluorescent dye that causes tumor cells to illuminate pink under specific light, improving the visualization of tumor margins during surgeries. This technology is particularly beneficial for cystic meningiomas, which often have indistinct boundaries and can resemble other lesions. By highlighting areas of tumor infiltration within the cyst wall, 5-ALA assists surgeons in more complete resections, potentially reducing recurrence. As this method continues to gain traction and with further refinements in fluorescence detection systems, it holds promise for optimizing the surgical removal of cystic meningiomas (13).

In this research, such a technology was not possible to be applied during the study period. Given that available clinical data has demonstrated the usefulness of 5-ALA fluorescence in identifying portions of infiltrated dura, it could potentially constitute a valuable tool for cystic meningioma surgery by providing direct visualization of infiltrated parts of the cystic wall in cases where complete cyst removal is not possible.

Cysts of intra- or peritumoral localizations remain uncommon features for meningiomas. The incidence of meningioma in worldwide populations from 2010 to 2014 is considered to be 8.3 per 100 000 people. In the next few years, the incidence tends to rise and in 2015 the incidence was 10.82 per 100 000 (14). The same situation of meningioma incidence increasing and reported in pediatric populations but here not identify any pediatric cases.

Conventional MRI sequences are not the best way to make differentiation between meningiomas grades and it is associated with numerous complications (15). In the past few years, a lot of attention has focused on DWI signals and apparent diffusion coefficient values (16). Most meningiomas have hyper-intensity in DWI, because of their densely cellular nature, and in the present research (19/24).

The benefits of ADC coefficients in predicting the grade of meningioma are controversial (17). Benign and aggressive meningiomas can be distinguished by using DWI with high b-values. Low ADC values can improve the possibility of distinguishing grade 2 and 3 meningiomas from angiomatous and microcystic meningiomas, which can mimic malignant meningiomas. The biggest and most recent research that was published showed that grade 1 meningiomas have significantly higher ADC values if compared with grade 2 and grade 3 (18). A similar result was shown in this research. It can be supposed that prognostic value in predicting of apparent diffusional coefficient may also apply to cystic meningioma.

In 5 of 24 cases, cystic components of large size were present. Most of these cases were found of convexity. Histological types of meningioma were microcystic 1/5, meningothelial 2/5, mixed meningothelial-microcystic 1/5, and 1/5 was malignant. This finding is in concordance with previous case reports (19-23). In 3/5 patients, imaging showed inside large cysts septum-like structures. Also, the entrapment of middle-cerebral artery branches was observed. It was possible to identify cortical venous structures inside large cysts (Figure 3).

Papillary, clear cell, and angiomatous are rare pathological types. In the present research, one case of each of those has been identified. Rare malignant variant is papillary meningiomas. Papillary meningiomas account from 1 % to 2.5 % of all intracranial meningiomas.

The characteristic difference of papillary meningiomas is the heterogeneous enhancement and uncertain margins, and in most cases can help to differentiate them from typical meningiomas. Moreover, cystic components are not infrequent. In the present research, a case with heterogeneous enhancement with irregular tumor margins and heterogeneous signal on T1 and T2, which was identified as multi-cystic skull base mass, was present.

Rare variant of grade 2 represented by clear cell meningiomas. Clear cell meningioma is most frequently located in the cerebellopontine angle. In most cases, it exhibits a cystic component and strong heterogeneous enhancement with edema around the tumor. The overall recurrence rate of clear cell meningiomas is about 50 %-60 % (24). Clear cell meningioma was observed and enhancement of multi-cystic mass in cerebrum palatine angle. Clear cell meningioma was also characterized by taking up contrast inside of cystic walls, but without edema around the lesion.

Angiomatous meningioma in this research was presented as a big size structure with multi-lobulated components with clear edema around the tumor and structures of a vascular nature around it.

The variation of meningiomas with micro cysts is supposed to be low dense on CT, to have low intensity on T1 and higher on T2 imaging, and imperceptible, homogeneous enhancement because of injecting the contrast. Numerous intra-tumoral micro cysts characterized by these features and attributes.

Edema around tumors in this subgroup was reported as a severe incidence (15). In the present research, the findings of microcystic meningiomas were different: edema was absent or with very low expressiveness in the majority (4/5).

One case in this research presented very unusual imaging with a pattern of reticular honeycomb, inhomogeneous, and weak contrast enhancement.

In 50 % of cases, purulent and mixed meningiomas with microcysts were identified, compared to only 24.5 % of remaining patients. Moreover, in 2 cases, mural nodules of small size within a large cyst, characterized as microcystic and mixed type were observed. In previous reports, the large cysts were more frequent despite the histological subtype (25).

Entrapment of structures with a vascular nature was observed in three cases inside large and with lobulated structure cysts periphery. Examinations of this case showed that mechanical blocking of cerebrospinal fluid spaces causes the cyst. This information helped to establish preoperatively whether the cystic part represents trapped cerebrospinal fluid (cysts of the arachnoid layer) or originates within the brain parenchyma (Nauta type 4 vs. type 3).

The incidence of cystic meningiomas in this cohort was 3.8 %, which is within the range of 1.6 %-10 % reported in other surgical series (26-28). This supports the rarity of these lesions relative to solid meningiomas. The hemispheric convexities were also a common localization in this and other studies (29), likely related to the prevalence of meningothelial subtype in convexity lesions which may predispose to cyst formation.

The pattern of lower ADC values differentiating higher-grade cystic meningiomas is well documented across multiple institutional datasets (30,31). The ability of advanced imaging to predict WHO grade in cystic and solid meningiomas alike underscores its value for preoperative planning.

While the 66.6 % rate of cyst wall tumor invasion was higher than some reports of up to 50 % (32), other authors have also observed invasion in over 60 % of specimens (33-35). This may relate to sampling techniques. The lack of recurrence with predominant gross total resection mirrors the general finding that cystic meningiomas likely require complete excision to minimize regrowth (36-39).

Today, the main problem of cystic meningioma surgery is the issue of excision of cystic wall components. It happens because neoplastic cells may be present at infiltrations inside the cyst wall. Such a situation will increase the risk of recurrent cystic meningioma or may cause it is spread through CSF (40). Theoretically, high recurrence risk is attributed to subtotal resection of cystic walls containing neoplastic cells (41,42). On the other hand, the identification of tumoral cells in the wall of the cysts in another research (43) suggested that total resection is not obligatory if cysts are performed only by reactive proliferation with gliotic or fibrous tissue (44,45). Today, there is no consensus on whether complete removal is necessary.

CONCLUSION

This retrospective case series of 24 cystic meningiomas identified an incidence of 3.8 % among 623 intracranial meningiomas resected, consistent with prior data, and demonstrated a hemispheric convexity tumor localization in 25 % of cases. Apparent diffusion coefficient values were significantly lower in WHO grade 2 and 3 compared to grade 1 lesions. Complete cystic component resection was achieved in 75 % of cases, with partial resection in 12.5 % and biopsy alone in 8.3 %. Importantly, neoplastic cyst wall invasion was confirmed histologically in 66.6 % of cases. No recurrences requiring re-resection were observed over an average 49-month follow-up. Given the high rate of tumor cell invasion into the cyst walls, maximal safe surgical resection of all cystic components is recommended when anatomically and functionally feasible to minimize recurrence risk based on this study, which provides evidence supporting aggressive excision of cystic elements when plausible given lack of recurrence with predominant total resection.

Pre-operative diagnosis of meningioma can be difficult to establish if the cystic component is present. Differential diagnosis of cystic meningioma is based on the presence of such lesions, which include localizations on the dura, the presence of the dural tail, and the presence of homogenous enhancement. To reduce the risk of cystic meningioma recurrence in future investigations need to be explored alternative surgical tactics for complete resections of tumor components when the a suspected risk of damage to critical structures and functional nervous areas. Further research directions include analysis of genetic, epigenetic, and protein profiles, which could help predict recurrence risk and guide individualized treatment. For cases where open total resection risks neurological deficits, less invasive techniques like endoscopic, radiosurgical, or cyst drainage approaches followed by radiotherapy should be evaluated in clinical trials. Standardized preoperative imaging protocols and machine learning applied to large databases may also advance diagnostic accuracy.

REFERENCES

1. Ostrom QT, Cioffi G, Gittleman H, Patil N, Waite K, Kruchko C, et al. Primary Brain and Other Central Nervous System Tumors Diagnosed in the United States in 2012-2016. Neuro-Oncol. 2019;21(5):1-100.
2. Buerki RA, Horbinski CM, Kruser T, Horowitz PM, James CD, Lukas RV. An overview of meningiomas. Future Oncol. 2018;14(21):2161-2177.
3. Chen TY, Lai PH, Ho JT, Wang JS, Chen WL, Pan HB, et al. Magnetic resonance imaging and diffusion-weighted images of cystic meningioma: Correlating with histopathology. Clinic Imag. 2004;28(1):9-10.
4. Salami AA, Okunlola AI, Ajani MA, Onakpoma F. WHO classification of meningiomas-a single institutional experience. Neurochirurgie. 2021;67(2):119-124.
5. Zhao H, Meng QL, Chen ZY. Atypical Cystic Meningioma: Report of One Case. Zhongguo. 2022;44(4):733-736.
6. Mittal A, Layton KF, Finn SS, Snipes GJ, Opatowsky MJ. Cystic meningioma: Unusual imaging appearance of a common intracranial tumor. Proceeding (Baylor University Medical Center). 2010; 23:429-431.
7. Garcia C, Slone S, Chau M, Neltner JH, Pittman T, Villano JL. Initial management of meningiomas: Analysis of the National Cancer Database. Cancer Epidem. 2019;60:16-22.
8. Yamada SM, Fujimoto Y, Kawanishi Y, Shimizu K. A cystic meningioma misdiagnosed as malignant glioma by radiologic and intraoperative histological examinations. Brain Tumor Pathol. 2010; 27:111-115.
9. Okunlola AI, Babalola OF, Okunlola CK, Akinmade A, Abiola P, Olayinka T. Awake craniotomy in neurosurgery: Shall we do it more often? Interdisciplinary Neurosurg. 2020;21:2-9.
10. Nauta HJ, Tucker WS, Horsey WJ, Bilbao JM, Gonsalves C. Xanthochromic cysts associated with meningioma. Neurology Neurosurge Psych. 1979;42:529-535.
11. Gendle C, Karthigeyan M, Salunke P. Pineal Region Meningioma in a Very Young Child. Pediatr Neurosurg. 2021;56(1):73-78.
12. Li B, Tao B, Bai H, Zhong J, Wu X, Shi J, et al. Papillary meningioma: An aggressive variant

meningioma with clinical features and treatment: a retrospective study of 10 cases. Int J Neurosci. 2015;26(10):878-887.

13. Foster N, Eljamel S. ALA- induced fluorescence image-guided surgery of meningiomas: A meta-analysis. Photodiagn Photodyn Ther. 2016;15:73-78.
14. Francis SS, Ostrom QT, Cote DJ, Smith TR, Claus E, Barnholtz-Sloan JS. The Epidemiology of Central Nervous System Tumors. Hematol Oncol Clin North Am. 2022;36(1):23-42.
15. Nowosielski M, Galldiks N, Iglseder S, Kickingereder P, von Deimling A, Bendszus M, et al. Diagnostic challenges in meningioma. Neuro Oncology. 2017;19(12):1588-1598.
16. Nagano H, Sakai K, Tazoe J, Yasuike M, Akazawa K, Yamada K. Whole-tumor histogram analysis of DWI and QSI for differentiating between meningioma and schwannoma: A pilot study. Radiology. 2019;37(10):694-700.
17, Xiaoai K, Qing Z, Lei H, Junlin, Z. Differentiating microcystic meningioma from atypical meningioma using diffusion-weighted imaging. Neuroradiology. 2020;62(5):601-607.
18. Surov A, Ginat DT, Sanverdi E, Lim CC, Hakyemez B, Yogi A, et al. Use of diffusion-weighted imaging in differentiating between malignant and benign meningiomas. A multicenter analysis. World Neurosurg. 2015;88:598-602.
19. Cheng Z, Chao Q, Zhang H, Wang DW, Shu HS. Intraventricular cystic papillary meningioma: A case report and literature review. Med (Baltimore). 2020;31(31):1-5.
20. Okunlola AI, Ibijola AA, Babalola OF, Okunlola CK, Erinomo OO. Parasagittal cystic meningioma mimicking hemangioblastoma: A case report. Surg Neurol Int. 2021;27(12):2-3.
21. Lahkim M, Andour H, Laamrani FZ, Nouali HE, Fenni JE. Cystic meningioma: A case report with a literature review. Radiology Case Report. 2021;16(10):2958-2961.
22. Diyora B, Kukreja S, Dhal G, Devani K, Patel M, Wankhede R. Extra-Axial Cystic Meningioma without Dural Attachment in an Adult: Case Report and Review of Literature. Asian J Neurosurg. 2022;17(2):173-177.
23. Diyora BD, Dhall G, Bhende BU, Mulla M. Intraparenchymal Cystic Meningioma - A Rare Occurrence with a Clinical Significance. Neurol India. 2021;69(5):1442-1443.
24. Wang XQ, Huang MZ, Zhang H, Sun FB, Tao BB, Feng BH, et al. Clear cell meningioma: Clinical features, CT, and MR imaging findings in 23 patients. Comp Assist Tomogr. 2014;38:200-208.
25. Sugiyama H, Tsutsumi S, Watanabe A, Nonaka S, Okura H, Izumi H, et al. A large cystic meningioma incidentally detected during general examination for breast cancer. Radiology. 2022;17(5):1777-1783.
26. Zhang D, Hu LB, Zhen JW, Zou LG, Feng XY, Wang WX, et al. MRI findings of intracranial cystic meningiomas. Clin Radiol. 2009;64:792-800.
27. Zee CS, Chen T, Hinton DR, Tan M, Segall HD, Apuzzo ML. Magnetic resonance imaging of cystic meningiomas and its surgical implications. Neurosurgery. 1995;36:482-488.
28. Go KO, Lee K, Heo W, Lee YS, Park YS, Kim SK, et al. Cystic Meningiomas: Correlation between Radiologic and Histopathologic Features. Brain Tumor Res Treat. 2018;6(1):13-21.
29. Wang P, Han S, Liu N, Yu C, Qi X, Zhu M, et al. Peritumoral cystic meningioma: A report of two cases and review of the literature. Exp Ther Med. 2016;11(3):904-908.
30. Utomo SA, Bajamal AH, Yueniwati Y, Sanjaya ID, Fauziah D. Apparent Diffusion Coefficient Values and Dynamic Contrast-Enhanced Magnetic Resonance Perfusion are Potential Predictors for Grading Meningiomas. Int J Med Sci. 2022;19(9):1364-1376.
31. Saraf S, McCarthy BJ, Villano JL. Update on meningiomas. Oncologist. 2011;16:1604-1613.
32. David EA, Marshall MB. Review of chest wall tumors: A diagnostic, therapeutic, and reconstructive challenge. Semin Plast Surg. 2011;25(1):16-24.
33. Jang KT, Park SM, Basturk O, Bagci P, Bandyopadhyay S, Stelow EB, et al. Clinicopathologic characteristics of 29 invasive carcinomas arising in 178 pancreatic mucinous cystic neoplasms with ovarian-type stroma: implications for management and prognosis. Am J Surg Pathol. 2015;39(2):179-187.
34. Al-Azzwi ZHN, Nazarov AN. Brain Tumor Classification based on Improved Stacked Ensemble Deep Learning Methods. Asian Pacific J Cancer Prevent. 2023;24(6):2141-2148.
35. Ilderbayeva G, Zhetpisbaev B, Ilderbayev O, Taldykbayev Zh, Bekeeva S. Metabolic processes of organism in remote period after the combined effects of radiation and emotional stress. Georg Med News. 2016;(250):76-82.
36. Diehl CD, Giordano FA, Grosu AL, Ille S, Kahl KH, Onken J, et al. Opportunities and Alternatives of Modern Radiation Oncology and Surgery for the Management of Resectable Brain Metastases. Cancers (Basel). 2023;15(14):3670.
37. Okassova AK, Ilderbayev OZ, Nursafina AZh, Zharmakhanova GM, Rakhimova BB, Bayan YT, et al. Evaluation of lipid peroxidation under immobilization stress in irradiated animals in experiment. Open Access Macedon J Med Sci. 2021;9:119-122.
38. Chu ECP, Spaska A, Monov D, Kasatkin M, Stroiteleva N. Examining the correlation between

salivary cytokine concentrations and CRP in people experiencing social-cognitive stress. Neurol Res. 2023;45(2):160-165.

39. Lisnyy I, Zakalska O, Dmytriiev D, Dmytriiev K, Dobrovanov O. Pre-emptive analgesia with nonsteroidal anti-inflammatory drugs randomized, double-blind placebo-controlled study. Lek Obz. 2021;70(5):195-202.

40. Sagandykova NS, Fakhradiyev IR, Sajjala SR, Taukeleva SA, Shemetova DE, Saliev TM, et al. Patient-specific CFD simulation of aerodynamics for nasal pathology: A combined computational and experimental study. Comp Meth Biomech Biomed Engin: Imag Visual. 2021;9(5):470-479.

41. Latka D, Waligora M, Latka K, Miekisiak G, Adamski M, Kozlowska K, et al. Virtual Reality Based Simulators for Neurosurgeons - What We Have and What We Hope to Have in the Nearest Future. Adv Intel Syst Comp. 2018;720:1-10.

42. Nukusbekova G, Toguzbayeva D, Hashimli R, Oguz H, Taukeleva S. Reflux Symptom Index: Translation to the Kazakh Language and Validation. J Voice. 2022. doi:10.1016/j.jvoice.2022.07.004

43. Tang AR, Chotai S, Grisham CJ, Guidry BS, McDermott JR, Le CH, et al. Outcomes following surgical resection of cystic intracranial meningiomas. Neurooncology. 2022;160(1):33-40.

44. Messina A, Fogliani AM. Valproate in conversion disorder: A case report. Case Rep Med. 2010;2010:205702.

45. Messina A, Cuccì G, Crescimanno C, Signorelli MS. Clinical anatomy of the precuneus and pathogenesis of the schizophrenia. Anatom Sci Int. 2023 98(4):473-481.