Non-Neurological Outcomes after Complete Traumatic Spinal Cord Injury: The Impact of Surgical Timing

Étienne Bourassa-Moreau,1,2 Jean-Marc Mac-Thiong,1–3 Debbie Ehrmann Feldman,4 Cynthia Thompson,2 and Stefan Parent1–3

Abstract

It remains unclear whether the benefits of early surgical timing are significant in neurologically complete spinal cord injury (SCI). We wanted to compare the effects of early and late surgical timing on non-neurological outcomes in persons with traumatic complete SCI. All cases of traumatic complete SCI referred to a single institution between 2000 and 2011 were retrospectively reviewed. The occurrence of pneumonia, urinary tract infection (UTI), pressure ulcer (PU), and all other postoperative complications were recorded. Cost of acute hospitalization was calculated for each patient based on administrative data. Patients operated on within 24 h of the trauma were compared with patients operated on later than 24 h after the trauma. The effects of surgical timing on complication rate and cost of hospitalization were adjusted for potential confounding variables using multiple regression analyses. Fifty-five patients were operated on £24 h from injury and 142 were operated on >24 h from injury. Baseline demographic and clinical variables were comparable between the two groups. Pneumonia, UTI, and the presence of any complications were significantly higher in the group operated on >24 h post-trauma. Cost of hospitalization was higher among patients operated >24 h post-trauma (£24 h: 22,828$ vs. >24 h: 29,714$). Surgical timing >24 h was a predictor of pneumonia, UTI, total complications, and higher cost of hospitalization after controlling for other confounding variables. This study shows that surgical decompression and stabilization £24 h following a complete SCI may be a cost-effective strategy to reduce the postoperative complication rate.

Key words: American Spinal Injury Association grade A; complete SCI; complications; SCI; surgical timing

Introduction

Evidence suggests that persons who sustain complete interruption in motor and sensory function in spinal cord injury (SCI) have a limited potential for neurological recovery, even with early surgical decompression. In a rat model, more severe spinal cord compression led to poorer neurological recovery, even if immediate surgical decompression was performed.1 Clinical studies on the natural history of SCI also suggested that complete SCI has poorer neurological improvement than incomplete SCI. Zariffa and colleagues2 found that only 3% of patients with complete SCI gained a functional level below the initial lesion. Fawcett and colleagues3 suggested that 80% of patients with complete SCI initially classified as grade A using the American Spinal Injury Association (ASIA) impairment scale remained grade A 1 year after the initial trauma. In comparison, up to 80% of patients with incomplete SCI classified as ASIA grade B or C improved by at least one grade 1 year post-injury.3

Some studies suggested that surgical treatment provided no benefits regarding neurological recovery in complete SCI.4–6 Therefore, some clinicians may choose to perform surgical decompression earlier in patients with incomplete SCI than in those with complete SCI.7

Much emphasis is put on neurological recovery to justify interventions in SCI. On the other hand, non-neurological outcomes such as complications and cost are important considerations as well. Prevention of complications is a major goal of SCI management, especially during the acute hospitalization phase.8–10 With traumatic SCI, the effect of surgical timing on complications in patients remains controversial, although recent studies tend to recommend early surgery.11–13 A recent study identified surgical timing as a predictor of complications14 after traumatic SCI but the authors did not specifically investigate the effect of early surgical intervention on complication occurrence in a uniquely complete SCI population.

1Faculty of Medicine, and 4École de Réadaptation, University of Montreal, Montreal, Canada.
2Hôpital du Sacré-Coeur, Montreal, Canada.
3CHU Sainte-Justine, Montreal, Canada.
Previous reports have suggested a decrease in cost of hospitalization with early surgery for traumatic SCI.10,11,15 Mac-Thiong and colleagues15 assessed the influence of surgical delay on acute hospitalization cost using logistical regression analyses, and found that surgical timing >24 h post-injury and ASIA grade were significant predictors of hospitalization cost. However, no previous studies specifically studied the cost of hospitalization in a neurologically complete SCI population.

The aim of this study was to assess the effect of surgical timing on non-neurological complications and cost of health care during acute hospitalization stay following a complete SCI.

Our hypothesis was that surgical intervention ≤24 h after traumatic complete SCI decreased the complication rate and cost of hospitalization compared with surgery performed >24 h following the SCI.

Methods

We studied a cohort of patients who sustained an acute traumatic SCI between April 1, 2000 and March 31, 2011, and were treated in the Hôpital du Sacré-Coeur de Montréal, a level I trauma center specializing in SCI care. The Institutional Review Board approved the study protocol. Patients were identified using the Quebec Trauma Registry, which prospectively registers all patients who have been treated for a traumatic injury at any acute health care facility in the province of Quebec in Canada. Cases were included in our study if they fulfilled the following criteria:

- Spinal fracture, dislocation or fracture-dislocation from C1 to L2
- Clinical evidence of complete SCI classified as ASIA grade A at the preoperative assessment
- Minimal age of 16 years
- Spine surgery performed at our center

Patients were excluded from our study if they had:

- Penetrating trauma to the spine
- Nonsurgical management
- Pre-existing or associated neurological disorders (including severe but not mild or moderate traumatic brain injury [TBI]) that preclude a reliable neurological assessment preoperatively in relationship to the SCI

Our cohort consisted of 197 patients from the 208 complete SCI cases found in the Quebec Trauma Registry database. Among the 11 patients who were excluded, 6 had severe TBI, 1 had a penetrating SCI, and 4 had had their surgery performed in another center. Demographic and clinical characteristics of patients are presented in Table 1.

Outcomes

The primary dependent variable was the occurrence of a non-neurological complication during the acute care hospitalization that was not present prior to the SCI. The main complications studied were: pneumonia, urinary tract infection (UTI), and pressure ulcers (PU). The presence of a complication was based on the clinical evaluation of the multidisciplinary medical team (intensive care, spine surgery, physical medicine, and rehabilitation) in charge of SCI patients at our institution. For the diagnosis of UTI, the microbiology guidelines in our institution specify that bacteriuria must be associated with symptoms of urinary infection (incontinence, increased spasticity, autonomic dysreflexia) or systemic symptoms (fever, general discomfort). Complications that occurred in <10% of patients were not considered as individual categories but were instead classified all together as other complications (pulmonary embolus, deep venous thrombosis, acute respiratory distress syndrome [ARDS], atelectasis, ventilator failure, bronchospasm, septicemia, Clostridium difficile colitis, postoperative ileus, delirium, peptic ulcer disease, and surgical wound dehiscence), and considered in the calculation of the total complication rate. The rates of pneumonia, UTI, and PU refer to the proportion of patients for whom the specific complication occurred. The total rate of complications refers to the proportion of patients who sustained at least one complication of any type.

The cost related to the acute hospitalization episode was considered as the secondary dependent variable. Transfer to intensive functional rehabilitation was based on similar criteria for all patients, and occurred only after they were medically and psychologically stable with no surgery planned within the next 7 days. Cost related to the acute care hospitalization was estimated based on the “Niveau d’intensite´ relative des ressources utilise´es” (NIRRU) [Relative intensity level of resources used] retrieved from the hospital administrative database.16 Previous studies have already used this index to estimate resource utilization and cost associated with different groups of patients.17-21 This index is specific to the province of Quebec, but is similar to the Resource

<table>
<thead>
<tr>
<th>Timing</th>
<th>≤24 h</th>
<th>&gt;24 h</th>
<th>Total</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>55</td>
<td>142</td>
<td>197</td>
<td></td>
</tr>
<tr>
<td>Sex(male)</td>
<td>89% (49)</td>
<td>82% (116)</td>
<td>84% (165)</td>
<td>0.28</td>
</tr>
<tr>
<td>Age (years)</td>
<td>36.4±14.5</td>
<td>40.4±16.2</td>
<td>39.3±15.8</td>
<td>0.11</td>
</tr>
<tr>
<td>CCI</td>
<td>0.16±0.46</td>
<td>0.24±0.79</td>
<td>0.22±0.72</td>
<td>0.51</td>
</tr>
<tr>
<td>TBI</td>
<td>42% (23)</td>
<td>39% (56)</td>
<td>40% (79)</td>
<td>0.87</td>
</tr>
<tr>
<td>Neurological level</td>
<td></td>
<td></td>
<td></td>
<td>0.145</td>
</tr>
<tr>
<td>C1-C4</td>
<td>11% (6)</td>
<td>11% (15)</td>
<td>11% (21)</td>
<td></td>
</tr>
<tr>
<td>C5-T1</td>
<td>18% (10)</td>
<td>25% (36)</td>
<td>23% (46)</td>
<td></td>
</tr>
<tr>
<td>T2-T10</td>
<td>31% (17)</td>
<td>40% (57)</td>
<td>38% (74)</td>
<td></td>
</tr>
<tr>
<td>T11-S1</td>
<td>40% (22)</td>
<td>24% (34)</td>
<td>28% (56)</td>
<td></td>
</tr>
<tr>
<td>ISS</td>
<td>32.6±8.7</td>
<td>32.5±8.9</td>
<td>32.9±9.6</td>
<td>0.75</td>
</tr>
<tr>
<td>SII</td>
<td>13.8±7.7</td>
<td>14.2±7.9</td>
<td>12.6±7.1</td>
<td>0.19</td>
</tr>
<tr>
<td>Delay(h)</td>
<td>17.6±5.0</td>
<td>67.3±92.1</td>
<td>53.5±81.3</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>Cost($CAD)</td>
<td>22,828±16,098</td>
<td>29,714±19,433</td>
<td>27,792±18,779</td>
<td>0.01</td>
</tr>
</tbody>
</table>

SCI, spinal cord injury; CCI, Charlson Comorbidity Index; TBI, mild and moderate traumatic brain injury; ISS, Injury Severity Score; SII, Surgical Invasiveness Index; Cost, cost of hospitalization.

Table 1. Demographic and Clinical Characteristics of the Complete Cohort and of Patients Categorized Based on the Surgical Timing (≤24 h vs. >24 h After SCI)
Intensity weights (RIW)\textsuperscript{22} used in other provinces in order to assess the resources dedicated to specific diagnosis-related groups of hospitalized patients. The NIRRU index is based on the Maryland cost index after adjusting for conditions particular to Quebec, in order to account for the longer length of stay in Quebec as compared with Maryland. The NIRRU encompasses all resources involved during the hospitalization, excluding physician fees. From the NIRRU index, cost (in 2011 Canadian $) were derived after adjusting for the patient’s clinical condition, risk of mortality, and resource use (diagnostic and therapeutic), as well as for the additional cost related to the teaching involved at our university-affiliated hospital. Cost was then adjusted according to the Canadian average rate of inflation between the year of hospitalization for each patient and 2011.

**Surgical timing**

The main independent variable was surgical timing, defined as the time between the accident and the surgery. Timing information was collected from the medical charts. Each patient was assigned to one of two timing groups: ≤24 h or >24 h following the traumatic SCI. Such grouping of patients was selected because of the increasing trend among spine surgeons to perform early surgery within 24 h following the SCI, and the fact that a threshold of 24 h is often proposed as a realistic time frame during which early surgery can be performed, considering the delays associated with transfer to a specialized SCI center, patient evaluation, and access to the operating room.

**Confounding variables**

Patient-related confounding variables consisted of demographic and clinical characteristics that potentially affected the occurrence of complications, and included age, sex, and the Charlson Comorbidity Index (CCI).\textsuperscript{23–26} The CCI was calculated by using algorithms from International Classification of Diseases, Ninth and Tenth revision codes with Quan and Deyo’s algorithm.\textsuperscript{27} Injury-related confounding variables were: neurological level of injury (tetraplegia: C1 to T1 vs. paraplegia: T2 to L2), injury severity score (ISS), and the presence of mild or moderate TBI. We also adjusted for one treatment-related potential confounding variable, the surgical invasiveness index (SII), which was specifically designed to measure the extent of a surgical procedure.\textsuperscript{28,29}

**Statistical analysis**

All statistical analyses were performed with IBM SPSS Statistics 19 (Chicago, IL). For all statistical tests, the level of statistical significance was set at an α of 0.05. Demographic, clinical variables as well as the complication rates were compared between the two surgical timing groups. Comparisons were assessed with χ² tests for categorical variables. For comparison of continuous variables, the Student t test was used. We used logistical regression analyses to model the presence of complications as a function of the timing of surgery (≤24 h vs. >24 h following the trauma) adjusted for the potential confounding variables described previously. Multivariate binary logistic regression analyses were separately performed for total complications, as well as for the specific rates of pneumonia, PU, and UTI. Linear regression analysis was performed to determine the association between cost of hospitalization and surgical timing, while taking into account potential confounding variables.

We used the backward elimination procedure, sequentially eliminating the variable associated with the highest p value after each iteration if the corresponding p value was > 0.05.

**Results**

Fifty-five (28%) of the 197 patients were operated on ≤24 h post-injury and the remaining 142 patients (72%) had their surgery >24 h after the trauma. None of the sociodemographic and clinical variables showed statistically significant differences between the two surgical timing groups (Table 1). The level of injury was classified as high cervical (C1-C4), low cervical (C5-T1), high thoracic (T2-T10) and low thoracic (T11-S1), and was statistically similar in the two groups. The mean time elapsed between trauma and surgical intervention differed by 49.7 h between the two groups (p < 0.001). The cost of hospitalization was significantly lower (6886$ difference) for patients operated ≤24 h after trauma than for patients operated later (22,828 ± 16,098$ vs. 29,714 ± 19,433$).

Table 2 describes the complication and death rates in the two timing groups. The total complication rate indicates that 57% of patients had at least one complication. The rate of total complications, pneumonia, and UTI were significantly lower in patients operated ≤24 h after injury whereas the rate of PU was not statistically different between the two groups.

Thirty-nine complications classified as other were found in 35 (18%) of patients. These complications were acute bronchitis (14 patients), ARDS (9 patients), C. difficile colitis (3 patients), pleural effusion (2 patients), acute pulmonary edema (2 patients), spontaneous pneumothorax (2 patients), wound infection (2 patients), delirium (2 patients), pulmonary embolus (1 patient), atrial fibrillation (1 patient), and acute renal failure (1 patient).

A total of six patients died during acute hospitalization; two patients (4%) were operated within the first 24 h post-trauma and four patients (3%) had their surgery later. Two patients with C4 and two with C6 SCI refused active care and died of respiratory failure soon after ventilator support was withdrawn. We could not retrieve the medical charts and determine the cause of death of the two other deceased patients.

Multivariate logistic regression analyses for prediction of complications are presented in Table 3. For the occurrence of total complications, surgical timing >24 h, tetraplegia, and ISS were significant predictors. For the occurrence of pneumonia, surgical timing >24 h, tetraplegia, ISS, and age were significant predictors. For the occurrence of PU, tetraplegia and SII were significant predictors. For the occurrence of UTI; surgical timing >24 h and SII were significant predictors.

Timing >24 h was an independent predictor of a 3777$ increase in acute hospitalization cost. Tetraplegia, age, and ISS were also identified as significant predictors of cost of hospitalization (see Table 4).

**Discussion**

This study is the first to confirm a reduction in complication rate with early surgical intervention specifically in patients with a complete SCI. Surgical timing is important because it is a potentially modifiable factor, and early surgical stabilization after a SCI is safe, even in polytrauma patients.\textsuperscript{30}

| Table 2. Complication and Death Rates for the Complete Cohort and for Patients Categorized Based on the Surgical Timing (≤24 h vs. >24 h after SCI) |
|---|---|---|---|---|
| Timing | ≤24 h | >24 h | Total | p value |
| n | 55 | 142 | 197 | |
| Total | 42% (23) | 63% (89) | 57% (112) | 0.01 |
| Pneumonia | 20% (11) | 36% (51) | 31% (62) | 0.04 |
| PU | 16% (9) | 25% (35) | 22% (44) | 0.255 |
| UTI | 15% (8) | 30% (42) | 25% (50) | 0.03 |
| Death | 4% (2) | 3% (4) | 3% (6) | 0.672 |

SCI, spinal cord injury; PU, pressure ulcer; UTI, urinary tract infection.
Clinicians may be tempted to minimize the importance of early surgical intervention for patients with a complete SCI, given the poorer neurological prognosis. However, rapid surgical stabilization greatly facilitates mobilization and pulmonary toilet, and, therefore, may reduce complications related to prolonged recumbence.

Early surgical timing is beneficial in spine trauma for decreasing complication rate, especially for pneumonia. The occurrence of any complications with complete SCI was lower in this study than in the study by Grossman and colleagues (57% vs. 84%). It is likely that because of the retrospective nature of our study, some mild complications remained unnoticed, or complications were not explicitly recorded in medical charts. This systematic misclassification bias may explain the abnormally low incidence of thromboembolic events found in our cohort.

Although this study was retrospective, its internal validity was increased by its being a standardized data collection made in a single institution. These findings may apply to cervical and thoracolumbar SCI, as well as to severely injured patients, because our cohort comprised all level of SCI and patients with mean ISS of 32.9. However, the study protocol excluded seven patients with severe trauma (higher ISS) to be predictors of pneumonia.24,35 In the current study, pneumonia was not a possible association between comorbidities and complications, which was opposite to previous reports.24,35 In the current study, pneumonia was not a predictor of complications in SCI. These exclusions were chosen because the surgical planning (including surgical timing) is often modified when the SCI is associated with severe TBI and/or penetrating trauma. Moreover, severe TBI frequently precludes a reliable ASIA grade evaluation.

Similarly to previous reports,24,25,35 we found increasing age and more severe trauma (higher ISS) to be predictors of pneumonia. However, the presence of comorbidity did not predict complications, which was opposite to previous reports.24,35 In the current study, patients with comorbidities had less severe trauma (median ISS = 21) and were more frequently paraplegics (47%) than the whole cohort. Knowing that a lower ISS and paraplegia tend to decrease the rate of complications, these two findings may have altered a possible association between comorbidities and complications.

Furthermore, this study identified a higher SII as a predictor of PU and UTI. The configuration and extent of spinal injury was not accounted for in this study, and may affect the extent of the procedure selected by the surgeon. Surgeons may select less invasive surgery to reduce the risk of complications, but this should not detract them from achieving the important surgical goals of decompression and stabilization.

In the current study, hospitalization cost was 6866$ lower in patients operated on within 24 h following the SCI. Multivariate regression analysis showed that surgical delay > 24 h in addition to tetraplegia, higher ISS, and increasing age were statistically significant predictors of higher cost of hospitalization. These findings support the cost benefits of performing surgery within 24 h following a traumatic complete SCI, especially considering the decrease in complication rates with early surgery.

**Study limitations**

There are several limitations that must be noted. The information on high doses of corticosteroids was absent in the study. Most of the subjects were transferred from other centers, and the information on initial management was incomplete, including exposure to corticosteroids early on. However, there are contradictory data about the effects of high dose corticosteroids on complication rates in patients with SCI.24,35 and corticosteroid use was abandoned in 2005 in our center.

Another limitation of this study relates to the estimation of hospitalization cost that does not include physician fees. Calculating physician fees specifically for each patient would be extremely complex, given the particular remuneration systems prevailing in our province. However, surgeons’ and anesthesiologists’ compensations are fixed for any type of traumatic SCI and it is therefore assumed that the fees specifically for the surgery would be similar between the two groups. For consultants involved in the preoperative and postoperative care (emergency care, intensive care, physical medicine and rehabilitation, internal medicine), the fee-for-service related to the initial consultation is fixed. Therefore, the bias from excluding physician fees in calculating hospitalization cost most likely represents a constant systematic error that will not affect the difference seen between patients in the early and late surgery groups.

Another potential bias is related to the justification of surgical delays. In our center, surgical delay is mainly the result of limited access to an operating theater. There is a general consensus on the indication to surgically decompress traumatic SCI within 24 h among the five spine surgeons working in our center. Poor access to the operating theater is believed to be the main cause of surgical delays in our institution. There may be a health care access bias related to transfer delays and surgery delays in medically unstable patients requiring resuscitation. However, the ISS were similar in the < 24 h and > 24 h patients, and this may reflect similar needs for medical resuscitation associated with trauma in thees two groups. Moreover in our study, patients operated within and after 24 h had statistically similar sociodemographic and clinical data, suggesting
that these characteristics did not result in significant biases with regard to the surgical timing. Further, we modeled the impact of surgical timing adjusted for potential confounders, and found that surgical timing remained a predictor of any complications, pneumonia, and UTI even after controlling for these variables.

Conclusion

Given the limited potential for neurological recovery, the urgency of performing early surgical decompression and stabilization in patients with a complete SCI can be questioned. This study showed that patients with a complete SCI operated on ≤ 24 h post-trauma had fewer complications and lower cost of hospitalization than those operated on later. We recommend surgical stabilization and decompression within 24 h of a complete traumatic SCI as a cost-effective strategy to decrease the rate of complications during acute hospitalization stay.

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Author Disclosure Statement

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Address correspondence to:
Jean-Marc Mac-Thiong, MD, PhD
Department of Surgery
Hotel du Sacre-Coeur de Montreal
5400 Boulevard Gouin Ouest
Montreal, Quebec
Canada H4J 1C5
E-mail: macthiong@gmail.com