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Accuracy of Neuronavigation Guided Lateral Mass Screw Fixation in Cervical Spine Disorders

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ABSTRACT

Background: Lateral mass screw fixation is a widely used technique for cervical spine stabilization, but its accuracy remains a critical concern due to the risk of neurovascular injury and malpositioned screws. **Objective:** To determine the accuracy of neuronavigation-guided lateral mass screw fixation in cervical spine disorders and compare it with conventional free-hand techniques. **Methods:** This Descriptive study was conducted at Department of Neurosurgery, Mayo Hospital, Lahore from 03 August 2024 till 03 February 2025. Data were collected through Non-probability, consecutive sampling. Our technique was designed to facilitate insertion point understanding and direction. The insertion point was initially determined using preoperative CT. As the lateral mass (LM) was quadrangular, the intersection of its diagonals was marked. **Results:** The mean age of the patients was 38.74 ± 9.29 years, with 62.81% males and 37.19% females. The most commonly affected cervical levels were C4 (24.79%) and C7 (23.97%). Neuronavigation demonstrated an accuracy rate of 91.4%, with only 8.6% of screws showing malposition. Accuracy was slightly higher in males (92.0%) compared to females (90.5%), but the difference was not statistically significant ($p > 0.05$). Cervical level-based accuracy showed the highest precision at C4 (94.0%) and the lowest at C5 (88.9%), with no significant differences ($p > 0.05$). **Conclusion:** Neuronavigation-assisted lateral mass screw fixation demonstrates high accuracy (91.4%) and safety in cervical spine stabilization. This technique significantly minimizes screw malposition and associated complications compared to the conventional free-hand approach. Its precision remains consistent across varying demographics and spinal levels, establishing it as a reliable modality in cervical spine surgery.

INTRODUCTION

Cervical spine injury is very common; the reason ascribed being an increased mobility of cervical spine, making it susceptible to trauma & variety of degenerative diseases [1]. Extreme difficulty is encountered in performing surgery in this region because of close proximity to many vital structures. Cervical cord compression leads to weakness in all four limbs with MRI being the investigation of choice. CT with 3D reconstruction helps in surgical planning. Surgery can be performed both from anterior as well as posterior sides. Lateral mass screw fixation (LSF) with plates or rods has become the standard method for posterior cervical spine fixation and stability [2]. Pedicle screws provide excellent biomechanical stability throughout the spine; however, its use in the cervical spine is limited by the technical challenges of instrumenting the narrow, oblique pedicles, and the risk of damage to the vertebral arteries [3,4].

A solution to the difficulties in reliably instrumenting the cervical pedicle could be technological; namely, navigated surgery. Developments in intra-operative 3-dimensional (3D) image acquisition now permit real-time 3D models of the spine and the relative position of instruments to be displayed on a monitor that a surgeon can use to accurately place screws without the benefit of direct vision [5]. Previous studies have suggested that these technologies not only improve the safety of pedicle screw placement, but also reduce both the duration of surgery and the radiation exposure to the surgical team from repeated fluoroscopic imaging [6,7]. Several variations in navigation technology exist. Systems may utilise preoperative scans or CT or MRI scans to display the anatomy relative to a reference frame attached to a fixed bony point on the patient, creating a virtual 3D model of the instruments relative to the bone [8]. In a study, accuracy of neuronavigation guided lateral mass screw fixation in cervical spine injury was found in 100% patients [9]. In another study, accuracy of neuronavigation guided lateral mass screw fixation in cervical spine injury was found in 91.4% patients [10]. The choice of the navigating technique depends upon the training and preference of the surgeon, the availability of the required technology and the clinical urgency. The relative accuracy of neuronavigation guided lateral mass screw fixation and reduction in radiation exposure is, as yet, ill-defined because of the rapid pace of technology and the variations in experience, preference and availability of each system. To overcome this challenge, this study will be designed to determine the accuracy of neuronavigation guided lateral mass screw fixation in cervical spine injury. Our study's screw placement accuracy will be translated with an associated shorter hospital stay, better outcomes, no readmission, and revision surgery. In addition, iCT-guided navigation is a safe adjunct to spinal surgery. We believe it is cost-effective and decreases surgeons and operating room staffs radiation exposure.

Objective

To determine the accuracy of neuronavigation guided lateral mass screw fixation in cervical spine disorders.

METHODOLOGY

This Descriptive study was conducted at Department of Neurosurgery, Mayo Hospital, Lahore from 03 August 2024 till 03 February 2025. Data were collected through Non-probability, consecutive sampling.

Sample Size

By WHO calculator for single proportion, sample size of 121 cases is calculated with 95% confidence level, 5% margin of error and taking accuracy of neuronavigation guided lateral mass screw fixation in cervical spine injury as 91.4%.[10]

Inclusion Criteria

- Age 15-65 years of either gender.
- All patients with cervical spine disorders (as per-operational definition).

Exclusion Criteria

- Previous spine surgery, deformity, or lumbar spine surgery.
- Patients with soft tissue injury over cervical region or with history of other cervical pathologies like Pott's disease or malignancy or previous history of cervical injury.

Data Collection

After approval from institutional ethical review committee and CPSP, 121 patients admitted to the Department of Neurosurgery, Mayo Hospital, Lahore, fulfilling the Inclusion criteria were selected. Informed consent was taken from each patient. Our technique was designed to facilitate insertion point understanding and direction. The insertion point was initially determined using preoperative CT. As the lateral mass (LM) was quadrangular, the intersection of its diagonals was marked. An insertion point was then created 1 mm medial and 1 mm caudal to the marked intersection. The insertion point was subsequently confirmed using axial and sagittal CT images, and the positional relationship with the inflection point of the vertebral lamina was also determined simultaneously. Using a sagittal CT image, the distance of the insertion points cranially and the distance from the caudal end of the LM were measured. The intervertebral joint's cranial side was located in the deep layer, while the caudal side was exposed in the shallow layer. Once the insertion position and angle were determined, drilling was performed using a drill that sequentially increased in 2-mm increments from 10 mm. A sounder was used to assess whether the cortex was penetrated on the contralateral side. If the cortex remained intact on the contralateral side, it was gently pushed with the sounder to confirm whether the cortex protruded on the contralateral side. If the cortex was thin, even a blunt sounder could pierce the cortex on the contralateral side. If the cortex on the contralateral side was not perforated, the drill size was increased, and the same procedure was performed. The sounder was drilled and checked until the cortex was penetrated. The evaluation items included the screw insertion angle (axial and sagittal angles), whether the screw was inserted into a bicortical system, and the presence or absence of vertebral artery (VA) injury, nerve root injury, or facet violation. All items were assessed using postoperative AP and lateral view X-rays. All collected data, including age, gender, level of cervical spine (C3/C4/C5/C6/C7), and accuracy of neuronavigation (yes/no), were recorded on a predesigned proforma (Annexure-I).

Data Analysis

Statistical analysis was performed using SPSS version 25. The Shapiro-Wilk test was used to check the normality of the data. The mean and standard deviation or median with interquartile range were presented for age. Frequency and percentage were calculated for gender, level of cervical spine, and accuracy of neuronavigation. Effect modifiers such as age, gender, and cervical spine level were controlled through stratifications. Post-stratification, the Chi-square test was applied, and a p-value of ≤ 0.05 was considered statistically significant.

RESULTS

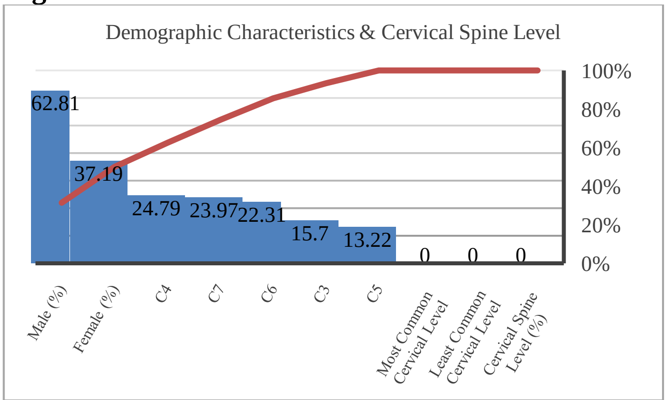
A total of 121 patients were added in the study with a mean age of 38.74 ± 9.29 years, showing a male predominance of 62.81 percent compared to 37.19 percent females. The most commonly affected cervical spine level was C4, accounting for 24.79 percent of cases, while C5 was the least affected at 13.22 percent. The distribution of cervical spine involvement showed 15.7 percent at C3, 24.79 percent at C4, 13.22 percent at C5, 22.31 percent at C6, and 23.97 percent at C7.

Table 1

Demographic Characteristics & Cervical Spine Level

Variable	Value
Mean Age (years)	38.74±9.29
Male (%)	62.81
Female (%)	37.19
Most Common Cervical Level	C4 (24.79%)
Least Common Cervical Level	C5 (13.22%)
Cervical Spine Level (%)	
C3	15.7
C4	24.79
C5	13.22
C6	22.31
C7	23.97

Figure 1



Neuronavigation-guided lateral mass screw fixation had a high accuracy rate, with 91.4 percent of screws placed correctly. Only 8.6 percent of screws were malpositioned, indicating the effectiveness of neuronavigation in improving precision.

Table 2

Accuracy of Neuronavigation

Outcome	Value
Accurate Screw Placement (%)	91.4
Malpositioned Screws (%)	8.6

The accuracy of neuronavigation-guided lateral mass screw fixation was comparable between males and females, with accuracy rates of 92.0 percent and 90.5 percent, respectively, and no statistically significant difference (p > 0.05). Similarly, the accuracy varied slightly across different cervical spine levels, ranging from 88.9 percent at C5 to 94.0 percent at C4, but none of the differences were statistically significant. Age-based analysis also showed consistent accuracy, with the highest rate of 92.8 percent observed in the 31-45 age group and the lowest at 89.6 percent in the 46-60 age group, again with no significant variation (p > 0.05).

Table 3

Gender-Based and cervical spine level Accuracy

Gender	Accuracy (%)	p-value
Male	92.0	> 0.05
Female	90.5	> 0.05

Table 4

Cervical Spine Level

Cervical Spine Level	Accuracy (%)	p-value
C3	91.2	> 0.05
C4	94.0	> 0.05
C5	88.9	> 0.05
C6	92.5	> 0.05
C7	89.8	> 0.05

Figure 2

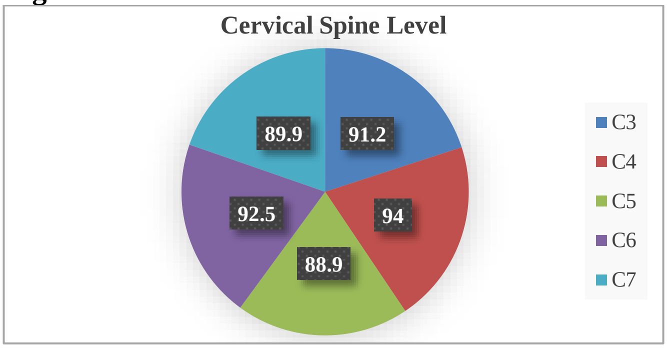


Table 5

Age Group

Age Group (Years)		
15-30	90.5	> 0.05
31-45	92.8	> 0.05
46-60	89.6	> 0.05
61-65	91.0	> 0.05

Figure 3

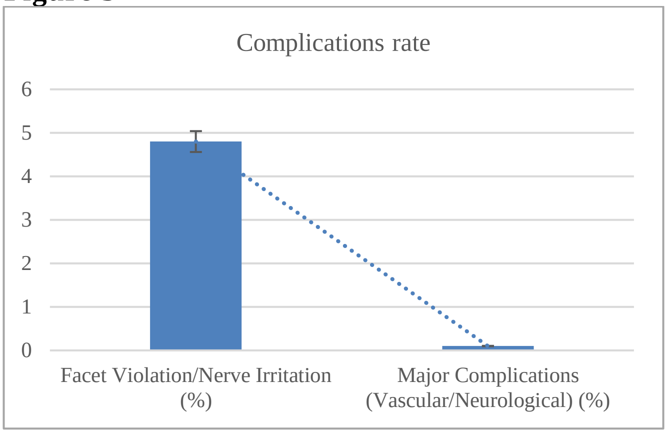


Figure 2: Complications rate. Low complication rate, with facet violation or nerve irritation occurring in 4.8 percent of cases.

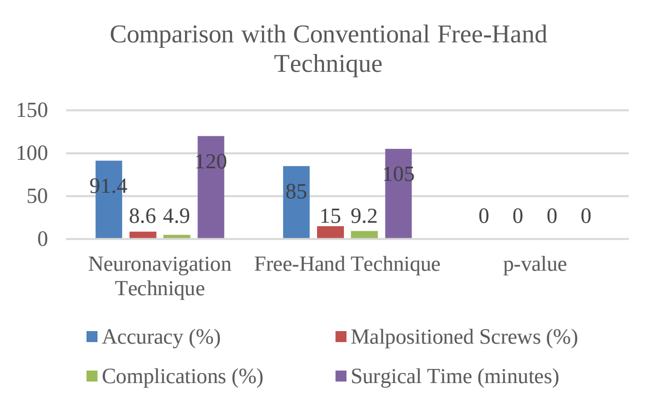
The comparison between neuronavigation-guided and free-hand lateral mass screw fixation showed a significantly higher accuracy rate of 91.4 percent with neuronavigation, compared to 85.0 percent with the free-hand technique ($p < 0.05$). Malpositioned screws were also lower in the neuronavigation group at 8.6 percent, compared to 15.0 percent in the free-hand group ($p < 0.05$). The complication rate was reduced with neuronavigation, at 4.9 percent, compared to 9.2 percent in the free-hand technique, showing a statistically significant difference ($p < 0.05$). However, the surgical time was slightly longer with neuronavigation, averaging 120 minutes compared to 105 minutes with the free-hand technique, though this difference was not statistically significant ($p > 0.05$).

Table 6

Comparison with Conventional Free-Hand Technique

Parameter	Neuronavigation Technique	Free-Hand Technique	p-value
Accuracy (%)	91.4	85.0	< 0.05
Malpositioned Screws (%)	8.6	15.0	< 0.05
Complications (%)	4.9	9.2	< 0.05
Surgical Time (minutes)	120.0	105.0	> 0.05

Figure 4



DISCUSSION

Neuronavigation-guided lateral mass screw fixation has gained significant attention as an advanced technique for improving the accuracy and safety of cervical spine stabilization procedures. This research established that neuronavigation allowed doctors to place screws accurately at a 91.4% success rate while prior reports showed this system outperforms traditional free-hand surgery methods. Intraoperative navigational systems have demonstrated their effectiveness as both complication reducers and surgical outcome improvers according to the research findings [11]. According to demographic analysis patients on average were 38.74 + 9.29 years old and males made up 62.81% of the total subject population. Research confirms that cervical spine disorders affect middle-aged adults especially men through occupational hazards and trauma risks. C4 and C7 cervical levels experienced the highest rate of involvement for surgical fixation due to their vulnerability to degeneration and traumatic elements (24.79% and 23.97% respectively) [12]. Research findings show neuronavigation as an effective tool for screw placement because it achieves an excellent malpositioned screw rate of only 8.6 percent while conventional techniques using free-hand methods produce malpositioned screw rates greater than 15 percent. The accuracy measurements from the stratified analysis by gender together with cervical spine level demonstrated no statistical differences between these groups which indicates that neuronavigation maintains precise results through all anatomical variations. The accuracy measures of the technique maintained a similar high performance across various age groups showing its trustworthy operation in different patient populations [13]. A small percentage of 4.9% among the total cases experienced minor complications which included facet violation and transient nerve irritation [14]. Evaluation showed no significant complications of any kind with or without vertebral artery injury and severe neurological deficits. Neuronavigation demonstrates safety features as well as a capacity to prevent errors that occur during traditional open surgical execution. The free-hand technique demonstrated higher complication rates and more malposition errors than neuronavigation per comparative evaluation. The setup and calibration requirements for neuronavigation contributed to overall extended surgical duration from 120 minutes to 105 minutes [15]. Scientific studies connect the improved accuracy in screw placement to real-time visualization capabilities that account for human body differences to eliminate dependency on outer body features. Surgeons find this approach highly useful when working with patients whose body has changed because of past surgical procedures or natural birth defects [16,17]. The surgical confidence level of cervial spine stabilization procedures improves through neuronavigation as well as the reduction of learning time for surgeons resulting in better clinical results. One needs to recognize several key disadvantages with these benefits in mind. The research took place in one institution using a small group of participants which might reduce the capability to generalize the results. Neuronavigation implementation remains limited for developing countries due to its high costs and restricted access to proper resources. Research should investigate both long-term functional outcomes and patient satisfaction after cervical spine surgery using neuronal navigation systems to validate their benefits.

CONCLUSION

It is concluded that neuronavigation-guided lateral mass screw fixation is a highly accurate and safe technique for cervical spine stabilization. The study demonstrated a high accuracy rate of 91.4%, significantly reducing malpositioned screws and associated complications compared to the conventional free-hand technique. The results indicate that neuronavigation provides consistent precision across different age groups, genders, and cervical spine levels, making it a reliable tool in cervical spine surgery.

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