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Original Article

Functional outcome and surgical efficacy of minimally invasive tubular retractor system in spinal tumor excision: A prospective cross-sectional study from a tertiary care centre.

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Page | 1

Abstract

Background:

Minimally invasive spinal surgery using tubular retractor systems has gained increasing acceptance in spinal oncology because of reduced tissue trauma, decreased blood loss, and faster postoperative recovery. However, prospective evidence on its functional outcomes and surgical efficacy remains limited.

Aim:

To evaluate the functional outcome and surgical efficacy of minimally invasive tubular retractor systems in spinal tumor excision.

Methods:

This prospective observational study was conducted at Kokilaben Dhirubhai Ambani Hospital and Medical Research Institute, Mumbai, over two years. Sixty adult patients (mean age: 48.2 ± 11.4 years; 35 males and 25 females) undergoing minimally invasive spinal tumor excision using tubular retractor systems were enrolled. Functional outcomes were assessed using the Modified McCormick Scale (MMS) and Visual Analog Scale (VAS). Operative duration, blood loss, extent of tumor excision, hospital stay, postoperative complications, and neurological recovery were evaluated.

Results:

Gross total excision was achieved in 48 (80.0%) patients. Favorable MMS grades (I–II) improved significantly from 41.7% preoperatively to 81.7% at 6 months ($p < 0.001$). Mean VAS score decreased from 7.1 ± 1.5 to 2.6 ± 1.1 ($p < 0.001$). Mean blood loss was 285.6 ± 92.4 mL, mean hospital stay was 5.2 ± 1.8 days, and the overall postoperative complication rate was 13.3%.

Conclusion:

Minimally invasive tubular retractor systems provide safe and effective spinal tumor excision with favorable functional recovery and low postoperative morbidity.

Recommendation:

This technique may be considered for appropriately selected patients with spinal tumors.

Keywords: Minimally invasive spinal surgery; tubular retractor system; spinal tumors; functional outcome; surgical efficacy.

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Introduction

Spinal space-occupying lesions that affect the meninges, spinal cord, vertebral column, and surrounding neural tissues are together referred to as spinal tumours. Pain, neurological impairments, gait abnormalities, sensory dysfunction, and spinal instability are common symptoms of these lesions, which can be primary or metastatic. To achieve decompression, tumour removal, neurological function preservation, and spinal column stabilisation, surgical management is still a crucial part of treatment (1). Wide exposure is possible with traditional open spinal tumour surgery, but it is often accompanied by considerable muscle dissection, substantial blood loss, extended hospital stays, postoperative pain, and delayed rehabilitation. Recent developments in operational microscopy, neuronavigation, endoscopy, and tubular retractor technology have led to a significant increase in interest in minimally invasive spinal surgery (MISS). A significant minimally invasive technique that minimises soft tissue injury and permits targeted access to spinal lesions through smaller incisions is the tubular retractor system (2).

Tubular retractors preserve normal muscle and posterior spinal parts while enabling microscopic or endoscopic visualisation of spinal tumours. Reduced intraoperative bleeding, less postoperative discomfort, quicker recovery, fewer infection rates, and faster mobilisation are just a few of the theoretical and practical benefits that these systems offer. Extradural lesions, certain intramedullary tumours, and intradural extramedullary tumours have all been excised using this technique more frequently. Because neurological state directly impacts patient independence, quality of life, and long-term rehabilitation, evaluation of functional outcome following spinal tumour surgery is crucial. Postoperative recovery and ambulatory capacity can be objectively assessed by functional evaluation utilising standardised neurological grading systems like the Modified McCormick Scale (MMS). Determining the viability and safety of minimally invasive techniques also requires assessing surgical efficacy through the degree of tumour removal, complication profile, and perioperative outcomes (3).

Although tubular retractor systems have shown promising results in a number of retrospective studies and case series, there is still a dearth of prospective institutional data from Indian tertiary care facilities. There is conflicting data on long-term neurological recovery and surgical success due to variations in tumour site, pathology, surgical skill, and

follow-up procedures. In order to assess the functional results and surgical effectiveness of minimally invasive tubular retractor systems in spinal tumour excision, the current prospective observational study was carried out at Kokilaben Dhirubhai Ambani Hospital and Medical Research Institute, Mumbai. The goal of the study is to present empirical data on neurological recovery, pain relief, surgical results, and complication rates after minimally invasive spinal tumour surgery (4).

Materials and Methods

Study Design

This was a prospective observational study conducted to evaluate the functional outcomes and surgical efficacy of minimally invasive tubular retractor systems in patients undergoing spinal tumor excision.

Study Setting

The study was conducted in the Department of Neurosurgery and Spine Surgery, Kokilaben Dhirubhai Ambani Hospital and Medical Research Institute, Mumbai, India, over one year from [Month Year] to [Month Year]. Consecutive eligible patients presenting during the study period and fulfilling the selection criteria were recruited.

Study Population

A total of 60 adult patients diagnosed with spinal tumors and scheduled for minimally invasive spinal tumor excision using a tubular retractor system were enrolled.

Inclusion Criteria

- Patients aged ≥ 18 years.
- Radiologically confirmed spinal tumors.
- Patients undergoing minimally invasive spinal tumor excision using a tubular retractor system.
- Patients who provided written informed consent.

Exclusion Criteria

- Previous spinal surgery.
- Severe cardiopulmonary comorbidities precluding surgery.
- Extensive spinal instability requiring open reconstruction.
- Patients with incomplete follow-up.



Study Size

The study included **60 consecutive eligible patients** treated during the study period. The sample size was determined based on the expected patient volume at the study center within the study duration and the feasibility of prospective recruitment, ensuring adequate representation of patients undergoing minimally invasive spinal tumor excision.

Bias

Potential sources of bias were minimized by prospectively enrolling **consecutive eligible patients** according to predefined inclusion and exclusion criteria. Standardized surgical techniques and postoperative management protocols were followed for all participants. Functional outcomes were assessed using validated instruments, including the **Modified McCormick Scale (MMS)** and **Visual Analog Scale (VAS)**, at predefined follow-up intervals to ensure consistency in outcome assessment.

Data Collection

Demographic characteristics, tumor location and type, operative duration, intraoperative blood loss, extent of tumor excision, duration of hospital stay, postoperative complications, neurological status, and functional outcomes were recorded prospectively. Functional recovery was assessed using the Modified McCormick Scale and Visual Analog Scale before surgery and at scheduled postoperative follow-up visits.

Ethical Considerations

The study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval was obtained from the Institutional Ethics Committee of Kokilaben Dhirubhai Ambani Hospital and Medical Research Institute, Mumbai. Written informed consent was obtained from all participants before enrollment.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 26.0. Continuous variables were expressed as mean $\pm$ standard deviation (SD), whereas categorical variables were presented as frequency and percentage. Paired *t*-tests and repeated-measures ANOVA were used to compare continuous variables, while the chi-square test was applied for categorical variables. A *p*-value <0.05 was considered statistically significant.

Results

A total of 60 patients were included in the study. The mean age was 48.2 ± 11.4 years, with 35 (58.3%) males and 25 (41.7%) females. Intradural extramedullary tumors were the most common tumor type (53.3%), followed by intramedullary (23.3%) and extradural tumors (23.3%). Thoracic tumors constituted the largest proportion (48.3%), followed by cervical (30.0%) and lumbar tumors (21.7%). No statistically significant difference was observed in tumor distribution across locations (*p* = 0.46).

Table 1: Baseline Demographic and Tumor Characteristics

Parameter	Value
Mean Age (years)	48.2 ± 11.4
Male/Female	35 / 25
Intradural Extramedullary Tumors	32 (53.3%)
Intramedullary Tumors	14 (23.3%)
Extradural Tumors	14 (23.3%)
Thoracic Tumors	29 (48.3%)
Cervical Tumors	18 (30.0%)
Lumbar Tumors	13 (21.7%)

p-value for tumor distribution: 0.46

The mean operative duration was 172.4 ± 34.2 minutes. The average intraoperative blood loss was 285.6 ± 92.4 mL, which was statistically significant (*p* < 0.001). Gross total excision was achieved in **48 (80.0%)** patients, while **12**

(20.0%) underwent subtotal excision (*p* = 0.002). The mean hospital stay was 5.2 ± 1.8 days, demonstrating a significant reduction in postoperative hospitalization (*p* < 0.001).



Table 2: Operative and Surgical Efficacy Outcomes

Parameter	Value	p-value
Mean Operative Time (min)	172.4 ± 34.2	0.07
Mean Blood Loss (mL)	285.6 ± 92.4	<0.001*
Gross Total Excision	48 (80.0%)	0.002*
Subtotal Excision	12 (20.0%)	
Mean Hospital Stay (days)	5.2 ± 1.8	<0.001*

Significant improvements in neurological function were observed following surgery. The proportion of patients with favorable Modified McCormick Scale (Grades I–II) increased from **41.7%** preoperatively to **81.7%** at 6 months ($p < 0.001$). Mean VAS pain scores decreased significantly

from **7.1 ± 1.5** to **2.6 ± 1.1** ($p < 0.001$). Independent ambulation improved from **48.3%** to **85.0%**, while the proportion of patients with motor power $\geq 4/5$ increased from **55.0%** to **83.3%**, indicating substantial postoperative functional recovery.

Table 3: Functional Neurological Outcomes

Parameter	Preoperative	6 Months	p-value
Favorable MMS Grade (I–II)	25 (41.7%)	49 (81.7%)	<0.001*
Mean VAS Score	7.1 ± 1.5	2.6 ± 1.1	<0.001*
Independent Ambulation	29 (48.3%)	51 (85.0%)	<0.001*
Motor Power $\geq 4/5$	33 (55.0%)	50 (83.3%)	0.003*

The overall postoperative complication rate was **13.3%** ($p = 0.04$). Individual complications, including cerebrospinal fluid leak, surgical site infection, neurological worsening, and respiratory complications, each occurred in **2 (3.3%)**

patients. These findings indicate a relatively low incidence of postoperative complications associated with the minimally invasive tubular retractor technique.

Table 4: Postoperative Complications

Complication	Number (%)	p-value
CSF Leak	2 (3.3%)	0.29
Surgical Site Infection	2 (3.3%)	0.31
Neurological Worsening	2 (3.3%)	0.28
Respiratory Complications	2 (3.3%)	0.33
Overall Complications	8 (13.3%)	0.04*

Figure 1 illustrates the extent of tumor excision achieved during surgery. Gross total excision was accomplished in **80%** of patients, whereas **20%** underwent subtotal excision,

demonstrating the effectiveness of the minimally invasive tubular retractor system in achieving satisfactory tumor removal.

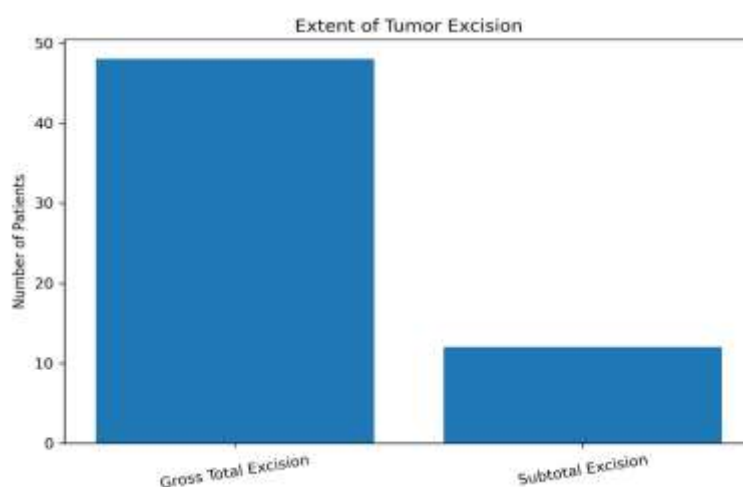


Figure 1: Extent of tumor excision

Figure 2 demonstrates the improvement in neurological functional status following surgery. The proportion of patients with favorable MMS grades increased markedly from **41.7%** before surgery to **81.7%** at the 6-month follow-up.

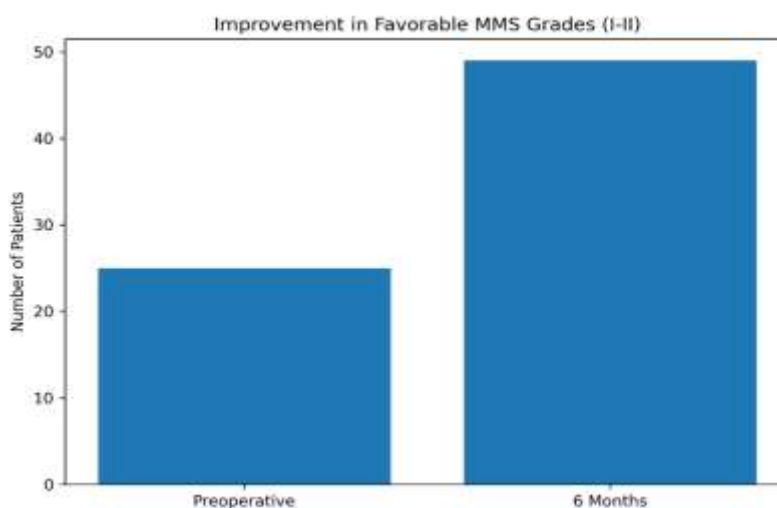


Figure 2: Improvement in favourable MMS grades (I-III)

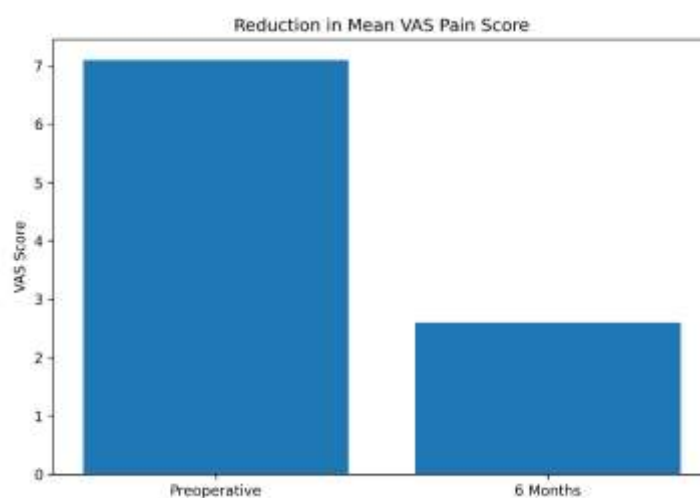


Figure 3: Reduction in mean VAS pain score

Figure 3 shows the significant reduction in postoperative pain. The mean VAS score decreased from 7.1 ± 1.5 before surgery to 2.6 ± 1.1 at 6 months, reflecting substantial pain relief after minimally invasive spinal tumor excision.

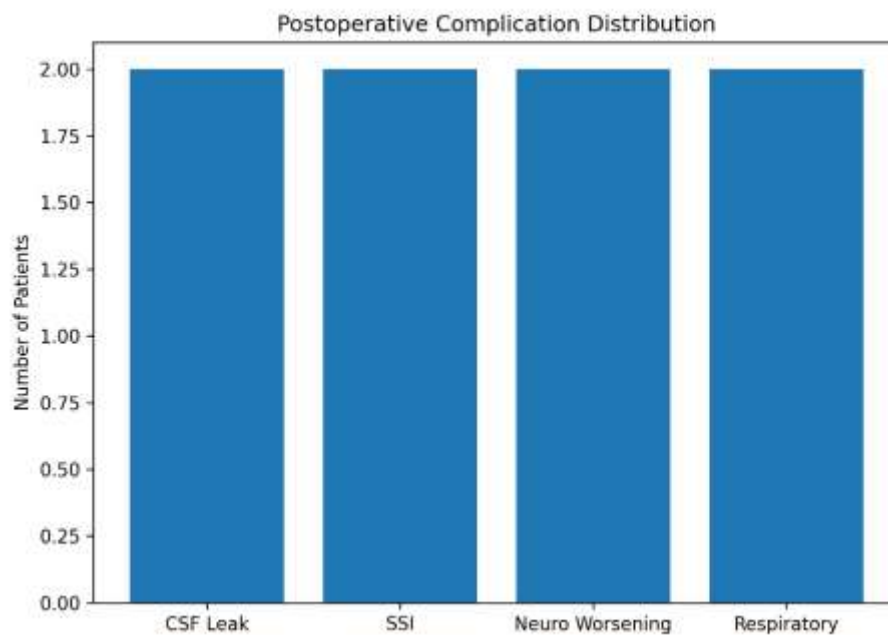


Figure 4: Postoperative complication distribution



Figure 4 presents the distribution of postoperative complications. The incidence of individual complications remained low, with each complication occurring in 3.3% of patients, resulting in an overall complication rate of 13.3%.

Page | 7 Discussion

The present prospective observational study evaluated the functional outcomes and surgical efficacy of minimally invasive tubular retractor systems in spinal tumor excision at a tertiary care center. The findings demonstrated favorable neurological recovery, significant pain reduction, a high rate of gross total tumor excision, and a low incidence of postoperative complications, highlighting the effectiveness of minimally invasive tubular retractor systems in appropriately selected patients.

One of the most important findings of the present study was the achievement of gross total excision in 80.0% of patients. This indicates that tubular retractor systems provide adequate surgical exposure while minimizing damage to surrounding soft tissues. Similar findings have been reported by previous studies, which demonstrated that minimally invasive tubular retractor-assisted surgery achieves satisfactory tumor resection with reduced muscle injury and preservation of spinal stability while maintaining surgical efficacy comparable to conventional open approaches (5).

The present study also demonstrated significant improvement in neurological function following surgery. The proportion of patients with favorable Modified McCormick Scale (MMS) grades increased from 41.7% preoperatively to 81.7% at the 6-month follow-up. These findings are consistent with previous reports showing that minimally invasive spinal surgery is associated with improved neurological recovery, functional independence, and better postoperative quality of life following adequate spinal cord decompression and tumor excision (6). Improvement in motor power and ambulatory status observed in the present study further supports the role of minimally invasive techniques in promoting functional recovery.

A significant reduction in postoperative pain was also observed, with the mean Visual Analog Scale (VAS) score decreasing from 7.1 ± 1.5 preoperatively to 2.6 ± 1.1 at six months. Similar reductions in postoperative pain have been reported by previous studies evaluating tubular retractor-assisted spinal surgery, where limited muscle dissection and preservation of posterior spinal musculature contributed to lower postoperative pain, earlier mobilization, and faster

rehabilitation (7). Additionally, the relatively low intraoperative blood loss and shorter hospital stay observed in the present study are comparable to findings reported in earlier studies evaluating minimally invasive spinal procedures (7).

The overall postoperative complication rate in the present study was 13.3%, with cerebrospinal fluid leak, surgical site infection, neurological worsening, and respiratory complications occurring infrequently. These findings are in agreement with previous studies that have reported low complication rates following minimally invasive spinal surgery, primarily because of reduced tissue disruption, smaller surgical incisions, and preservation of normal paraspinal musculature (8). Nevertheless, minimally invasive tubular surgery requires careful patient selection and considerable surgical expertise, particularly in patients with large, highly vascular, or circumferential spinal tumors where visualization may be limited (8).

Overall, the findings of the present study are comparable with those reported in previous literature and support the growing evidence that minimally invasive tubular retractor systems provide safe and effective spinal tumor excision with favorable neurological recovery, reduced postoperative pain, lower perioperative morbidity, and shorter hospitalization. However, larger multicenter prospective studies with longer follow-up are required to further validate these findings and evaluate long-term oncological outcomes.

Generalisability

The findings of this study may be generalized to adult patients undergoing minimally invasive spinal tumour excision in tertiary care hospitals with appropriate neurosurgical expertise and infrastructure. The use of standardized surgical techniques and validated functional outcome measures enhances the external validity of the results. However, because this was a single-center study with a relatively small sample size, caution should be exercised when extrapolating these findings to other healthcare settings, different patient populations, or institutions with varying levels of surgical experience. Further multicenter studies involving larger and more diverse populations are required to confirm the generalizability of these findings.

Conclusion

A safe and efficient surgical method for removing spinal tumours is the use of minimally invasive tubular retractor



systems. Following minimally invasive spinal tumour surgery, the current prospective observational study showed notable functional neurological improvement, significant pain reduction, good tumour excision rates, and low postoperative complication rates. Tubular retractors minimised tissue damage, blood loss, surgical pain, and hospital stay while enabling sufficient tumour access. The positive effects of minimally invasive surgery on patient recovery and quality of life are demonstrated by the notable improvement in ambulatory function and Modified McCormick Scale grades. Compared to open surgery, the method has a number of benefits, such as less soft tissue damage, quicker recovery, lower wound morbidity, and earlier mobilisation. These advantages are particularly significant for patients with spine cancer, who often have other systemic comorbidities and a poor neurological state. To achieve the best results, however, thorough preoperative planning, surgical skill, and patient selection are still crucial. Open surgical techniques may still be necessary for complex lesions involving widespread spinal instability or circumferential tumour dissemination. To assess recurrence rates, oncological management, and survival outcomes, more multicentric comparative studies with bigger sample sizes and long-term follow-up are needed. All things considered, minimally invasive tubular retractor-assisted spinal tumour excision seems to be a viable and useful technique in modern spine oncology surgery.

Limitations

The present study has several limitations. First, it was conducted at a single tertiary care center with a relatively small sample size, which may limit the generalizability of the findings. Second, long-term oncological outcomes, including tumor recurrence and overall survival, were not evaluated because of the limited follow-up period. Third, the absence of a comparative group undergoing conventional open spinal tumor surgery prevented direct comparison between the two surgical approaches. Finally, variations in tumor pathology and anatomical location may have influenced surgical outcomes. Future multicenter studies with larger sample sizes and longer follow-up periods are warranted to validate these findings.

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Data Availability

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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List of Abbreviations

MISS: Minimally Invasive Spinal Surgery

MMS: Modified McCormick Scale

VAS: Visual Analog Scale

CSF: Cerebrospinal Fluid

SPSS: Statistical Package for the Social Sciences

SD: Standard Deviation

MRI: Magnetic Resonance Imaging

Author Contributions

Rahul Deo: Conceptualization, study design, patient recruitment, data collection, manuscript preparation, and final approval.

Anirudha Doshi: Surgical procedures, supervision, methodology development, manuscript review, and final approval.

Prathamesh Pathrikar: Data collection, statistical analysis, interpretation of results, manuscript drafting, and literature review.

Sumitkumar Pundlik Bhagat: Data acquisition, manuscript editing, critical revision of the manuscript, and final approval.

All authors read and approved the final manuscript.

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