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Minimally Invasive Endoscopic Approach to Large Intraventricular Tumors

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ABSTRACT

AIM: To analyze the safety and effectiveness of the minimally invasive endoscopic approach in the treatment of large intraventricular tumors.

MATERIAL and METHODS: We retrospectively reviewed the demographic, radiological, and surgical data of 8 patients who were operated on using the endoscope-plus-port technique for large (>5 cm) intraventricular tumors at our clinic between 2015 and 2020. All procedures were performed using the minimally invasive endoscopic approach.

RESULTS: The cohort comprised 3 females and 5 males, with a mean age of 40.88 years. All tumors were located in the lateral ventricle; near-total resection was achieved in 3 patients and subtotal resection in 5 patients. External ventricular drainage was inserted in all patients postoperatively. The histological diagnosis was neurocytoma in 3 patients, glioblastoma in 2 patients, metastasis in 2 patients, and a grade II meningioma in 1 patient. No complications or mortality were reported in the 31-month follow-up period.

CONCLUSION: Safe and effective tumor resection of intraventricular tumors is possible using the endoscope-plus-port, even in tumors >5 cm. This technique permits dynamic mobilization and facilitates bimanual operation, increasing resection rates and improving outcomes for these tumors.

KEYWORDS: Intraventricular, Tumor, Endoscopy, Surgery, Minimally invasive

ABBREVIATIONS: MRI: Magnetic resonance imaging, **CT:** Computed tomography, **TR:** Total resection, **NTR:** Near total resection, **STR:** Subtotal resection

INTRODUCTION

Intraventricular tumors comprise 1%-10% of all intracranial mass lesions; they arise from periventricular structures, including the ventricular walls, septum pellucidum, and choroid plexus (21,22), and form a heterogeneous group in terms of histology and treatment, often similar in clinical history and radiological features. The majority of intraventricular tumors are benign and low-grade lesions, such as choroid plexus papilloma, meningioma, central neurocytoma, and ependymoma (2,7,14). Tumors arising from the adjacent brain tissue with significant growth in the ventricular cavity are defined as secondary ventricular tumors with transependymal invasion; most of these are gliomas (15,22).

Although the classical treatment of intraventricular tumors involves microsurgical resection of the lesion by performing craniotomy under microscopic vision via transcortical-transcallosal-transventricular or interhemispheric-transcallosal route (22), the deep intracranial location of these tumors and their proximity to critical neurovascular structures often make microsurgical access to these lesions difficult. The choice of approach for surgical resection depends on the type, size, and location of the lesion, as well as the ventricular size and its

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proximity to adjacent anatomical structures (22). Furthermore, resection usually requires retraction and dissection of important brain structures to protect the corridor created to reach the lesion and to proceed with bimanual microsurgical resection (10,13). This surgical insult may damage important brain structures, such as the thalamus, caudate nucleus, fornix, and others, leading to complications, such as seizures, neurological deficits, and sometimes cognitive impairment related to venous infarction in the postoperative period, and even mortality (7).

Although traditional microsurgical techniques are the gold standard for intraventricular tumor resection, their invasiveness and the resultant morbidity and mortality have increased interest in more minimally invasive treatments, such as neuroendoscopic resection (15). With advances in surgical skills and experience, the use of endoscopic surgery has expanded, particularly in the treatment of brain tumors and tumor-related hydrocephalus (1,6). Endoscope-assisted microsurgical excision of intraventricular tumors reportedly minimizes neural tissue retraction and provides a better and more comfortable surgical approach with less traumatic surgical sequelae (12). While it allows direct tumor visualization with minimal brain retraction, major limitations were noted when resecting large tumors (16). Initially, the use of endoscopy was limited to the biopsy stage when approaching intraventricular tumors, especially when accessing potentially hazardous areas with important neurovascular structures. Although microsurgery is the gold standard method for resection of intraventricular tumors, endoscopy is still the first-line modality for biopsy owing to its effectiveness and reliability in providing accurate pathological specimens (14,18,19). Additionally, the use of endoscopic methods allows access to the hydrocephalus condition (6,9); in selected cases, it also allows for partial or total resection. In this study, we present a retrospective analysis to demonstrate the effectiveness and safety of the minimally invasive endoscopic resection (endoscope-plus-port technique) for intraventricular tumors larger than 5 cm in their maximum dimension.

MATERIAL and METHODS

Patient Population

Between 2015 and 2020, eight patients with intraventricular tumors (>5 cm) were operated on using the endoscope-plus-port technique at our clinic. We retrospectively reviewed the medical records, radiological images, pathology reports, and surgical reports of these patients to collect data regarding demographic information, preoperative signs and symptoms, anatomical location and size of the lesion, presence of associated hydrocephalus, endoscopic maneuvers performed, resection rate, intraoperative or postoperative complications, histopathological diagnosis, follow-up period, and recurrence.

Ethical approval for this retrospective study was obtained from the Gülhane Training and Research Hospital Ethics Board (approval number: 22.04.2021/185). Written informed consent was obtained from all participants.

Preoperative Evaluation

Routine cranial magnetic resonance imaging (MRI), computed tomography (CT), and CT-angiography were performed in all patients to evaluate the relationship of the tumor with the surrounding vascular structures. In addition, navigation MRI was performed preoperatively to facilitate follow-up of the transcortical trace and port placement in the appropriate location during surgery.

Based on MRI scans taken at three months postoperatively, tumor resection was classified as total resection (TR), near-total resection (NTR), and subtotal resection (STR). TR was defined as radiographic removal of the entire lesion; NTR was defined as the removal of ≥ 95% of the lesion, while STR was used to indicate the removal of < 95% of the lesion. Table I presents a summary of the demographic, clinical, and operative outcomes of the study patients.

In preoperative images, tumor volume was calculated using the modified formula $[A \times B \times C] / 2$, where A, B, and C represent the maximum diameter of the tumor in the three dimensions. Colloid cysts and tumors < 5 cm in size were excluded from the study.

Surgical Strategy

All intraventricular tumors were accessed via the transcortical-transventricular and transcortical-transventricular-transforaminal routes. Patients were positioned according to lesion localization and surgical strategy; an intraoperative navigation system (Stealth Station®, Medtronic, MN, USA) was introduced for each patient.

Under general anesthesia, a 3-pin head holder was inserted in the patient's cranium. A lazy-S-shaped incision was made at the Kocher point or the posterior parietal region, passing through the skin and subcutaneous tissue. Next, a craniotomy was performed (approximately 3 x 3 cm^2) and the dura was opened in an "X" shape. After a 1-cm corticotomy, the lateral ventricle was reached with navigation-guided parenchymal dissection, and a port was placed there. The endoscope was advanced to visualize the intraventricular choroid plexus, fornix, vascular structures, and the tumor. Continuous irrigation was performed using Ringer's lactate solution to provide clear images and maintain hemostasis during the procedure. The use of 3D endoscopy increased our functional depth perception and facilitated anatomical orientation. The tumor was excised under endoscopic vision.

After adequate resection and hemostasis maintenance, the endoscope, followed by the thoracoport, was carefully and gradually removed. After bleeding control was achieved in the port cavity, the ventricular system was filled with plenty of Ringer's lactate solution. In all patients, an external ventricular drainage (EVD) catheter was placed in the lateral ventricle using the trace. Finally, the dura was sutured, and the bone flap was placed back in the cranium.

RESULTS

Among the 8 patients, there were 5 males and 3 females; the mean age of the patients was 40.88 years (range: 21-71 years). The most common complaint was headache, followed by memory disturbance, seizures, and visual symptoms. The mean duration of surgery in the study cohort was 65.63 min-

Table I: Age, Gender, Tumor Location and Size, Clinical Presentation, Resection Rates, Operative Time, Blood Loss, Pathological Diagnosis, and Follow-Up Times of The Cases

Case	Age/Sex	Location	Clinical Presentation	Tumor size (mm)	Approach	Resection	Operative time (min)	Blood Loss (mL)	Diagnosis	Follow-up (month)
1	30/M	LV	Headache, seizure	51x55x49	Kocher-TC-TV	STR	45	150	Glioblastoma	14
2	29/F	LV (Atrium)	Headache, vomiting	53x35x50	Posterior parietal-TC	NTR	40	100	Atypical meningioma	58
3	71/M	LV	Headache and memory disturbance	71x61x90	Kocher-TC-TV	STR	110	250	Central Neurocytoma	17
4	21/M	LV	Visual disturbance	75x45x55	Posterior parietal-TC	STR	90	200	Central Neurocytoma	36
5	51/M	LV	Seizure, visual disturbance	55x35x50	Posterior parietal-TC-TV	STR	50	100	Glioblastoma	9
6	64/M	LV	Headache	55x60x53	Kocher-TC	STR	60	50	Metastasis	47
7	27/F	LV	Headache	64x43x54	Posterior parietal-TC	NTR	70	70	Metastasis	12
8	34/F	LV	Memory disturbance	54x58x50	Posterior parietal-TC	NTR	60	120	Central Neurocytoma	56

***M:** Male, **F:** Female, **LV:** Lateral Ventricle, **TC:** Transcortical, **TV:** Transventricular, **NTR:** Near total resection, **STR:** Subtotal resection, **EVD:** External ventricular drainage*

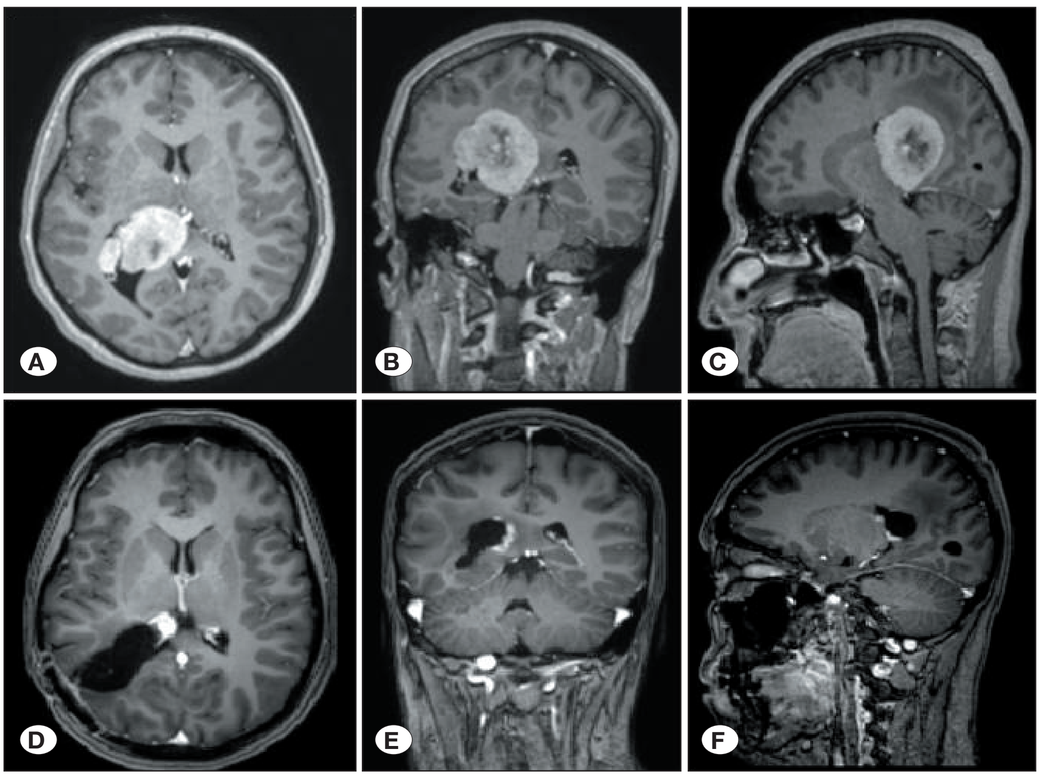

Figure 1: Illustrative case of near-total resection of an intraventricular tumor in a 29-year-old female patient. Preoperative **A)** axial, **B)** coronal, and **C)** sagittal T1-weighted magnetic resonance imaging (MRI) scans with contrast show a large intraventricular tumor located in the right atrium of the lateral ventricle. The tumor was removed using the minimally invasive endoscopic approach, and the histological diagnosis was confirmed as a grade II atypical meningioma. Postoperative **D)** axial, **E)** coronal, and **F)** sagittal T1-weighted MRI scans with contrast confirmed near-total resection of the tumor.

utes, and the mean blood loss was 130 ml; STR was achieved in five patients and NTR in three patients (Table I). Figures 1-3 present illustrative cases of NTR and STR achieved using the endoscope-plus-port technique.

No intraoperative or postoperative complications were reported in any patient. EVD catheters placed during the intraoperative period were monitored for an average of 3 days. The catheter was eventually removed as no patient developed hydrocephalus or required a ventriculoperitoneal shunt.

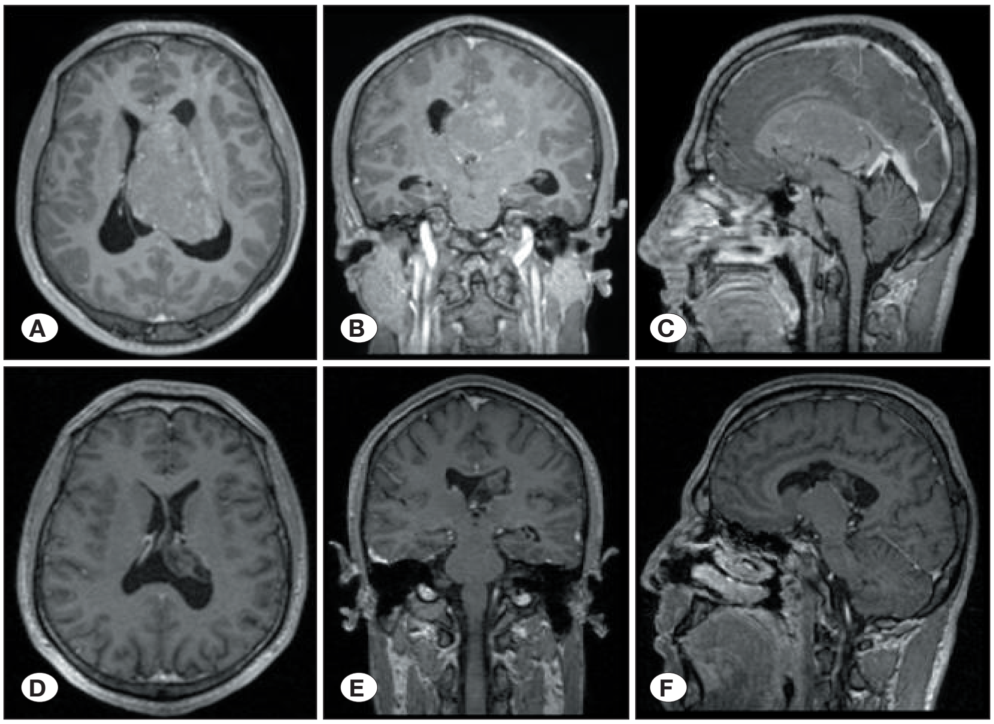

Figure 2: Illustrative case of subtotal resection of an intraventricular tumor in a 71-year-old male patient. Preoperative **A)** axial, **B)** coronal, and **C)** sagittal T1-weighted magnetic resonance imaging (MRI) scans with contrast show a large intraventricular tumor located in the lateral ventricle. The tumor was removed using the minimally invasive endoscopic approach. The diagnosis was confirmed as a central neurocytoma. Postoperative **D)** axial, **E)** coronal, and **F)** sagittal T1-weighted MRI scans with contrast confirmed subtotal resection of the tumor.

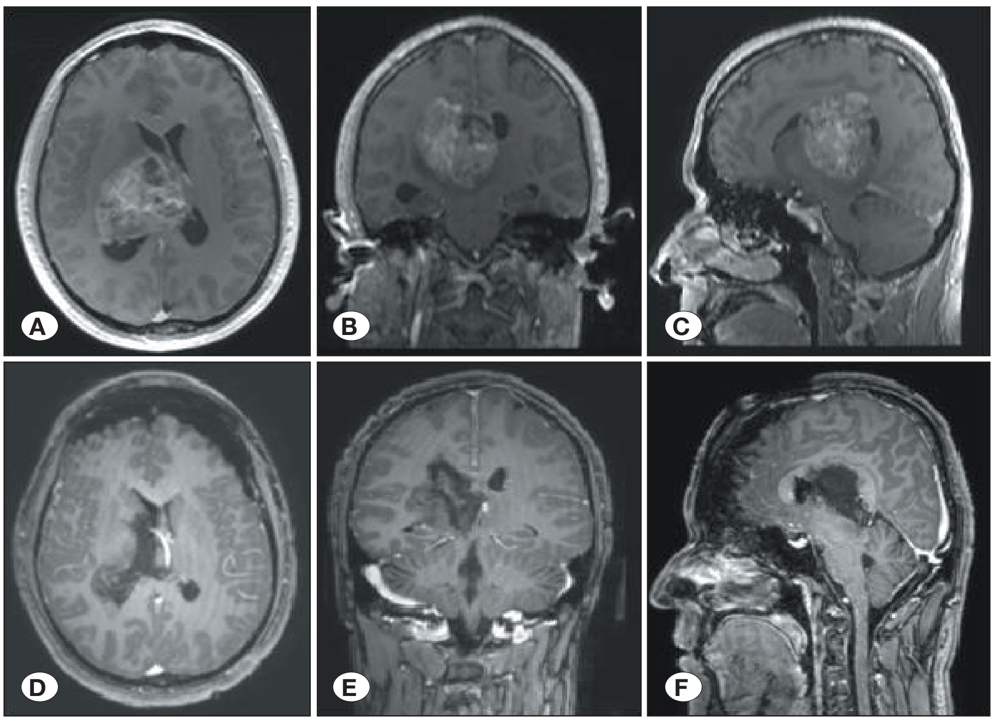

Figure 3: Illustrative case of subtotal resection of an intraventricular tumor in a 30-year-old male patient. Preoperative **A)** axial, **B)** coronal, and **C)** sagittal T1-weighted magnetic resonance imaging (MRI) scans with contrast show a large intraventricular tumor located in the lateral ventricle. The tumor was removed using the minimally invasive endoscopic approach. The diagnosis was confirmed as a glioblastoma. Postoperative **D)** axial, **E)** coronal, and **F)** sagittal T1-weighted MRI scans with contrast confirmed subtotal resection of the tumor.

Serial MRI scans were performed at patients were followed-up with MRI scans at 3, 6, and 12 months postoperatively within the first year if there was no deterioration in neurological status. In addition, all cases were referred to the radiation oncology clinic after the histopathological diagnosis was confirmed. None of the patients required reoperation during the follow-up period.

DISCUSSION

Intraventricular and paraventricular brain tumors often present with similar clinical and radiological symptoms (15,17). Intraventricular tumors are usually deep-seated intracranial pathologies that pose a diagnostic and therapeutic challenge (20); these tumors are treated by microsurgical resection under a microscope by performing a standard craniotomy (21,22). However, due to the proximity of intra- and paraventricular tumors to critical centers monitoring vascular and neural structures, patients may develop functional, cognitive, and even life-threatening complications in the postoperative period (7,11,15).

Sufficient retraction of the brain tissue is required to reach these deep-seated lesions (13,16). Traditional retraction methods disrupt the nutrition of the surrounding brain tissue, leading to seizures, focal neurological deficits, and cognitive impairments. To address this concern, neurosurgeons now use endoscopic ports to access these deep-seated tumors instead of traditional retractor systems using spatulas (10,11,13). The port technique leads to radial distribution of forces over a large number of points (17), minimizing the net force applied to a given surface area. The port also provides a means for stereotactic removal of deep-seated intracranial lesions and protects the surrounding tissues from iatrogenic injuries resulting from instrument entry and re-entry. Many studies using the microscope-plus-port technique have reported less damage to the surrounding neurovascular structures in the postoperative period, highlighting the potential of endoscopic methods to be an even less invasive technique.

The advent of modern endoscopic techniques, together with the recent development of endoscopic-specific instrumentation, has greatly increased microsurgical access to the ventricular system. In the context of intraventricular tumors, endoscopy is primarily used for correcting cerebrospinal fluid (CSF) obstruction, clarifying the histology of a specimen, and, if possible, complete tumor removal. Endoscopic methods offer a number of advantages, some of which include the capacity for panoramic vision, close-up images, clear detail, and ideal illumination of the operating field. In addition, the inherent benefits of minimally invasive techniques, such as minimal brain retraction, reduced surgical time, improved cosmetic results, shorter hospital stay, and lower costs, enhance the effectiveness of neurosurgical endoscopy for the treatment of intraventricular tumors (18,23).

In recent years, endoscopes and ports have been used together to obtain a wider corridor for more convenient maneuverability of surgical instruments during endoscopic surgery (15). In particular, the endoscopic-plus-port technique is widely used in the treatment of intraventricular tumors owing to its ability to facilitate dynamic mobilization and bimanual operation (10,11,13,15). Earlier, endoscopic resection of intraventricular tumors was only performed at the biopsy stage (9); many studies have described the benefits of neuroendoscopy in determining the pathological diagnosis of intra- and paraventricular tumors (15,17,23). However, emerging evidence suggests that complete endoscopic resection of intraventricular brain tumors is safe and feasible in selected cases, such as lesions that are generally < 2-3 cm, mild to moderately vascular, and have a soft consistency (15).

Despite its popularity, endoscopic intraventricular surgery is also associated with several intraoperative and postoperative complications, which can be categorized as vascular, neural, and technical failures (8). Bleeding is an important intraoperative vascular complication of endoscopic surgery secondary to rupture of tumor feeders or thin subependymal vascular structures; it can be controlled using unipolar or bipolar cauterization (8). Postoperative infection is another serious complication that results in significant morbidity. Prolonged use of an EVD device is the primary cause of postoperative infection that may manifest as a wound infection or ventriculitis. Seizures constitute an important late postoperative complication of endoscopic surgery. Neurological deficit after endoscopic surgery can be avoided by selecting distant routes to the eloquent brain areas (1). Other technical complications of endoscopic ventricular surgery include visual field defects, cognitive deficits, recurrence, CSF leak, and hydrocephalus (8); among these, hydrocephalus is the most common complication, with studies suggesting that CSF leak and hydrocephalus are more frequent in endoscopic surgery than in microsurgical technique (1).

A study reporting the results of 33 cases of endoscopic removal described that TR was achieved in only three cases (9.3%) (two of subependymoma, and one oligodendroglioma) (19). In another review of 649 intraventricular tumors resected with the endoscopic technique, including colloid cysts and other intraventricular lesions, TR or NTR was achieved in only 36 patients (45.5%) with non-colloid cyst cases (2). Notably, this review study emphasized that the probability of TR or NTR is higher in tumors < 2 cm. Likewise, a study including 20 intra-paraventricular tumors operated on with the combined endoscope plus microscope technique using a port described that 70% of patients achieved GTR, 20% achieved NTR, and 10% were deemed as STR (15). Engh et al. used the endoscope-plus-port technique and described GTR/TYR in 80% of the cases (11). Thus, careful selection of patients, preoperative evaluation and planning, and adequate experience with surgical technique, neuroendoscopic anatomy, surgical approaches, and equipment are very important to achieve adequate resection and surgical success (15,17,20,22). In our study, 5 out of 8 patients (62.5%) achieved STR, whereas the remaining 3 achieved NTR (Table I), demonstrating similar results as the existing literature. Although we could not achieve TR in any of the patients, our findings indicate that the endoscope-plus-port technique may help increase the effectiveness of adjuvant treatment in the postoperative period by reducing the tumor burden. TR is usually not possible in high-grade glial tumors due to their infiltrative nature and lack of a clear surgical plane. Accordingly, STR was achieved in patients with intraventricular glioblastoma. Moreover, achieving TR is also difficult in large intraventricular central neurocytoma and metastasis cases because of delicate intraventricular anatomical structures and poorly defined surgical borders between the tumor and ventricular walls (5,24). Thus, small intraventricular tumors are more suitable for TR using the endoscopic technique, while NTR and STR are pragmatic outcomes with large tumors (2). Improvements in endoscopic instruments may allow better resection rates in the future.

Russo et al. reported meningitis, seizures, intraventricular hemorrhage, subdural collection, and transient hemiparesis as chief complications in the postoperative period after undergoing intraventricular tumor removal using microscopic techniques (19). In this study, nine patients developed hydrocephalus requiring a ventriculoperitoneal shunt, whereas one patient died due to ventriculitis (3%). Likewise, Chaves et al. reported a case where surgery was terminated due to intraoperative bleeding within a 12-year-old giant central neurocytoma operated on using the microscopic transcortical method; postoperatively, the patient developed diabetes insipidus, hemiparesis, and meningitis (5). Other studies on intraventricular tumors undergoing endoscopic biopsy described the infection rate as 0%-6.5%, the morbidity rate as 6%-18%, and the mortality rate as 0%-6.3% (7,14,18,24). A 2.33%-3.6% incidence was reported for bleeding during endoscopic biopsy (23). Another study described infarction due to thalamostriate vein thrombosis (3).

With endoscopic resection, the bleeding rates were reported to be between 0% and 9.7% (2,17,18,20). Memory loss due to fornix injury during endoscopic resection of intraventricular tumors is reported by multiple studies (6,23); other complications include epileptic seizure and hydrocephalus requiring ventriculoperitoneal shunt (23). In a study involving intraventricular tumors operated on with the endoscopic method, the authors described seven cases of Parinaud syndrome, one of oculomotor paralysis, two of meningitis, four of motor weakness, one with partial pituitary insufficiency, one with memory loss, and one with hydrocephalus in the postoperative period (4). In our series, none of the patients developed Parinaud Syndrome or other neurological deficits during the 31-month follow-up period; no other morbidity or mortality occurred during the intraoperative and postoperative periods. This complication-free outcome may be attributed to the use of the port with the endoscope during the surgery, as well as the utilization of Ringer's lactate solution for irrigation to control intraoperative bleeding. No re-operation was required in any of our cases during the follow-up period.

Despite the surgical success, the main limitation of our study is the small sample size, which should be considered when interpreting our results. The absence of a control group also precludes the applicability of our results because of the interference of potential confounding factors. However, we mainly focused on the safety and efficacy of the endoscopic approach in large intraventricular tumors.

CONCLUSION

The endoscope-plus-port technique allows for safe and effective resection of intraventricular tumors, even for those >5 cm. While TR is extremely difficult in some cases due to the nature and size of tumors, this technique facilitates the dynamic mobilization of neural structures and bimanual operation, increasing the overall resection rates in these tumors.

Declarations

Funding: This research did not receive any specific grant from funding agencies in the public, not-for-profit, or commercial sectors.

Availability of data and materials: The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Disclosure: The authors have no relevant financial or non-financial interests to disclose.

AUTHORSHIP CONTRIBUTION

Study conception and design: MK
Data collection: AD
Analysis and interpretation of results: SK
Draft manuscript preparation: AD
Critical revision of the article: AD, MK
Other (study supervision, fundings, materials, etc...): AD, MK
All authors (AD, SK, MK) reviewed the results and approved the final version of the manuscript.

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