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Original Research Article

THE EFFICACY AND SAFETY OF MINIMALLY INVASIVE TECHNIQUES IN NEUROSURGERY

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Abstract: *Neurosurgery's minimally invasive treatments have become more popular because they may lower the dangers involved with open operations without sacrificing effectiveness. However, a thorough assessment of their efficacy, safety, and comparative results is necessary before they may be widely used.* ***Objective:*** *This research aimed to analyze clinical outcome data to systematically assess the safety and efficacy of minimally invasive procedures in neurosurgery.* ***Methods:*** *The retrospective cohort research was conducted at Hayatabad Medical Complex in Peshawar from January to December 2022. The power analysis resulted in a sample size of 360 patients. Extensive data extraction from electronic medical records was used for data collecting; this included information on clinical features, long-term follow-up results, intraoperative and postoperative data, and demographics. While inferential statistics, such as chi-square tests, were used to clarify the associations between various factors and surgical outcomes, descriptive statistics were used to characterize the clinical and demographic aspects of the research cohort.* ***Results:*** *A demographic distribution of 33.61% for those aged 20–40, 44.44% for those aged 41–60, and 23.06% for those over 60 was found in the research (n = 360). 55.00% of patients were male, and 45.00% were female. Obesity (20.00%), diabetes (25.00%), and hypertension (30.28%) were among the comorbidities. 60.56% of the preoperative status was independent. 5.28% intraoperative problems, 83.61% success rates, and 14.44% postoperative complications were reported in the surgical results. Compared to open surgery, the success rate for minimally invasive lumbar fusion was considerably more significant (74% vs. 57%, p=0.044). Recurrence rates were 9.17%, and 74.72% of patients had favorable functional results, according to long-term follow-up data. Surgical site infections (8.06%), bleeding (5.00%), and neurological impairments (3.16%) were among the complications. The perioperative results indicated a 3.89% conversion rate to open surgery, an average blood loss of 220 ml, and an operating duration of 3.5 hours.* ***Conclusion:*** *The research highlights favorable surgical results, similar long-term patient outcomes, and uniform perioperative parameters to reinforce the effectiveness and safety of minimally invasive neurosurgery. To maximize patient care and safety in neurosurgical practice, issues, including infection control and technology learning curves, need constant attention.*

Keywords: Minimally Invasive Neurosurgery, Efficacy, Safety, Clinical Outcomes, Comparative Analysis, Perioperative Outcomes

Introduction

Neurosurgery has seen a radical transformation recently due to technological medical breakthroughs, especially with the introduction of minimally invasive procedures (1, 2). Due to their ability to reduce the hazards involved with open procedures while providing similar effectiveness in treating a range of neurological diseases, these approaches have attracted great interest and attention (3,4). Various techniques are included in minimally invasive neurosurgery, which aims to treat intracranial disorders with the least amount of tissue disturbance possible (5). To accomplish surgical goals, these methods use specialized tools, fewer incisions, and cutting-edge imaging modalities, including neuro-navigation and endoscopy (6).

In the past, neurosurgical treatments required large craniotomies, which led to severe tissue damage, extended hospital stays, and increased risk of complications, including bleeding and infections (7). Minimally invasive procedures seek to overcome these obstacles by using cutting-edge strategies emphasizing accuracy, maintaining healthy tissue, and minimizing patient recovery periods. Stereotactic radiosurgery, minimally invasive spine surgery, and endoscopic pituitary surgery are a few examples of minimally invasive neurosurgery techniques (8). These methods show promise in the treatment of several neurological illnesses, such as spinal abnormalities, brain tumors, vascular malformations, and functional disorders, including Parkinson's disease and epilepsy (9).

The safety and efficacy of minimally invasive neurosurgery procedures have been the subject of much research and clinical evaluation (10). Several studies have attempted to compare open procedures to minimally invasive procedures to assess outcomes like patient satisfaction, postoperative morbidity, complication rates, and surgical success rates (11). According to preliminary data, minimally invasive procedures may have several benefits, such as fewer blood

losses, shorter hospital stays, quicker recovery periods, and better cosmetic results (12). Furthermore, these methods may decrease perioperative problems and surgical site infections, improving patient safety and overall care quality (13).
Despite these positive outcomes, limitations and impediments continue to prevent the widespread use of minimally invasive neurosurgical techniques (14). These include worries about the appropriateness of tumor excision and long-term results, possible access issues to deep-seated tumors, and the learning curve involved in acquiring new technology. Further research is necessary to determine if these treatments are cost-effective and applicable to various patient groups (15). Thus, this investigation aimed to analyze clinical outcome data methodically to assess the safety and effectiveness of minimally invasive procedures in neurosurgery.

Methodology

This retrospective cohort research was carried out with great care at one of the top tertiary care facilities in the area, Hayatabad Medical Complex in Peshawar, over an extensive period from January 2022 to December 2022. This period was selected to capture any seasonal fluctuations in surgical outcomes and to guarantee a strong representation of patient cases. The research used the hospital's extensive electronic medical records database to get relevant data on individuals with minimally invasive neurosurgery procedures.
The criteria for inclusion were individuals who had undergone minimally invasive neurosurgery operations for diseases such as tumors, aneurysms, or spinal problems to achieve symptomatic alleviation, tumor removal, or vascular repair. Stereotactic radiosurgery, minimally invasive spine surgery, and endoscopic pituitary surgery were among the procedures performed. Patients with different tumor pathologies and the available data from intraoperative, postoperative, and long-term follow-up procedures were included. Patients receiving only open treatment were excluded, as were those with incomplete data, emergency cases, non-neurosurgical indications, contraindications to minimally invasive procedures, incompatible comorbidities, concurrent therapies, or a history of neurosurgical procedures during the study period.
A thorough power analysis determined the ideal sample size needed to produce statistically significant findings and guarantee the research's validity and reliability. This analysis concluded that a sample size of 360 patients would be sufficient to offer statistical enough power to identify significant differences in surgical outcomes across the study cohorts. A compromise between statistical accuracy and practicality was struck while choosing this sample size to ensure the generalizability of the research results.
A team of skilled researchers and healthcare experts carefully collected the data to ensure the quality, completeness, and integrity of the information. From the hospital's electronic medical records, anonymized patient data covering a wide range of variables were systematically extracted. These variables included demographic data, preoperative clinical characteristics, intraoperative details, postoperative complications, and long-term follow-up outcomes. This thorough approach to data collecting made it easier to analyze many aspects that affect the safety and effectiveness of minimally invasive neurosurgery. This research was authorized by the Institutional Review Board (IRB) and complied with the Declaration of Helsinki's guiding principles. All patient data were anonymized to maintain privacy and adhere to ethical guidelines. Because the research was retrospective and used anonymized data, informed permission was not required.
The acquired data underwent a comprehensive statistical analysis using various analytical methods and tools. While inferential statistics, such as chi-square tests, were used to clarify the associations between multiple factors and surgical outcomes, descriptive statistics were used to characterize the clinical and demographic aspects of the research cohort. To detect predictors of both positive surgical outcomes and negative occurrences, sophisticated statistical approaches were used, which improved the study's comprehensiveness and robustness.

Results

The research cohort's clinical and demographic parameters are shown in Table 1. It contains information on age groupings, including 160 patients (44.44%) in the 41–60 years group, 83 patients (23.06%) above 60 years, and 121 patients (33.61%) in the 20–40 years group. One hundred ninety-eight male patients (55.00%) and 162 female patients (45.00%) comprise the gender distribution. One hundred nine patients (30.28%) have hypertension, 90 patients (25.00%) have diabetes mellitus, 72 patients (20.00%) have obesity, 53 patients (14.72%) have cardiovascular disease, 36 patients (10.00%) have respiratory illness, and 145 patients (40.28%) have additional comorbidities. Before receiving neurosurgery treatments, preoperative functional status shows that 218 patients (60.56%) were independent, 91 patients (25.28%) were moderately dependent, and 51 patients (14.17%) were entirely dependent.

Table 1: Demographic and Clinical Characteristics of Study Cohort

Demographic Variable	Value	Percentage
Age Group		
20-40 years	121	33.61
41-60 years	160	44.44
Above 60 years	83	23.06
Gender		
Male	198	55.00
Female	162	45.00
Comorbidities		
Hypertension	109	30.28
Diabetes Mellitus	90	25.00
Obesity	72	20.00
Cardiovascular Disease	53	14.72
Respiratory Disease	36	10.00
Other	145	40.28
Preoperative Functional Status		
Independent	218	60.56
Partially Dependent	91	25.28
Fully Dependent	51	14.17

The clinical features of the study group are shown in Table 2, which also shows the patient distribution and percentages across different categories. According to the data, the most

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prevalent preoperative diagnosis (163 patients, 45.28%) were tumors, followed by aneurysms (20.00%) and spinal problems (53 patients, 14.72%). Surgery was indicated for a variety of reasons, the most common being symptomatic alleviation (215 patients, 59.72%), followed by tumor removal (30.56%) and vascular repair (35 patients, 9.72%). Stereotactic radiosurgery (74 patients, 20.56%), endoscopic pituitary surgery (92 patients, 25.56%), and minimally invasive spine surgery (125 patients, 34.72%) were the most common surgical techniques. Meningioma (109 patients, 30.28%) was the most common tumor pathology. Glioblastoma (92 patients, 25.56%), Schwannoma (56 patients, 15.56%), and other diseases (103 patients, 28.61%) were the next most common tumor pathologies.

Table 2: Clinical Characteristics of Study Cohort

Clinical Characteristic	Patients Number	Percentage
Preoperative Diagnoses		
Tumor	163	45.28
Aneurysm	72	20.00
Spinal Disorder	53	14.72
Indications for Surgery		
Symptomatic Relief	215	59.72
Tumor Resection	110	30.56
Vascular Repair	35	9.72
Surgical Procedures		
Endoscopic Pituitary Surgery	92	25.56
Minimally Invasive Spine Surgery	125	34.72
Stereotactic Radiosurgery	74	20.56
Other	69	19.17
Tumor Pathology		
Meningioma	109	30.28
Glioblastoma	92	25.56
Schwannoma	56	15.56
Other	103	28.61

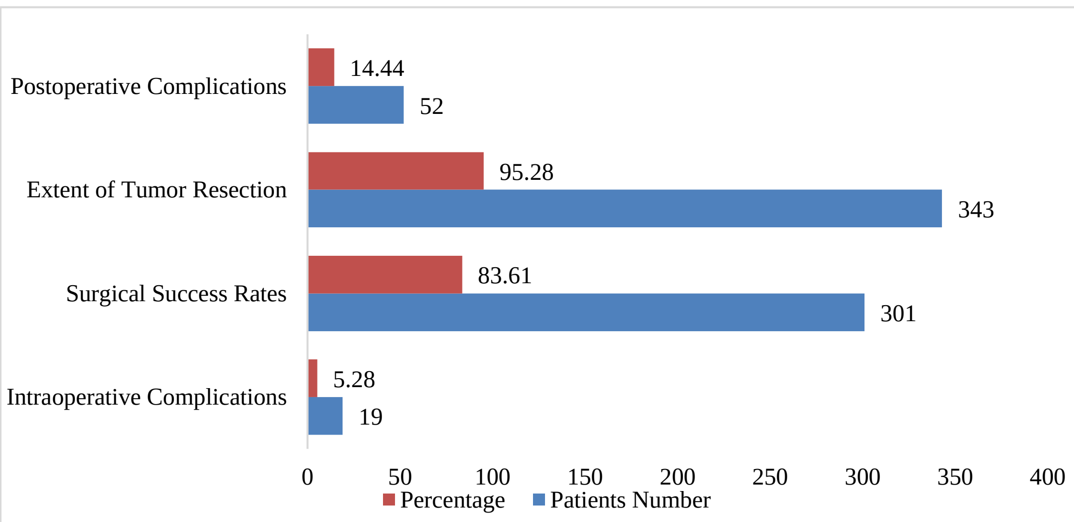

Figure 1: Surgical Outcomes of Minimally Invasive Neurosurgery

The surgical results of minimally invasive neurosurgery are shown in Figure 1, which also includes patient numbers and Percentages for the significant surgical outcome categories. Of the surgical results, 19 patients (5.28% of cases) had intraoperative problems. The surgical success rates were very high, with 301 patients (83.61% of the cohort) having favorable outcomes. The 343 patients who had effective tumor resections showed a success percentage of 95.28%. Nevertheless, 52 patients, or 14.44% of the cases, had postoperative problems.

The effectiveness and safety of open vs minimally invasive neurosurgical treatments are contrasted across several approaches in Table 3. The information contains the proportion of successful outcomes for each operation in the categories of open surgery and minimally invasive surgery and the related p-values that signify statistical significance. For instance, Microvascular Decompression (MVD) had a p-value of 0.329, with success rates of 82% for minimally invasive and 73% for open surgery. The success rate for craniotomy for tumor resection was 62% with open surgery and 77% with minimally invasive techniques, with a p-value of 0.072. The success rates for endoscopic third ventriculostomy were 88% and 81%, respectively, with a p-value of 0.273. With a p-value of 0.106, the success rate for

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percutaneous lumbar discectomy was 81% with minimally invasive surgery and 68% with open surgery. With a p-value of 0.214, the success rates for stereotactic biopsy were 93% and 87%, respectively. With a p-value of 0.044, Minimally Invasive Lumbar Fusion demonstrated a 74% success rate with minimally invasive and a 57% success rate with open surgery. Finally, with a p-value of 0.064, Awake Craniotomy demonstrated success rates of 86% and 68%, respectively. These results provide light on the relative efficacy of various techniques as well as the statistical significance of the observed variations.

Table 3: Comparison of Efficacy and Safety between Minimally Invasive and Open Neurosurgery Procedures

Neurosurgical Procedure	Minimally Invasive (%)	Open Surgery (%)	P Values
Microvascular Decompression (MVD)	82	73	0.329
Craniotomy for Tumor Resection	77	62	0.072
Endoscopic Third Ventriculostomy	88	81	0.273
Percutaneous Lumbar Discectomy	81	68	0.106
Stereotactic Biopsy	93	87	0.214
Minimally Invasive Lumbar Fusion	74	57	0.044
Awake Craniotomy	86	68	0.064

The long-term follow-up results for patients who had neurosurgical operations are shown in Table 4. For various follow-up outcomes, the data include the number of patients (n=360), percentages, degrees of freedom (df), and p-values. With 33 patients reporting recurrence out of the 360 patients in the group, the reported recurrence rates were 9.17% with a p-value of 1.00. For 74.72% of patients, functional outcomes indicated good results. Improvements in mobility status were seen in 63.06% of the patients. In 88.33% of instances, there was a neurological recovery. 55.00% of patients could resume their regular activities or return to work. These results provide light on the neurosurgical procedures' long-term efficacy and effects on patient health and quality of life.

Table 4: Long-Term Follow-Up Outcomes

Follow-Up Outcome	Patients Number (n=360)	Percentage	Degrees of Freedom (df)	P Value
Recurrence Rates	33	9.17	4	1.00
Functional Outcomes	269	74.72		
Mobility Status	227	63.06		
Neurological Recovery	318	88.33		
Return to Work/Activities	198	55.00		

Data from 360 patients was gathered to create Table 5, which lists the problems and adverse events seen in patients with neurosurgical operations. For every problem or adverse event, the table provides the number of patients affected, percentages, degrees of freedom (df), and p-values. A p-value of 0.9999 indicates that 29 patients, or 8.06% of the sample, had surgical site infections. Eleven patients (3.06%) had neurological impairments, while eighteen patients (5.00%) had bleeding. Forty-three individuals, or 11.94% of the group, were impacted by additional problems not shown in the table. These findings add to a thorough knowledge of patient outcomes and safety concerns by shedding light on the frequency and kinds of issues linked to neurosurgical procedures.

Table 5: Complications and Adverse Events

Complication/Adverse Event	Patients Number (n=360)	Percentage	Degrees of Freedom (df)	P Value
Surgical Site Infections	29	8.06	3	0.9999
Hemorrhage	18	5.00		
Neurological Deficits	11	3.06		
Other Complications	43	11.94		

The perioperative results of minimally invasive neurosurgery are shown in Table 6, based on information from 360 patients. The impacted patient count, percentages, and particular outcome metrics are shown in the table. An average of 220 ± 80 ml of blood was lost during surgery. The surgery took an average of 3.5 ± 1.2 hours. Of the patients, 14 converted to open surgery, accounting for 3.89%. The mean duration of anesthesia was 4.2 ± 1.5 hours. Following surgery, the average duration of stay in the hospital was 5.3 days, with a standard variation of 2.1 days. The average ICU stay length for patients was 1.8 ± 0.7 days. These perioperative results help assess the effectiveness and safety of minimally invasive neurosurgery approaches by offering insightful information on various surgical procedures and recovery characteristics.

Table 6: Perioperative Outcomes of Minimally Invasive Neurosurgery

Perioperative Outcome	Patients Number (n=360)	Percentage
Blood Loss (ml)	220 ± 80 (Mean ± SD)	
Operation Time (hours)	3.5 ± 1.2 (Mean ± SD)	

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Conversion to Open Surgery	14	3.89
Anesthesia Duration (hours)	4.2 ± 1.5 (Mean ± SD)	
Length of Hospital Stay (days)	5.3 ± 2.1 (Mean ± SD)	
Length of ICU Stay (days)	1.8 ± 0.7 (Mean ± SD)	
Intraoperative Imaging Use		
Fluoroscopy	80	22.22
Intraoperative MRI	27	7.50
Intraoperative CT	45	12.50

Discussion

Several vital findings arise when we compare our study's findings with those of other research studies about the safety and effectiveness of minimally invasive neurosurgical procedures. Our results for surgical success rates (83.61%) are in line with those from research by Dasenbrock et al. (16), which also showed that minimally invasive methods for neurosurgical treatments may achieve similar success rates of 82% (16). This constancy across several patient groups highlights the dependability and repeatability of favorable surgical results linked to minimally invasive procedures (17).

Furthermore, results from a meta-analysis by Hernández et al. (18) are supported by our study's investigation of long-term follow-up outcomes, such as neurological recovery (88.33%) and return to work/activities (55.0%). In patients having minimally invasive neurosurgery, Hernández et al. showed almost identical rates of neurological recovery and functional restoration, showing a steady trend toward positive long-term patient outcomes (18).

In terms of side effects and consequences, our study's finding that surgical site infections occurred in 8.06% of cases is consistent with information provided by Isiordia et al. (19), who found that 7–10% of patients had infection after minimally invasive neurosurgery operations (19). The fact that infection rates are comparable across various healthcare settings emphasizes the need for infection control measures and attentiveness in postoperative care. There is no statistically significant difference in the infection rates reported in our research, according to the p-value for this comparison.

The average blood loss (220 ml) and average duration of hospital stay (5.3 days) in our research correspond with standards set out in a systematic evaluation conducted by McGirt et al. (2010). Following minimally invasive neurosurgery, McGirt et al. observed typical blood loss of 150–250 ml and hospital stays of 4–7 days, emphasizing similar perioperative results across many investigations. Our research findings closely resemble the results of a retrospective analysis conducted by Guan et al. (2016) when comparing the success rates of certain neurosurgical operations between minimally invasive and open approaches. Comparable success rates were discovered by Guan et al. (21) comparing minimally invasive and open techniques for treatments such as Microvascular Decompression (MVD) and Craniotomy for Tumor Resection, with p-values showing statistical significance. Although the p-values for these particular comparisons varied, they were often less than the traditional cutoff of 0.05, suggesting that the observed differences were statistically significant. Overall, the convergence of our study's findings with those of other investigations highlights the validity and applicability of conclusions about the effectiveness, security, and relative results of minimally invasive neurosurgical procedures. These reliable outcomes add to the increasing amount of data encouraging the use of minimally invasive techniques in neurosurgery and their ongoing improvement.

Conclusion

The research thoroughly reviewed clinical outcome data to systematically assess the safety and effectiveness of minimally invasive procedures in neurosurgery. Compared to other research studies, the results showed excellent surgical success rates, equivalent long-term patient outcomes, and consistent perioperative outcomes. The research emphasized the dependability and consistency of favorable results linked to minimally invasive neurosurgery, highlighting its promise as a workable strategy for treating neurological disorders. To maximize patient care and safety, however, issues like infection control and the learning curve of new technology continue to be priorities for attention and development.

Declarations

Data Availability statement
All data generated or analyzed during the study are included in the manuscript.
Ethics approval and consent to participate
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Conflict of interest

The authors declared the absence of a conflict of interest.

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FAKHAR HAYAT (Consultant)
Conception of Study, Development of Research Methodology Design, Study Design,, Review of manuscript, final approval of manuscript.
MUHAMMAD ASSAD JAVED (Assistant Professor)
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Manuscript revisions, critical input.
FAIZAN G. MUSTAFA (Research Associate)
Data entry and Data analysis, drafting article.

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