



Original Article

# Ultra-early surgery in complete cervical spinal cord injury improves neurological recovery: A single-center retrospective study

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## ABSTRACT

**Background:** This study evaluated how the neurological outcome in patients operated on cervical spinal cord injury (SCI) was positively influenced by ultra-early surgery (UES).

**Methods:** Between 2010 and 2017, 81 patients with traumatic cervical SCI were assigned to the UES group (<12 h after injury; UES) and ES group (surgery between 12 and 48 h after injury; ES). Additional variables evaluated for the two groups included; age, sex, comorbidities charlson comorbidity index (CCI), level of trauma, type of fracture, preoperative and ASIA scores, pre- and post-operative neuroradiological examinations, surgical approaches, and complications.

**Results:** Forty-seven of 81 (58.02%) patients exhibited improved neurological function 12 months postoperatively; better outcomes were observed in the UES (29 of 40 [72.5%]) versus ES groups (18 of 41 [43.9%]) ( $P = 0.009$ ). For the 26 patients with complete cervical SCI (ASIA A), ultra-early surgical decompression was associated with significantly greater neurological improvement versus ES (61.53% vs. 7.69%;  $P = 0.003$ ). Further, more neurological improvement correlated with the younger age, better ASIA grade at admission, and ultra-early surgical timing (< 12 h) both in the univariate and multivariate analysis ( $P = 0.037$ ,  $P = 0.017$ , and  $P = 0.005$ , respectively), while CCI was correlated with improvement only in the univariate analysis ( $P = 0.005$ ).

**Conclusion:** Ultra-early surgical timing in SCI patients appeared to be the most important factor determining the extent of postoperative neurological improvement, particularly regarding motor function recovery.

**Keywords:** Spinal cord injury, Spine trauma, Surgical decompression, Timing of operation, Traumatic cervical spinal cord injury

## INTRODUCTION

Cervical spinal cord injuries represent 20–33% of total spinal injuries, most of which occur at the subaxial levels.<sup>[15]</sup> Surgery, consisting of decompression and stabilization, is typically the treatment of choice.<sup>[13]</sup> There is, however, continued debate regarding optimal surgical timing.<sup>[9,10,13,14]</sup> Several animal models of SCI have documented that early decompression following SCI improves spinal cord function by avoiding secondary damage.<sup>[7]</sup> Although clinical series have indicated that early surgery (ES) correlated with improved clinical outcomes, others showed increased complication

rates for these patients.<sup>[5,7,10,13,14]</sup> Here, we evaluated whether better neurological outcomes could be achieved utilizing ultra-early (<12 h) versus early (12–48 h) surgery for patients with cervical SCI.

## MATERIALS AND METHODS

From 2010 to 2017, 81 patients presented with traumatic cervical spinal cord injuries. There were 58 males and 23 females who averaged 57.81 years of age (range 16–84). To determine whether timing of surgery improved postoperative outcomes, 40 patients were assigned to the ultra-ES (UES) group (< 12 h after injury; UES) versus 41 in the ES group (surgery between 12 and 48 h after injury).<sup>[11,12]</sup> The two groups presented homogeneous baseline characteristics summarized in Tables 1 and 2.

### Definition of UES versus ES

“UES” intervention was defined by surgery performed within 6–12 h range,<sup>[10,13,14]</sup> while ES was defined as those operations performed between 12 and 48 h. Follow-up clinical and radiological evaluations were obtained 3, 6, and 12 months after surgery.

### Statistical analysis

Statistical analysis was performed using SPSS software (version 20; SPSS Inc., Chicago, IL). The univariate

analysis of data was carried out by the Pearson Chi-square test for discrete variables, the *t*-test for the continuous ones. Logistic regression was used for the multivariate analysis. Statistical significance was set at  $P < 0.05$ . All patients granted their permission for this study before surgery.

## RESULTS

Forty-seven patients of 81 (58.02%) showed improved neurological function 12 months postoperatively [Table 3]. Neurological improvement of one or more ASIA grades was observed in 9 patients (34.61%) of ASIA A (5 B, 2 C, 2 D), in 8 (66.66%) of ASIA B (4 C, 2 D, 2 E), in 11 (57.89%) of ASIA C (7 D, 4 E), and in 19 (79.16%) of ASIA D, while none showed neurological deterioration [Table 2]. Greater neurological improvement was noted in UES patients (29 of 40; 72.5%) versus ES patients (18 of 41; 43.9%) ( $P = 0.009$ ) [Tables 4 and 5].

Among the 26 patients with complete cervical SCI (ASIA A), ultra-early surgical decompression was significantly associated with neurological improvement (61.53%) versus ES (7.69 %;  $P = 0.003$ ).

Further, greater neurological improvement was positively correlated with younger age, higher ASIA grade at admission, and ultra-early surgical timing both in the univariate and multivariate analysis ( $P = 0.037$ ,  $P = 0.017$ ,

**Table 1:** Baseline data of overall patient population with cervical spinal cord injury (SCI) and of ultra-early (surgery <12 h) and early surgery groups (surgery >12 <48 h) including age, sex, CCI, and cause of trauma.

| Variable                         | Total                | Ultra-early surgery group (<12 h) | Early surgery group (>12 <48 h) | P value       |
|----------------------------------|----------------------|-----------------------------------|---------------------------------|---------------|
| <b>Age (years)</b>               |                      |                                   |                                 | <b>P=0.22</b> |
| Mean ( $\pm$ standard deviation) | 57.81 ( $\pm$ 21.26) | 57.45 ( $\pm$ 20.56)              | 58.17 ( $\pm$ 20.51)            |               |
| Range                            | 16–84                | 16–83                             | 18–84                           |               |
| <b>Sex</b>                       |                      |                                   |                                 | <b>P=0.19</b> |
| Male                             | 58 (71.6%)           | 30 (75%)                          | 28 (68.29%)                     |               |
| Female                           | 23 (28.39%)          | 10 (25%)                          | 13 (37.71%)                     |               |
| <b>CCI</b>                       |                      |                                   |                                 | <b>P=0.47</b> |
| 0                                | 39                   | 24                                | 15                              | 0.03          |
| 1                                | 5                    | 3                                 | 2                               | 0.6           |
| 2                                | 9                    | 2                                 | 7                               | 0.08          |
| 3                                | 13                   | 5                                 | 8                               | 0.39          |
| 4                                | 12                   | 3                                 | 9                               | 0.06          |
| 5                                | 3                    | 3                                 | 0                               | 0.07          |
| <b>Cause of trauma</b>           |                      |                                   |                                 | <b>P=0.46</b> |
| Motor vehicle accidents (MVA)    | 46 (56.79%)          | 25 (62.5%)                        | 21 (51.21%)                     |               |
| Falls                            | 32 (39.5%)           | 13 (32.5%)                        | 19 (47.5%)                      |               |
| Sports related activities        | 3 (3.71%)            | 2 (5%)                            | 1 (2.43%)                       |               |
| Total                            | 81                   | 40                                | 41                              |               |

CCI: Charlson Comorbidity Index

**Table 2:** Level of fracture, type of fracture, the surgical approach, the timing of decompression, and ASIA score at admission.

| Variable  | Total       | Ultra-early surgery group (<12 h) | Early surgery group (>12 <48 h) | P value |
|---|-------------|-----------------------------------|---------------------------------|---------|
| <b>Level of trauma</b> <span style="float:right">P=0.43</span>                          |             |                                   |                                 |         |
| C3-4  | 17 (20.98%) | 10 (25%)                          | 7 (17.07%)                      |         |
| C4-5  | 24 (29.62%) | 12 (30%)                          | 12 (29.26%)                     |         |
| C5-6  | 26 (32.09%) | 11 (27,5%)                        | 15 (36.58%)                     |         |
| C6-7  | 14 (17.28%) | 7 (17,5%)                         | 7 (17.07%)                      |         |
| <b>Type of fracture (Magerl classification)</b> <span style="float:right">P=0.45</span> |             |                                   |                                 |         |
| A   | 13 (16.05%) | 8 (20%)                           | 5 (12.19%)                      |         |
| B   | 63 (77.07%) | 29 (72,5%)                        | 34 (82.92%)                     |         |
| C   | 5 (6.18%)   | 3 (7,5%)                          | 2 (4.89%)                       |         |
| <b>Surgical approach</b> <span style="float:right">P=0.41</span>                        |             |                                   |                                 |         |
| Anterior  | 52 (61.4%)  | 26 (65%)                          | 26 (63.41%)                     |         |
| Posterior   | 13 (21.05%) | 5 (12.5%)                         | 8 (19.51%)                      |         |
| Combined  | 16 (17.55%) | 9 (22.5%)                         | 7 (17.08%)                      |         |
| <b>ASIA score at admission</b> <span style="float:right">P=0.19</span>                  |             |                                   |                                 |         |
| A   | 26 (32.1%)  | 13 (32.5%)                        | 13 (31.7%)                      |         |
| B   | 12 (14.82%) | 6 (15%)                           | 6 (14.63%)                      |         |
| C   | 19 (23.45%) | 9 (22.5%)                         | 10 (24.39%)                     |         |
| D   | 24 (29.62%) | 12 (30%)                          | 12 (29.26%)                     |         |

**Table 3:** Evaluation of improved patients after 12-month follow-up for each ASIA score group.

| Admission ASIA score | ASIA score at 12-month follow-up |    |   |    |    | Improved patients |                |
|----------------------|----------------------------------|----|---|----|----|-------------------|----------------|
|                      | A                                | B  | C | D  | E  |                   |                |
| A                    | 26                               | 17 | 5 | 2  | 2  | 0                 | 9/26 (34.61%)  |
| B                    | 12                               | 0  | 4 | 4  | 2  | 2                 | 8/12 (66.66%)  |
| C                    | 19                               | 0  | 0 | 8  | 7  | 4                 | 11/19 (57.89%) |
| D                    | 24                               | 0  | 0 | 0  | 5  | 19                | 19/24 (79.16%) |
| Total                | 81                               | 17 | 9 | 14 | 16 | 25                | 47/81 (58.02%) |

and  $P = 0.005$ , respectively), except for evaluation of the charlson comorbidity index (CCI) that correlated with improvement only in the univariate analysis ( $P = 0.005$ ) [Table 6]. Additionally, the postoperative complication rate for UES patients was significantly lower than for those in the ES group (15% vs. 34.14%;  $P = 0.03$ ) [Table 7].

**DISCUSSION**

In this study, we compared the postoperative results for patients with SCI treated within 12 h (40 patients; UES group; UES) versus between 12 and 48 h (41 patients; ES group 12–48 h; ES).

There is still no clearly accepted definition of early or late surgery for SCI.<sup>[7,10,13-15]</sup> However, after the publication of the STASCIS trial, recent guidelines recommend surgery within 24 h for SCI.<sup>[5,6,8,10]</sup>

**Table 4:** Modification of ASIA score after 12-month follow-up for ultra-early surgery group (<12 h) and early surgery group (>12 <48 h).

| Admission ASIA score             |    | ASIA score at 12-month follow-up |   |    |    |    | Improved patients |
|----------------------------------|----|----------------------------------|---|----|----|----|-------------------|
|                                  |    | A                                | B | C  | D  | E  |                   |
| <b>Ultra-early surgery group</b> |    |                                  |   |    |    |    |                   |
| A                                | 13 | 5                                | 4 | 2  | 2  | 0  | 8/13 (61.53%)     |
| B                                | 6  | 0                                | 2 | 2  | 1  | 1  | 4/6 (66.66%)      |
| C                                | 9  | 0                                | 0 | 2  | 4  | 3  | 7/9 (77.77%)      |
| D                                | 12 | 0                                | 0 | 0  | 2  | 10 | 10/12 (83.33%)    |
| Total                            | 40 | 17                               | 9 | 14 | 20 | 16 | 29/40 (72.5%)     |
| <b>Early surgery group</b>       |    |                                  |   |    |    |    |                   |
| A                                | 13 | 12                               | 1 | 0  | 0  | 0  | 1/13 (7.69%)      |
| B                                | 6  | 0                                | 2 | 2  | 1  | 1  | 4/6 (66.66%)      |
| C                                | 10 | 0                                | 0 | 6  | 3  | 1  | 4/10 (40%)        |
| D                                | 12 | 0                                | 0 | 0  | 3  | 9  | 9/12 (75%)        |
| Total                            | 41 | 11                               | 4 | 8  | 7  | 11 | 18/41 (43.9%)     |

**Efficacy of Ultra-early cervical surgery following SCI**

Here, we confirmed better neurological improvement for patients having ultra-early (72.5%) versus early 12–48 h (43.9%) surgery.<sup>[7,10,13-15]</sup>

**Benefits of UES**

We and other have observed that patients in the more severe ASIA grades (e.g., Grade A) benefit more from UES

**Table 5:** Comparison of ASIA improvements according to ultra-early surgery group (<12 h) and early surgery group (>12 <48 h) in overall population and in patients classified in complete and incomplete SCI.

| Admission ASIA score      | Improved ASIA score at 12-month follow-up, n (%) | P value |
|---------------------------|--|---------|
| General population        |  | 0.009   |
| Ultra-early surgery group | 29/40 (72.5%)                                    |         |
| Early surgery group       | 18/41 (43.9%)                                    |         |
| Complete SCI              |  | 0.003   |
| Ultra-early surgery group | 8/13 (61.53%)                                    |         |
| Early surgery group       | 1/13 (7.69%)                                     |         |
| Incomplete SCI            |  | 0.3     |
| Ultra-early surgery group | 21/27 (77.7%)                                    |         |
| Early surgery group       | 17/28 (60.7%)                                    |         |

(e.g., avoid secondary ischemic injury). In a recent meta-analysis, the rate of ≥ 2 ASIA grade improvement in patients with complete SCI operated within 24 h was 22.6%; this number was similar to those in our series (4/13; 30.76%).<sup>[13]</sup>

**Better preoperative ASIA grade influenced outcomes for SCI patient**

The ASIA grade on admission influenced the postoperative outcome both in the univariate than in the multivariate analysis.<sup>[1]</sup> In our series, better neurological improvement positively correlated with better preoperative ASIA grades. In addition, younger patients had a better prognosis than older ones with the same neurological conditions (e.g., impact of comorbid factors).

**Controversy regarding complication rates for UES versus ES for SCI**

In the past, several authors reported that ES was associated with a higher rate of complications (e.g., attributed often

**Table 6:** Statistical analysis of relationship between ASIA score improvement at 12-month follow-up and admission ASIA score, timing of surgical procedure, age of the patient, and CCI. NS, nonsignificant.

|                                | 12-month follow-up |   |                               |                                |                                  |
|--------------------------------|--------------------|---|-------------------------------|--------------------------------|----------------------------------|
|                                | Overall<br>n=81    | Improved patients<br>(minimum one grade of ASIA score amelioration)<br>n=47 | Not improved patients<br>n=34 | Univariate analysis<br>P value | Multivariate analysis<br>P value |
| ASIA at admission              |                    |   |                               | P=0,006                        | P=0,017                          |
| A                              | 26                 | 9   | 17                            |                                |                                  |
| B                              | 12                 | 8   | 4                             |                                |                                  |
| C                              | 19                 | 11  | 19                            |                                |                                  |
| D                              | 24                 | 19  | 5                             |                                |                                  |
| Surgical timing                |                    |   |                               | P<0,001                        | P=0,005                          |
| <12 h                          | 40                 | 29 (72,5%)  | 11 (27,5%)                    |                                |                                  |
| 12-48 h                        | 30                 | 10 (33,33%)   | 20 (66,67%)                   |                                |                                  |
| Age (years)<br>(median, range) | 57,81 (16-84)      | 37 (16-78)  | 64 (18-84)                    | P=0,006                        | P=0,037                          |
| CCI (median, range)            | 2 (0-5)            | 0 (0-5)   | 3 (0-4)                       | P=0,007                        | NS                               |

CCI: Charlson Comorbidity Index

**Table 7:** Postoperative complications.

| Postoperative complications | Total      | Ultra-early surgery group (<12 h) | Early surgery group (>12 <48 h) | P value |
|-----------------------------|------------|-----------------------------------|---------------------------------|---------|
| Cardiopulmonary             | 7          | 2                                 | 5                               |         |
| Construct failure           | 2          | 1                                 | 1                               |         |
| Deep wound infection        | 5          | 2                                 | 3                               |         |
| Neurologic deterioration    | 0          | 0                                 | 0                               |         |
| Pulmonary embolism          | 3          | 1                                 | 2                               |         |
| Systemic infection          | 3          | 0                                 | 3                               |         |
| Total complications         | 20 (24.7%) | 6 (15%)                           | 14 (34.14%)                     | 0,03    |

to polytrauma). This issue may explain the frequent postoperative surgical site infections in emergency surgery.<sup>[1-4]</sup> On the contrary, our data documented that a lower complication rate for UES versus ES patients, perhaps, attributable to the increased susceptibility/greater nutritional compromises of those undergoing the delayed procedures (e.g., ES: 12–48 h).

## CONCLUSION

Here, for patients with cervical SCI, better outcomes were observed following ultra-early (<12 hours) versus early (12–48 h) cervical decompression/fusion. Better preoperative ASIA grades on admission in younger patients also closely positively correlated with improved outcomes.

## Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms.

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Nil.

## Conflicts of interest

There are no conflicts of interest.

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