Early *Versus* Delayed Decompression in Cauda Equina Syndrome: Neurological and Functional Outcomes

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ABSTRACT

Objective: To compare the neurological and functional outcomes of early *versus* delayed surgical decompression in patients with cauda equina syndrome (CES).

Study Design: Descriptive study.

Place and Duration of the Study: Department of Neurosurgery, Medical Teaching Institution, Mardan Medical Complex, Mardan, Pakistan, from June 2020 to May 2025.

Methodology: Adult patients diagnosed with CES who underwent surgical decompression were included. Patients were categorised into the early decompression (ED) group (≤48 hours from symptom onset) and the delayed decompression (DD) group (>48 hours from symptom onset). Neurological function was evaluated using the Modified Frankel Scale (MFS) at presentation and at 12-month follow-up. The primary outcome was bladder function recovery, and secondary outcomes included neurological improvement (≥1-grade improvement on the MFS) and the resolution of saddle paraesthesia. The Fisher's exact test was used for statistical analysis.

Results: Thirty-six patients were included (mean age: 34 years; 66.7% male). CES with urinary retention (CES-R) was spotted in 77.8% of the cases. The most frequently involved levels were L5–S1 (55.6%) and L4–L5 (44.4%). Early surgery was performed in 15 patients (41.7%), while 21 (58.3%) underwent delayed surgical decompression. At one-year follow-up, persistent bladder dysfunction was distinctly lower in the ED group (13.3%) compared to the DD group (47.6%; p = 0.040). Saddle paraesthesia was more common in the DD group, without any statistical significance. Overall, 88.9% of patients displayed improvement of ≥1 Frankel grade, and most regained independent ambulation.

Conclusion: Early surgical decompression within 48 hours of symptom onset is linked with significantly better bladder and neurological outcomes in CES. Systemic delays in diagnosis and referral highlight the urgent need for national CES protocols and efficient referral pathways in resource-limited settings.

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INTRODUCTION

Cauda equina syndrome (CES) is a rare but critical neurosurgical emergency resulting from compression of the lumbosacral nerve roots below the conus medullaris, leading to variable motor, sensory, and autonomic deficits.[1]

A 2020 systematic review predicted the incidence of CES at 0.3–0.6 per 100,000 in the general population, increasing to around 7 per 100,000 among working-age adults.[2] National registry data from Scotland reported an overall incidence of 2.7 per 100,000, rising to 4 per 100,000 in Scottish individuals aged 18–64 years.[3] In South Asia, data remain scarce. A study from India estimated an incidence of 1 per 100,000, with CES reported in 2–3% of lumbar disc herniation cases.[4]

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A 2022 Pakistani series found that CES accounted for 2–4% of lumbar disc surgeries, underscoring its clinical significance despite its low population-wide prevalence.[5]

The clinical presentation of CES includes severe low back pain, bilateral radicular leg pain, saddle anaesthesia, lower limb weakness, and urinary or bowel dysfunction. Among these, bladder dysfunction, particularly urinary retention or altered sensation, is often the initial and most diagnostically significant symptom.[6,7]

CES is broadly classified into incomplete (CES-I) and retention (CES-R) types. CES-I involves altered bladder sensation with preserved voluntary voiding, whereas CES-R presents with painless urinary retention and bladder dysfunction. Prognosis is typically better in CES-I than in CES-R.[8] Neurological outcomes in CES are usually assessed using authenticated tools such as the Modified Frankel Scale (MFS), which grades neurological status from complete motor/sensory loss (Grade A) to normal function (Grade E).[9]

Timely recognition of CES requires urgent spinal MRI when red-flag symptoms such as bilateral radicular leg pain, saddle anaesthesia, or urinary dysfunction are present.[10]

Diagnostic accuracy is significantly higher when post-void residual (PVR) ≥200 ml is observed. A large prospective study found that PVR ≥200 ml had 94% sensitivity and 99% negative predictive value for CES.[11] Other clinical signs, such as decreased anal tone, perineal sensory loss, and absence of the bulbocavernosus reflex (BCR), can further increase diagnostic confidence. In one series, BCR alone established 100% sensitivity and specificity.[12]

Timely surgical decompression is crucial in CES. DeLong *et al*. conducted a meta-analysis of 322 patients and found meaningfully better motor, sensory, urinary, and rectal outcomes when surgery was performed within 48 hours of symptom onset. These findings are reaffirmed by a subsequent large cohort study that also demonstrated superior neurological and functional outcomes with earlier intervention.[13,14]

While data from Pakistan is limited, a tertiary care study from Peshawar reported that 11% of patients underwent lumbar disc surgery presented with CES, signifying a disproportionate burden within surgical cohorts.[15] However, there is no published data from Mardan Medical Complex (MMC) or its catchment area on CES, thereby creating a gap in regional literature.

Despite its critical nature, CES thereby is frequently under-recognised in resource-limited settings, leading to delays in referral, imaging, and surgical intervention. In semi-urban areas such as Mardan, inadequate awareness and restricted neurosurgical access may contribute to poorer outcomes. This study aimed to estimate the institutional burden of CES at MMC, to describe its clinical presentation, to evaluate delays in the diagnosis and management of the disease, and to assess surgical outcomes in relation to the timing of decompression.

METHODOLOGY

This descriptive study was conducted in the Department of Neurosurgery, MMC, a tertiary care centre in Khyber Pakhtunkhwa, Pakistan. A total of 36 consecutive CES cases fulfilling the inclusion criteria were included.

All adult patients (≥18 years) diagnosed with CES who underwent surgical decompression at MMC between 1st June 2020 and 31st May 2025 were included. Patients with complete medical records and at least 12 months of postoperative follow-up were considered for inclusion. Ethical approval was obtained from the Institutional Review Board of BKMC/MMC (Approval No. 178/BKMC).

The diagnosis of CES was made on the basis of clinical presentation and radiological findings. Patients were excluded if CES resulted secondary to trauma, infection, tumour, or spinal anaesthesia. Those patients who did not undergo surgery, were lost to follow-up, or had incomplete documentation were also excluded.

A standardised data collection proforma was used to document demographic, clinical, and radiological information. Collected data included patient age and gender, MRI findings, and time from symptom onset to surgical intervention. Patients were classified into the Early decompression (ED) group (≤48 hours) and Delayed decompression (DD) (>48 hours) group based on the interval from symptom onset to surgery. Symptom onset was defined as the initial documented red-flag signs, such as urinary retention, bilateral leg pain, or saddle anaesthesia, in clinical notes or referral records. For patients with progressive symptoms, the first symptom suggestive of CES was used to minimise recall bias.

Preoperative features included urinary retention, residual motor or sensory deficits, and saddle anaesthesia. Postoperative outcomes at 12-month comprised bladder function, residual motor or sensory deficits, saddle paraesthesia, and ambulatory status. All patients were assessed in person at follow-up clinics by neurosurgical residents using a structured clinical assessment form.

The primary outcome was recovery of bladder function, defined as voluntary voiding without catheterisation at 12 months postoperatively. Secondary outcomes were neurological improvement, (≥1-grade increase on the MFS) and persistence of saddle paraesthesia, indicating incomplete sensory recovery in the sacral dermatomes. The MFS was selected due to its validated application in CES and its compatibility with retrospective review of clinical notes. Neurological status was assessed using the MFS. This scale categorises motor and sensory function as follows: Grade A: complete neurological deficit; Grade B: preserved sensation only; Grade C: preserved motor function but not useful for ambulation; Grade D: useful motor function with the ability to ambulate independently with or without assistance; and Grade E: normal motor and sensory function. For the purposes of this study, Grades D and E were considered to indicate recovery of independent ambulation.

Data were entered into Microsoft Excel and analysed using the SPSS version 22. Categorical variables were shown as frequencies and percentages. For analyses involving small sample sizes or small expected cell counts (<5 in any cell), the Fisher's exact test was an appropriate option. For larger samples with sufficient cell counts, the Chi-square test was used. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 36 patients with CES were included. The mean age was 34 ± 5.08 years, with a male predominance (24 males, 66.7%; 12 females, 33.3%). Of these, 28 patients (77.8%) presented with CES-R, while 8 patients (22.2%) had CES-I. The most frequently involved levels were L5–S1 in 20 patients (55.6%) and L4–L5 in 16 patients (44.4%).

All patients underwent surgical decompression. Early decompression (≤48 hours from symptom onset) was performed in 15 patients (41.7%), whereas 21 patients (58.3%) underwent delayed decompression (>48 hours). The baseline clinical features, including bladder dysfunction, saddle paraesthesia, and neurological status, are presented in Table I.

At presentation, bladder dysfunction was observed in 12 patients (80.0%) of the ED group and in 16 patients (76.2%) of

the DD group. Saddle paraesthesia was present in 13 (86.7%) and 16 (76.2%) patients, respectively. According to the MFS, the ED group consisted of two patients with Grade A, seven with Grade B, and six with Grade C, while the DD group included one patient with Grade A, six with Grade B, and 14 with Grade C.

Table I: Distribution of preoperative clinical features including bladder dysfunction, saddle paraesthesia, and MFS grades (n = 36).

Clinical features	ED Group (n = 15)	DD Group (n = 21)	Total (n = 36)
Bladder dysfunction			
Present	12 (80.0%)	16 (76.2%)	28 (77.8%)
Absent	3 (20.0%)	5 (23.8%)	8 (22.2%)
Saddle paraesthesia			
Present	13 (86.7%)	16 (76.2%)	29 (80.6%)
Absent	2 (13.3%)	5 (23.8%)	7 (19.4%)
MFS			
Grade A	2 (13.3%)	1 (4.8%)	3 (8.3%)
Grade B	7 (46.7%)	6 (28.6%)	13 (36.1%)
Grade C	6 (40.0%)	14 (66.7%)	20 (55.6%)
Total patients	15 (100%)	21 (100%)	36 (100%)

ED: Early decompression; DD: Delayed decompression; MFS: Modified Frankel scale.

Table II: Comparison of clinical outcomes at one-year follow-up in the ED *vs.* DD groups (n = 36).

Clinical outcomes	ED Group (n = 15)	DD Group (n = 21)	p-values[1]
Persistent bladder dysfunction	2 (13.3%)	10 (47.6%)	0.040
Saddle paraesthesia	5 (33.3%)	10 (47.6%)	0.501
≥1 Frankel grade improvement	14 (93.3%)	18 (85.7%)	0.952

[1]*p-values calculated using the Fisher's exact test. ED: Early decompression; DD: Delayed decompression.*

Table III: Comparison of neurological improvement based on MFS grade between the ED and DD surgery groups.

Groups	Median MFS grade at admission	Median MFS grade at follow-up	% with ≥1 grade improvement
ED Group (n = 15)	B	D	93.3%
DD Group (n = 21)	C	D	85.7%

ED: Early decompression; DD: Delayed decompression; MFS: Modified Franked scale.

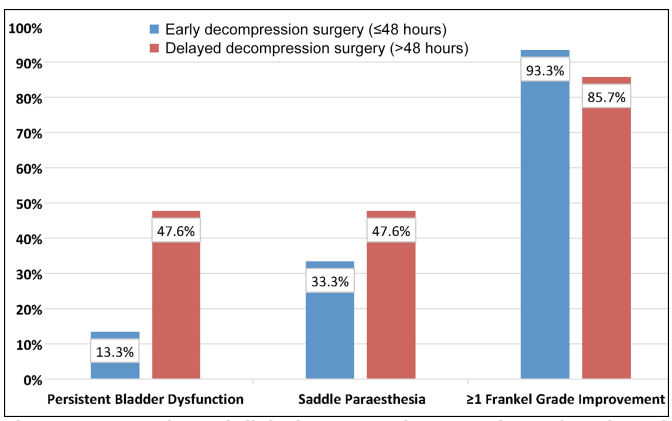

Figure 1: Comparison of clinical outcomes between the ED (≤48 hours) and DD (>48 hours) surgery groups in CES. Only persistent bladder dysfunction exhibited statistically significant improvement in the ED group (p = 0.040).

At one-year follow-up, persistent bladder dysfunction was significantly less frequent in the ED group compared with the DD group (13.3% *vs.* 47.6%, p = 0.040). Residual saddle paraesthesia was also lower in the ED group (33.3% *vs.* 47.6%), although the difference did not reach statistical significance (p = 0.501). Neurological recovery, defined as an improvement of at least one Frankel grade, was achieved in 14 patients (93.3%) in the ED group and 18 patients (85.7%) in the DD group, with no statistically significant difference (p = 0.952; Table II).

Median Frankel grades improved from B at admission to D at follow-up in the ED group and from C to D in the DD group (Table III). Although both groups demonstrated neurological recovery, early decompression was associated with a more favourable shift in functional outcomes. Nearly all patients improved by one to two Frankel grades, and at final follow-up, most had attained Grade D or E, recovering ambulatory function. A graphical comparison of outcomes is presented in Figure 1.

DISCUSSION

In this retrospective cohort study conducted at a tertiary care centre in a semi-urban area of Pakistan, it was found that patients with CES who underwent surgical decompression within 48 hours of symptom onset had significantly better neurological outcomes compared to those who received delayed intervention. Significantly, persistent bladder dysfunction was present in only 13.3% of early surgery patients compared to 47.6% in the DD group (p <0.05). These results support the crucial role of timely surgical intervention in mitigating long-term disability caused by CES, even in resource-limited settings.

These findings are consistent with the previous literature, highlighting the importance of timely decompression in CES. The meta-analysis conducted by DeLong *et al.*, involving 322 patients, demonstrated that delays beyond 24, 48, and 72 hours significantly increased the risk of poor bladder outcomes, with relative risks ranging from 1.77 to 2.19.[13] More recently, Li *et al.* conducted a meta-analysis focusing specifically on CES with CES-R, showing that surgery delayed beyond 24 hours increased the hazard of abnormal urinary function by 54%, and decompression after 48 hours raised the risk of requiring catheterisation by 47%. The observed decrease in persistent bladder dysfunction from 47.6% in delayed surgery cases to 13.3% with early surgery echoes these findings, indicating that decompression within 48 hours may represent a critical window for enhancing bladder recovery in CES.[16]

While bladder function demonstrated clear dependence on surgical timing, this study, such as earlier research by Ahn *et al.*, found that motor and sensory recovery were less sensitive to timing and often partial despite early intervention. Although Beculic *et al.* noted that complete sensory recovery was more common in patients operated on within 48 hours, they also stated that over one-third of patients had incomplete or no sensory recovery despite early decompression, suggesting incomplete recovery once CES becomes fully established.[17,18] These findings are consistent with Korse *et al.*, who reported that sensory and autonomic dysfunctions, especially micturition and sexual function, may persist despite timely decompression.[19] Neurological improvement was measured using the MFS, which grades motor and sensory function from Grade A (complete loss) to Grade E (normal). The majority of patients improved by one to two grades, with the majority regaining

ambulation at follow-up. This scale-based stratification permits more objective comparison with prior literature, although its use in CES studies remains limited.[20]

In contrast, Kumar *et al*. found no statistically significant difference in bladder or bowel recovery between early (<24 hours) and delayed decompression. However, their stricter timing threshold (24 hours *vs*. 48 hours in the current study) and the predominance of CES-R cases (90%) may have diminished the potential benefits of early surgery. This inconsistency highlights how variations in the definitions of early intervention and CES subtyping affect outcome interpretation and limit direct comparability across studies.[5]

The results of this study emphasise the critical importance of timely recognition, diagnosis, and surgical intervention in patients with CES. In particular, the obvious difference in bladder dysfunction between the ED and DD groups (13.3% *vs*. 47.6%) emphasises that surgical timing remains the most modifiable determinant of neurological outcome. This has key implications for frontline clinicians, emergency services, and referral pathways in Pakistan.

Despite presenting with evident red flag symptoms, including urinary dysfunction and saddle anaesthesia, the majority of patients (58.3%) in this study underwent surgery more than 48 hours after symptom onset. This delay likely reflects system-level barriers, including limited awareness among primary care and emergency physicians, late access to MRI imaging–especially during off-hours, and geographic and financial limitations, thereby affecting timely neurosurgical referral.

The small sample size, mainly in the ED group (n = 15), limited statistical power for detecting subtle differences and prohibited subgroup analysis. No preliminary power calculation was conducted due to retrospective data collection. Although the sample size is modest, CES is a rare neurosurgical emergency, and large cohorts are seldom available. The sample size is consistent with prior single-centre reports, such as Fayaz *et al*. (46 patients) and Krishnan *et al*. (15 patients), supporting the adequacy of the cohort.[4,21]

These findings highlight an urgent need to strengthen early detection protocols and streamline care pathways. Specific recommendations include educational initiatives for general practitioners and emergency clinicians to improve the diagnosis of CES, the response to red flag signs, the implementation of fast-track MRI protocols for suspected CES cases, and the development of decentralised triage and referral systems to reduce inter-facility delays.

Similar delays in CES recognition and referral have been reported in other low- and middle-income countries, where primary care providers often lack neurosurgical exposure, and MRI facilities are centralised or limited to tertiary centres.[22]

Moreover, the findings underline the inequity of outcomes based on surgical timing often determined by logistical or institutional limitations rather than clinical severity. Addressing these blockages can improve long-term neurological recovery and lessen the disability burden in affected patients.

This study has various limitations. Its retrospective design introduces the potential for recall and selection bias, particularly regarding symptom onset timing. The small sample size (n = 36) limited subgroup comparisons and prevented multivariate analysis. Although the MFS provides a standardised neurological assessment, it does not adequately capture autonomic dysfunction. Future research should consider CES-specific outcome instruments, such as the Oswestry Disability Index or Spinal Cord Independence Measure.[12,20]

Despite these limitations, the study provides valuable real-world data from a semi-urban tertiary care setting, where access delays are common but underreported. This appears to be the first published data from Mardan Medical Complex evaluating CES outcomes. By comparing early *versus* delayed decompression in a distinct cohort and using one-year follow-up data, the study offers clinically relevant insights for both neurosurgeons and health policymakers. Furthermore, by highlighting the burden of CES-R at presentation, it adds a perspective on the consequences of delayed recognition in resource-limited environments. Additionally, by stratifying outcomes based on the 48-hour cut-off, the study aligns with international guidelines and proposes a practical framework for triage in similar healthcare settings. The data can serve as a benchmark for audits and quality improvement initiatives across South Asia.

CONCLUSION

CES remains a neurosurgical emergency in which time to intervention is the important modifiable factor affecting long-term neurological outcomes. The data indicate that delays beyond 48 hours, common in this setting, significantly increase the risk of persistent bladder dysfunction. This study advocates for the development of national guidelines, fast-track MRI protocols, the training of frontline providers, and rationalised referral systems. A national CES registry and multicentre prospective studies are urgently needed to improve patient care and inform policy in Pakistan.

ETHICAL APPROVAL:

The study was approved by the Institutional Review Board of BKMC/MMC (Approval No. 178/BKMC).

PATIENTS' CONSENT:

Written informed consent was obtained from all the participants included in the study.

COMPETING INTEREST:

The authors declared no conflict of interest.

AUTHORS' CONTRIBUTION:

GA: Conception of the study, design, methodology, and critical revision of the manuscript.
WS: Manuscript writing, data analysis, interpretation, and revision.

MZA: Data collection, calculations, data interpretation, and critical revision of the manuscript.
SS: Interpretation of study results, intellectual input, and critical review.
MNK: Literature review, drafting of relevant sections, and manuscript review.
MK: Referencing, formatting, editorial assistance, and manuscript review.
All authors approved the final version of the manuscript to be published.

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