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MINIMALLY INVASIVE UNILATERAL HEMILAMINECTOMY APPROACH FOR THE REMOVAL OF SPINAL SCHWANNOMAS IMPACT ON PAIN AND NEUROLOGICAL RESULTS

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ABSTRACT

Objective: Spinal intradural tumors are commonly removed using laminectomy or laminotomy; however, these approaches can lead to postoperative pain, discomfort, kyphosis, and instability. Unilateral hemilaminectomy (UHL) is a minimally invasive alternative that may minimize these issues by using a smaller incision and less disruption to spinal structures.

Materials and Methods: From 2010 to 2021, 79 patients with schwannoma underwent UHL surgery. Surgery was generally limited to three levels, and the tumor was removed en bloc or piecemeal after ultrasonic debulking. Paramedial opening of the dura was performed, and neurophysiological monitoring was performed. Baseline medical data on demographic and clinical variables were analyzed, including patients' sex, age, tumor location and volume, overall operative time, length of postoperative immobilization, duration of hospitalization, preoperative (1-month/3-month postoperative Denis Pain Scale value), comorbidities, and modified McCormick Scale.

Results: Of these patients, 35 were female and 44 were male, with ages ranging from 19 to 72 years (mean 48.9±14.6). Pain and radiculopathy were the first symptoms in 56 (70.8%) and 36 (45.5%) patients, respectively. No spinal instability was observed postoperatively, and the mean estimated blood loss was 285 mL, ranging from 245-420 mL. The maximal sagittal diameter of the tumor was measured on contrast-enhanced T1-weighted images, with a mean of 26.0±12.4 mm (range, 8.2-36.2 mm).

Conclusion: Unilateral microsurgery for spinal intradural tumor removal has resulted in good neurologic and oncologic outcomes and reduced postoperative pain and discomfort. In addition, this approach has preserved spinal stability, eliminating the need for bracing, and enabling earlier rehabilitation.

Keywords: Spinal surgery, spinal schwannoma, pain, hemilaminectomy, minimally invasive neurosurgery

INTRODUCTION

Schwannomas of the spine are generally non-cancerous growths that develop gradually, originating from Schwann cells. These cells envelop and provide insulation to nerve fibers found in the peripheral nervous system(1). They are most commonly found in the intradural extramedullary (IDEM) region of the spine(1). Although these tumors are usually benign, they can cause symptoms by compressing nearby nerves or the spinal cord itself. Treatment options for spinal schwannomas typically involve surgical removal of the tumor(2). In the field of neurosurgery, the technique of total laminectomy or laminotomy at single or multiple levels is frequently employed for the removal of intradural or extramedullary tumors within the spinal region, such as spinal schwannomas(3). The selection of the surgical technique hinges on factors like the tumor's size and location, as well as the surgeon's personal preferences and level of expertise(4). Both laminectomy and laminotomy techniques can effectively remove spinal tumors while minimizing damage to the spinal cord and nerves. However, the choice of surgical approach may differ based on factors such as tumor size, location, the patient's specific condition, and various other considerations. It's important to note that total laminectomy or laminotomy procedures can result in the removal of posterior bony structures, detachment of the paraspinal muscles, and disruption of the interspinous ligament, potentially leading to postoperative pain, the need for external bracing, and an increased risk of delayed spine instability or kyphosis. The detachment of the paraspinal muscles can also lead to persistent back pain. For tumors located anteriorly, the spinal cord may need to be manipulated or rotated after sectioning the dentate ligament, which can increase the risk of neural damage(5). To minimize the potential complications associated with total laminectomy/laminotomy, some surgeons may opt for more conservative surgical approaches, such as

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hemilaminectomy or laminoplasty[4,5]. These techniques can preserve more of the spinal structures and may result in fewer postoperative complications.

In minimally invasive procedures, there is a greater emphasis on reducing the amount of bone and tissue removal compared to traditional open surgery[5]. This is done in order to reduce postoperative pain, minimize blood loss, shorten hospital stays, and eliminate the potential risk of instability[6]. Although minimally invasive methods and microsurgery have advanced in the field of spinal tumor removal, the unilateral hemilaminectomy (UHL) approach is not commonly employed and lacks widespread acceptance. There are limited recent publications on this technique, and it is typically referenced in neurosurgical textbooks only for addressing small tumors situated in lateral positions[5,7,8]. However, recent studies have suggested that the unilateral approach may be a valuable surgical option for certain spinal tumors, particularly those located in the thoracic spine[9,10]. The objective of this study appears to be to investigate whether a less invasive surgical strategy, consisting of UHL, tumor removal, and duraplasty, can achieve comparable surgical and clinical results to traditional open surgery for spinal tumors. The study aimed to determine whether this less invasive approach resulted in an increased risk of tumor recurrence, as has been reported in some studies in the literature[4,6].

MATERIALS AND METHODS

The study involved 79 adult patients who underwent minimally invasive UHL for IDEM spinal schwannoma which was confirmed by histopathological examination between 2010 and 2021, in the University of Health Sciences Turkey, Ankara Bilkent City Hospital, Clinic of Neurosurgery. Ethical approval for this study was obtained from the Ankara City Hospital No. 2 Clinical Research Ethics Committee (decision no: E2-23-5066, date: 27/09/2023). This retrospective study received approval from the Institutional Review Board, and written informed consent was obtained from each patient.

A total of twenty-two patients were excluded from the study. This exclusion comprised six patients with extradural paravertebral schwannoma, five patients with spinal schwannoma associated with neurofibromatosis, and eleven patients with extradural sacral schwannoma, whether or not they had retroperitoneal elongation. Patients with extradural paravertebral schwannoma may require a different surgical approach or have a different prognosis compared to patients with IDEM spinal schwannoma, so these patients were excluded from the study. Similarly, patients with spinal schwannoma due to neurofibromatosis may have a different clinical presentation or require a different management approach compared to patients with sporadic spinal schwannoma. In addition, patients diagnosed with non-schwannoma in histopathological examination were not included in the study.

We analyzed baseline medical data encompassing a variety of demographic and clinical variables, such as patients' gender, age, tumor location, and size, total surgical duration, duration of postoperative immobilization, length of hospital stay, preoperative, 1-month, and 3-month postoperative Denis Pain Scale values (DPS), comorbidities, and the modified McCormick Scale (mMcS)[11,12]. The DPS is a validated tool for measuring pain intensity and quality and can provide important information about the effectiveness of pain management strategies[12] (Table 1). In addition to pain evaluation, the study also included assessments of neurological function and quality of life at admission and 12 months after surgery. The modified mMcS, as applied by Klekamp for intramedullary tumors, was used to evaluate neurological function[11]. The mMcS is a widely used tool for assessing neurological function in patients with spinal cord injury or disease and can help determine the extent of any motor or sensory deficits[11] (Table 2).

To manage postoperative pain, intravenously infused analgesics were used for the first 24 hours after surgery. After this initial period, oral analgesics may be used to manage any remaining pain. For patients experiencing postoperative radicular and meningeal pain, methylprednisolone can be considered for reducing inflammation caused by cerebrospinal fluid (CSF) blood contamination. The choice of analgesic will depend on the severity of pain and individual patient factors. Prolonged analgesic therapy may be considered if pain persists beyond the initial postoperative period, and should be carefully managed to minimize the risk of adverse effects.

The tumor size was measured using the widest diameter in three planes and the volume was calculated using the ellipsoid method (D1xD2xD3/2). This is a common method for calculating tumor volume, and it allows for a more accurate assessment of the size and complexity of the tumors. Skilled neurosurgeons conducted all procedures.

Table 1. Denis' Pain Scale[12]

Grade	Description
P1	No pain
P2	Occasional minimal pain; no need for medication
P3	Moderate pain, occasionally medications and no interruption of work or activity of daily living
P4	Moderate pain, occasionally absent from work; significant changes in activities of daily living
P5	Constant, severe pain; chronic pain medications

Table 2. Modified McCormick Scale (Klekamp)[11]

Grade	Description
I	Neurologically intact, minimal dysesthesia
II	Mild motor and/or sensory deficit, independent
III	Moderate deficit, functionally impaired, external aid
IV	Severe deficit, limited function, dependent
V	Paraplegia or quadriplegia

Statistical Analysis

Data analysis was carried out using two statistical software programs: IBM SPSS 25.0 (IBM Corp., Armonk, NY) and MedCalc 15.8 (MedCalc Software bvba, Ostend, Belgium). The analysis included various descriptive statistical methods such as frequency, percentage, mean, standard deviation, median, minimum, and maximum values. To compare qualitative data, chi-square tests were employed, including Pearson's chi-square tests, Yates' Corrected chi-square tests, and Fisher's exact test. Relationships between variables were assessed using Spearman's rho correlation test. The statistical significance level was set at α=0.05.

Operative Technique

The patient was positioned in a prone orientation under general anesthesia. A midline skin incision, aligned with the radiograph marker located over the tumor's spinous process, was employed. Intraoperative neurophysiologic monitoring, a critical safety measure during surgery, was applied to all patients. Retaining the paravertebral muscles of the tumor side is a key feature of the UHL technique, as this helps to minimize damage to the muscles and surrounding tissue. The surgical procedure involved using a high-speed drill to remove the hemilaminae, exposing the dural sac. In cases where patients had lateral tumor extensions, a partial facetectomy was performed to access the tumor. A surgical procedure was performed involving a single-level hemilaminectomy using bone forceps and/or a high-speed drill. If necessary, the hemilaminectomy was extended to the adjacent cranial or caudal interlaminar spaces and, in some cases, to an additional lamina. To create more space, a section of the interspinous ligament, usually the most deep portion, was removed with Kerrison bone forceps, typically 2-3 millimeters. In cases where the mass could not be initially identified, the surgical team would begin their search by extending the surgical opening in a cranial direction. Before opening the protective layer known as the meninges, intraoperative ultrasonography with specialized probes was employed to assist in locating the mass. Following this, the dura, the outermost protective layer of the spinal cord, was carefully opened in a paramedial fashion, ensuring a sufficient medial flap remained to facilitate easy suturing. Subsequently, the spinal cord and/or nerve roots were visualized through a tangential corridor. If better visibility was needed, the operating table could be rotated to optimize exposure of the ventral aspect of the spinal cord. For enhanced visualization, an operating microscope was utilized, and a cavitron ultrasonic aspirator helped decompress the tumor internally. Subsequently, the next step was to meticulously dissect the capsule from the surrounding tissues. Occasionally, particularly in the thoracic region, it was necessary to sacrifice the sensory nerve root when capsule dissection wasn't feasible. In situations where the tumor was located in the cervical and lumbar regions, a small residue of tumor tissue might intentionally be left behind to prevent nerve damage. Following the removal or decompression of the tumor, the dura mater was securely sutured with an appropriate thickness of non-absorbable surgical suture, ensuring a watertight closure. Typically, fibrin glue and fat were applied epidurally to reinforce the closure and support the healing process.

RESULTS

Of these patients, 35 were female and 44 were male, and their ages ranged from 19 to 72 years (mean 48.9±14.6). Pain and radiculopathy were the first symptoms to occur in 56 (70.8%) and 36 (45.5%) patients, respectively. Regional pain and radiculopathy were seen together in 20 (25.3%) patients (Table 3).

According to the DPS, when preoperative pain evaluated, 16 patients were graded P5 (constant pain), 34 patients were P4 and 16 patients were P3. 13 patients had no pain. At first month's follow-up, the grading improved to P1 in 23 patients, P2 in 20 patients, and P3 in 36 patients. At third months follow-up grading improved to P1 in 33 patients and P2 in 39 patients. 7 of patients were graded P3. The overall results on pain were also evaluated: preoperative versus 3rd month's follow-up pain decreasement was significant ($p<0.05$) (Table 4).

Out of the 79 patients, 31 experienced varying degrees of paraparesis/monoparesis: 5 had moderate paraparesis (mMcS: III), while 6 had severe paraparesis (mMcS: IV). Sphincter

Table 3. Baseline characteristics of patients and tumors

Patient characteristics	Value (Range)
Patient numbers	79
Male	44
Female	35
Age (years)	48.9±14.6 (19-72)
Symptom duration (months)	20.8±27.8 (0.5-120)
Tumors' details	
Number of tumors (total)	79
Maximal sagittal diameter (mm)	26.0±12.4 mm (range, 8.2-36.2 mm)
Maximal axial diameter (mm)	14.2±6.1 mm (range, 8.0-33.1 mm)
Tumor volume (cm)	0.52 cm (range, 0.35-0.70)
Location of tumors	
Cervical	20
Cervicothoracic	5
Thoracic	21
Thoracolumbar	5
Lumbar	24
Lumbosacral	4
Histopathology	
Grade 1	77
Malignant transformation	2

Values are numbers or mean ± Standard deviation

Table 4. Details of the symptom "pain", classified according to Denis Pain Scale

Denis grade	Preoperative	1st month	3rd month
P1	13	23	33
P2	None	20	39
P3	16	36	7
P4	34	None	None
P5	16	None	None

dysfunction and plegia (mMcS: V) were observed in 10 patients. Remarkably, 13 patients achieved complete neurological recovery (mMcS: I), while 7 exhibited residual spasticity and minor hypoesthesia (mMcS: II). Four patients regained the ability to walk independently, albeit with moderate spasticity and occasional assistance (mMcS: IV). However, complete recovery from sphincter dysfunction and paraplegia was notably challenging, with only three patients achieving it. In the overall analysis of neurological recovery, no statistically significant differences were observed ($p>0.05$) (Table 5).

It seems that the duration of surgery for the cases ranged from 100 to 220 minutes with an average of 160 minutes. It's important to note that the duration of surgery can be affected by various factors such as the complexity of the procedure, the patient's medical condition, and the surgeon's experience and skill level. In this study, the mean estimated blood loss of 285 mL, ranges between 245-420 mL.

When the location of tumors are evaluated; there were lumbosacral tumors in 4 patients, lumbar tumors in 24 patients, thoracolumbar tumors in 5 patients, thoracic tumors in 21 patients, cervicothoracic tumors in 5 patients, and cervical tumors in 20 patients (Table 3, Figure 1).

The tumor maximal sagittal diameter was measured on contrast-enhanced T1-weighted images: 26.0±12.4 mm (range, 8.2-36.2 mm). In addition, maximal axial diameter was measured 14.2±6.1 mm (range, 8.0-33.1 mm). Tumor volume was calculated by the ellipsoid method, with a mean of 0.52 cm (range, 0.35-0.70). A foraminal tumor extension was identified in 19 (24.05%) patients.

All tumors in this study were successfully dissected and excised, even in the foraminal extended portion. The achievement of GTR in all tumors was accomplished. There is no need for posterior fixation in any patient. The histopathological confirmation of all tumors were done as schwannomas (Figure 2).

Three patient developed CSF leakage on postoperative, and revision surgery for dural repair was performed for 1 patient. Lumbar drain were inserted to other 2 patients. Otherwise, no serious postoperative complications developed. The patients' mean hospital stay were 5.8 days (range, 2-19 days). Recurrence was seen in 4 patients. Three patients were reoperated, and one patient was treated with stereotactic radiosurgery.

The mean follow-up time was 41.2±35.3 months. We considered that a 12-month follow-up period is a common and reasonable time frame for evaluating the outcomes of surgical treatment.

Table 5. Outcome of patients, modified McCormick Scale

Grade	Preoperative	Postoperative 12th month
I	48	61
II	10	7
III	5	None
IV	6	4
V	10	7

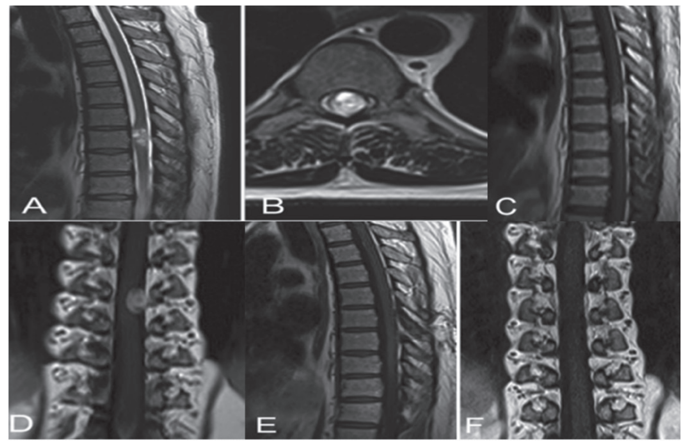

Figure 1. A 50-year-old male patient who presented with low back pain and numbness in both lower regions. Pre-op T2 sagittal **(A)** and axial **(B)** MR images, sagittal (**C**) and axial **(D)** contrast MR images. T1-weighted sagittal **(E)** and axial **(F)** images with contrast 3rd month postop, postop axial CT image

MR: Magnetic resonance, CT: Computed tomography

It allows sufficient time for patients to recover from surgery and for any potential complications or recurrence of symptoms to become apparent. Additionally, it provides a meaningful assessment of the effectiveness of the surgical intervention and any associated therapies.

DISCUSSION

The size of the transosseous, transligamentous corridor required for safe and effective intraspinal benign tumor resection depends on various factors such as the location, size, and extent of the tumor, as well as the surgeon's experience and skill. Generally, the corridor should be wide enough to provide adequate exposure of the tumor margins while minimizing the risk of damaging the spinal cord and nerve roots[13,14]. A thorough preoperative evaluation and planning, including imaging studies and neurological assessment, can help guide the surgeon in determining the appropriate size of the corridor needed for safe and effective removing the tumor completely; and avoid spinal deformity and/or instability[13].

The study utilized the DPS to assess preoperative pain levels and observed significant improvements in pain levels at one-month and three-month follow-up assessments, highlighting the surgical intervention's effectiveness in relieving pain, a primary treatment goal for spinal cord schwannomas. A

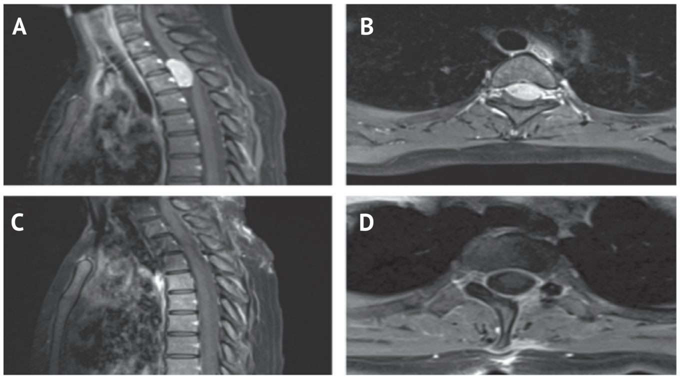

Figure 2. A 44-year-old female patient. **A, B)** A ventral intradural extramedullary tumor was detected at T2-T3 level on sagittal and axial preoperative T1-weighted contrast-enhanced MR images. **C, D)** Sagittal and axial postoperative T1-weighted contrast-enhanced MR images showed no residual tumor

MR: Magnetic resonance

significant proportion of patients had preoperative paraparesis or monoparesis. While many achieved full neurological recovery, overcoming sphincter dysfunction and paraplegia proved more challenging. Nevertheless, surgery led to substantial neurological improvements, offering promise for spinal cord schwannoma patients.

The average surgery duration (160 minutes) and estimated blood loss were within safe ranges, underscoring the procedure's feasibility and safety, particularly in the hands of experienced surgeons. Complication rates related to surgery duration and blood loss were low, supporting the procedure's safety. Tumor locations varied, with cervical and lumbar regions being the most common. GTR was achieved in all tumors, even those with foraminal extension, affirming the surgical approach's effectiveness. Despite a generally low postoperative complication rate, a few cases of CSF leakage required revision surgery. Notably, no posterior fixation was needed, demonstrating surgical stability. Tumor recurrence rates were relatively low, with successful reoperation or stereotactic radiosurgery for recurrent cases. The lengthy average follow-up period of 41.2 months provides a comprehensive evaluation of short and long-term outcomes, shedding light on surgical outcome durability and potential late complications or recurrences.

Certain authors have documented that hemilaminectomy is a surgical approach that has the potential to alleviate pain and maintain spinal stability in cases involving schwannomas. Additionally, they suggest that this restricted surgical corridor may be suitable for addressing ventral and lateral meningiomas[15].

While laminotomy may preserve more of the spinal stability than laminectomy, it still involves the sectioning of the interspinous ligament, bilateral stripping and retraction of muscles, and bilateral disruption of the ligamentum flavum, which may result in spinal instability in some cases[16]. Furthermore, laminotomy may not provide sufficient exposure for complete tumor removal in all cases, particularly for larger or more complex tumors[7,16]. In these cases, a more extensive laminectomy or other surgical approach may be necessary to achieve adequate exposure and safe tumor removal. Postoperative spinal instability, deformity, and epidural fibrosis are potential complications of laminectomy, laminotomy, and other spinal surgeries. External bracing may be necessary to help support the spinal column during the healing process and reduce the risk of postoperative complications[17].

Yaşargil et al.[14] indeed advocated for the unilateral approach as the primary choice when it comes to removing intraspinal tumors, especially when these tumors are situated in the ventral and lateral regions of the spinal canal. This recommendation was grounded in the concept that a UHL offers sufficient tumor exposure while reducing the potential for spinal instability and deformity when contrasted with more extensive laminectomy techniques[5,14]. By removing only, a portion of the affected lamina, the unilateral approach preserves spinal stability and avoids the need for external bracing, while also reducing the risk of postoperative spinal deformity and epidural fibrosis. The approach also allows for better preservation of the paraspinal muscles and soft tissues, which may contribute to better postoperative pain control and faster recovery[17].

It's truly reassuring to note that all patients in our series experienced an improvement in their preoperative pain, with the majority able to discontinue analgesic medications shortly after surgery. Prolonged and intense pain stemming from muscular or spinal sources can have substantial adverse effects on patients, including extended hospital stays, reduced comfort, an increased risk of depression, prolonged recovery at home, elevated social and healthcare expenditures, and potential legal issues. Beyond the impact on the patient's physical and emotional well-being, unmanaged pain can also influence the quality of care delivered by healthcare providers and, consequently, the broader healthcare system[18,19]. It is important to acknowledge that our paper does not provide a detailed analysis of chronic pain treatment, but rather focuses on the surgical approach for the removal of benign intradural tumors. However, the results of our study suggest that the unilateral approach may be superior to the bilateral approach in terms of improving pain as a main symptom in these patients. Exploring the potential advantages of the unilateral approach in pain management for patients with benign intradural tumors, such as meningiomas and schwannomas, certainly merits further investigation. Subsequent studies could delve deeper into the analysis of medication regimens, usage patterns, treatment durations, and an evaluation of the comprehensive costs linked to the care of these patients.

It is reassuring to hear that none of the cases in our study experienced early or late spinal deformity or instability, and that external bracing was not necessary. Low complication rate, with only one case of transient new neurological deficit and negligible postural headache and meningeal inflammation, is also noteworthy in this study. However, the three cases of CSF leakage/pseudo meningocele requiring reoperation or lumbar drain insertion are a potential concern. While these complications are not uncommon following intradural spinal surgery, they can lead to significant morbidity and may require further intervention.

It is important to continue to monitor and assess the potential risks and benefits of surgical approaches for the removal of benign intradural tumors, and to develop strategies to minimize the risk of complications such as CSF leakage and pseudo meningocele. This may include optimizing surgical techniques, implementing strict postoperative protocols for monitoring and management, and providing appropriate patient education and follow-up care.

Study Limitations

The study suggests that identifying anatomical structures through a narrow surgical corridor can be difficult for beginners and that dural closure is particularly challenging in microsurgical techniques. The study also notes that the choice of surgical approach is subjective and based on the preferences and experience of the individual surgeons. This suggests that there may be variability in the techniques used by different surgeons and highlights the importance of individualized patient care. It is worth noting that this study represents the experience of a single surgeon and may not be generalizable to other surgical contexts or practitioners. Further research is needed to fully understand the challenges and benefits of UHL approaches for intradural schwannoma removal and to develop standardized guidelines for surgical management.

CONCLUSION

When employed accurately and following a reasonable learning curve, the UHL approach offers an efficient and sufficient path to access the dural sac. As a result, it ensures the secure removal of nearly all schwannomas encountered in neurosurgical practice. This technique presents numerous advantages in the management of intraspinal tumors. These benefits encompass its capacity to avert instability, facilitate early mobilization and rehabilitation, limit manipulation of the spinal cord, mitigate blood loss, and diminish postoperative discomfort. These advantages can profoundly influence the patient's recuperation and overall quality of life.

Ethics

Ethics Committee Approval: Ethical approval for this study was obtained from the Ankara City Hospital No. 2 Clinical Research Ethics Committee (decision no: E2-23-5066, date: 27/09/2023).

Informed Consent: Written informed consent was obtained from each patient.

Authorship Contributions

Surgical and Medical Practices: A.E.S., Ö.Ö., A.D., Concept: A.E.S., E.Ç., A.D., Design: E.Ç., A.D., Data Collection or Processing: A.E.S., D.D., Analysis or Interpretation: D.D., Literature Search: E.Ç., Ö.Ö., Writing: A.E.S., E.Ç.

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