CONGRESS OF NEUROLOGICAL SURGEONS SYSTEMATIC REVIEW AND EVIDENCE-BASED GUIDELINES ON THE EVALUATION AND TREATMENT OF PATIENTS WITH THORACOLUMBAR SPINE TRAUMA: TIMING OF SURGICAL INTERVENTION

Sponsored by: Congress of Neurological Surgeons and the Section on Disorders of the Spine and Peripheral Nerves in collaboration with the Section on Neurotrauma and Critical Care

Endorsed by: Joint Guidelines Committee of the American Association of Neurological Surgeons (AANS) and the Congress of Neurological Surgeons (CNS)

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Abbreviations

ASIA - American Spinal Injury Association

ISS - Injury Severity Score

NASS - North American Spine Society

No part of this article has been published or submitted for publication elsewhere.

ABSTRACT

Background: Thoracolumbar fractures include complete and incomplete spinal cord injuries. Treatments for these fractures range from conservative therapy with bedrest and bracing, to decompression and stabilization of the spine with instrumentation. There are many variables that may affect the outcome of patients undergoing such treatments. The effect of the time between injury and surgical intervention has not been well established.

Objective: To determine if the timing of surgical intervention influences the neurological outcome for patients with thoracic and lumbar fractures.

Methods: The National Library of Medicine PubMed and the Cochrane Library databases were searched for publications related to the timing of surgical intervention and thoracic and lumbar fracture treatment. After exclusion criteria were applied, full-text articles were reviewed by the authors and the Task Force. Studies were graded based on a modified North American Spine

Society evidence-based guideline development methodology, and recommendations were made by the Task Force based on the review of the full-text articles.

Results: A total of 1172 abstracts were screened. Of these, 69 full-text articles were reviewed. Fifty-eight were rejected for not meeting inclusion criteria. Eleven articles were selected for inclusion in this systematic review. Two studies provided level III evidence, while 9 studies provided level IV evidence. There was inconsistency in these studies regarding the effects of timing of surgical intervention on the neurological outcome of patients with thoracic and lumbar fractures, as well as inconsistency regarding what amount of time constituted “early” versus “late” surgical intervention.

Conclusion: There is insufficient and conflicting evidence regarding the effect of timing of surgical intervention on neurological outcomes in patients with thoracic and lumbar fractures. It is suggested that “early” surgery be considered as an option in patients with thoracic and lumbar fractures to reduce length of stay and complications. The available literature has defined “early” surgery inconsistently, ranging from <8 hours to <72 hours after injury.

RECOMMENDATIONS

Question

Does early surgical intervention improve outcomes for patients with thoracic and lumbar fractures?

Recommendations

There is insufficient and conflicting evidence regarding the effect of timing of surgical intervention on neurological outcomes in patients with thoracic and lumbar fractures.

Strength of Recommendation: Grade Insufficient

It is suggested that “early” surgery be considered as an option in patients with thoracic and lumbar fractures to reduce length of stay and complications. The available literature has defined “early” surgery inconsistently, ranging from <8 hours to <72 hours after injury.

Strength of Recommendation: Grade B

INTRODUCTION

Goals and Rationale

This clinical guideline has been created to improve patient care by outlining the appropriate information gathering and decision-making processes involved in the evaluation and treatment of patients with thoracolumbar spine trauma. The surgical management of these patients often takes place under a variety of circumstances and by various clinicians. This guideline has been created as an educational tool to guide qualified physicians through a series of diagnostic and treatment decisions to improve the quality and efficiency of care.

Background

Thoracolumbar fractures include a variety of traumatic spine injuries, both in isolation and in conjunction with other injuries. Over the decades, the treatment of thoracolumbar fractures has significantly evolved. Traditional conservative therapy involved bed rest and bracing. Adverse consequences of prolonged bed rest and the evolution of surgical technique have led to effective operative approaches for stabilization of thoracolumbar fractures. In many circumstances, surgery is now considered the optimal treatment for patients presenting with unstable thoracolumbar spine fractures.

However, the timing of surgical intervention in the setting of thoracolumbar fractures has been debated over the years, and the relationship of timing of surgical intervention to clinical outcome has not been well defined. While one might argue that “early” or “late” surgery may or may not improve clinical outcome, even the definition of what constitutes “early” versus “late” surgery is not well defined.

The goal of this guideline is to evaluate the available literature to determine if the timing of surgical intervention has an effect of the clinical outcome for patients suffering thoracic and lumbar fractures.

METHODS

The guidelines task force initiated a systematic review of the literature relevant to the diagnosis and treatment of patients with thoracolumbar trauma. Through objective evaluation of the evidence and transparency in the process of making recommendations, this evidence-based clinical practice guideline was developed for the diagnosis and treatment of adult patients with thoracolumbar injury. These guidelines were developed for educational purposes to assist practitioners in their clinical decision-making processes. Additional information about the methods utilized in this systematic review can be found in the introduction and methodology chapter.

Literature Search

The task force members identified search terms/parameters, and a medical librarian implemented the literature search, consistent with the literature search protocol (see Appendix I), using the National Library of Medicine PubMed database and the Cochrane Library (which included the Cochrane Database of Systematic Reviews, the Database of Abstracts of Reviews of Effect, the Cochrane Central Register of Controlled Trials, the Health Technology Assessment Database, and the National Health Service Economic Evaluation Database) for the period from January 1, 1946, to March 31, 2015, using the search strategies provided in Appendix I.

RESULTS

The literature search yielded 1172 abstracts. Task force members reviewed all abstracts yielded from the literature search and identified the literature for full-text review and extraction, addressing the clinical questions, in accordance with the literature search protocol (Appendix I). Task force members identified the best research evidence available to answer the targeted clinical questions. When level I, II, and/or III literature was available to answer specific questions, the task force did not review level IV studies.

The task force selected 69 articles for full text review. Of these, 58 articles were rejected for not meeting inclusion criteria or for being off topic. Eleven studies were selected for inclusion in this systematic review (Appendix II).

Inclusion/Exclusion Criteria

Articles were retrieved and included only if they met specific inclusion/exclusion criteria. These criteria were also applied to articles provided by guideline task force members who supplemented the electronic database searches with articles from their own files. To reduce bias, these criteria were specified before conducting the literature searches.

Articles that do not meet the following criteria were, for the purposes of this evidence-based clinical practice guideline, were excluded. To be included as evidence in the guideline, an article had to be a report of a study that:

- Investigated patients with thoracolumbar injuries;
- Included patients ≥18 years of age;
- Enrolled ≥80% of thoracolumbar injuries (studies with mixed patient populations were included if they reported results separately for each group/patient population);
- Was a full article report of a clinical study;
- Was not an internal medical records review, meeting abstract, historical article, editorial, letter, or commentary;
- Appeared in a peer-reviewed publication or a registry report;
- Enrolled ≥10 patients per arm per intervention (20 total) for each outcome;
- Included only human subjects;
- Was published in or after 1946 through March 31, 2015;
- Quantitatively presented results;
- Was not an in vitro study;
- Was not a biomechanical study;
- Was not performed on cadavers;

- Was published in English;
- Was not a systematic review, meta-analysis, or guideline developed by others[*];
- Was a case series (therapeutic study) where higher level evidence exists.

Rating Quality of Evidence

The guideline task force used a modified version of the North American Spine Society's evidence-based guideline development methodology. The North American Spine Society methodology uses standardized levels of evidence (Appendix III) and grades of recommendation (Appendix IV) to assist practitioners in easily understanding the strength of the evidence and recommendations within the guidelines. The levels of evidence range from level I (high quality randomized controlled trial [RCT]) to level IV (case series). Grades of recommendation indicate the strength of the recommendations made in the guideline based on the quality of the literature. Levels of evidence have specific criteria and are assigned to studies before developing recommendations. Recommendations are then graded based upon the level of evidence. To better understand how levels of evidence inform the grades of recommendation and the standard nomenclature used within the recommendations, see Appendix IV.

Guideline recommendations were written using a standard language that indicates the strength of the recommendation. "A" recommendations indicate a test or intervention is 2 "recommended"; "B" recommendations "suggest" a test or intervention; "C" recommendations indicate a test or

[*]The guideline task force did not include systematic reviews, guidelines, or meta-analyses conducted by others. These documents are developed using different inclusion criteria than those specified in this guideline; therefore, they may include studies that do not meet the inclusion criteria specific in this guideline. In cases where these types of documents' abstract suggested relevance to the guideline's recommendations, the task force searched their bibliographies for additional studies.

intervention or "is an option." "Insufficient evidence" statements clearly indicate that "there is insufficient evidence to make a recommendation for or against" a test or intervention. Task force consensus statements clearly state that "in the absence of reliable evidence, it is the task force's opinion that" a test or intervention may be considered. Both the levels of evidence assigned to each study and the grades of each recommendation were arrived at by consensus of the workgroup employing up to three rounds of voting when necessary.

In evaluating studies as to levels of evidence for this guideline, the study design was interpreted as establishing only a potential level of evidence. As an example, a therapeutic study designed as a RCT would be considered a potential level I study. The study would then be further analyzed as to how well the study design was implemented and significant shortcomings in the execution of the study would be used to downgrade the levels of evidence for the study's conclusions (see Appendix V for additional information and criteria).

Revision Plans

In accordance with the Institute of Medicine's standards for developing clinical practice guidelines and criteria specified by the National Guideline Clearinghouse, the task force will monitor related publications following the release of this document and will revise the entire document and/or specific sections "if new evidence shows that a recommended intervention causes previously unknown substantial harm; that a new intervention is significantly superior to a previously recommended intervention from an efficacy or harms perspective; or that a recommendation can be applied to new populations."[1] In addition, the task force will confirm within 5 years from the date of publication that the content reflects current clinical practice and the available technologies for the evaluation and treatment for patients with thoracolumbar trauma.

DISCUSSION

Cengiz et al[2] conducted a RCT of 27 patients with fractures between T8 and L2. All patients in this study were treated with pedicle screw fixation one level above and below the fracture. These patients were assigned to surgery at <8 hours or in 3 to 15 days. Randomization was by the day of the week that the patient was admitted to the hospital. The mean duration of follow-up was 14.5 months (range 12–20 months). The study evaluated American Spinal Injury Association (ASIA) scores, and hospital and intensive care unit (ICU) length of stay. ASIA scores were similar in both groups preoperatively, but group I (surgery <8 hours) had a better postoperative score than group II ($p < .011$). In group I, 83% had improvement in ASIA scores, while in group II, 26% showed improvement. The median hospital length of stay for group I was 12.5 days (range 5–30 days), and for group II it was 26 days (range 14–54 days; $p < .001$). No patients in either group were admitted to the ICU. Group II had 3 patients with pulmonary failure and 1 patient had sepsis. No complications were reported in group I. The deficiencies of this study are a small sample size, poor follow-up, and no power analysis. In addition, the time to surgery was not reported for either group. This study provides level III evidence that early surgery may improve neurologic outcome in patients with thoracolumbar fractures between T8 and L2, and may lead to shorter hospitalization and complication rates.

Rahimi-Movaghar et al[3] performed a RCT of 35 patients who had T1 to L1 fractures with spinal cord injury, comparing surgical decompression <24 hours (early; n = 16) to surgery at 24–72 hours (late; n = 19). Surgery included pedicle screw fixation from 2 to 5 levels, and 2 patients had combined anterior and posterior surgery performed in 2 stages. ASIA scores and vertebral height and angle reduction were compared preoperatively and at 12 months. Length of hospitalization and complications were also compared. Sixteen patients had complete spinal cord injury (AIS A), and those patients showed no motor improvement. Of patients with AIS A scores, 1 of 6 in the early group had a 1-grade improvement, while 1 of 9 had a 1-grade improvement in the late group. The improvement in these patients' AIS scores were solely related to increased sensory scores. Three of 16 incomplete (AIS B–E) patients in the early group showed a 2-grade improvement in AIS scores, compared to 1 patient in the late surgery group. For incomplete patients, the mean motor score improved from 77 (±22) to 92 (±12) in the early surgery group, and from 68 (±22) to 82 (±16) in the late surgery group. Mean length of stay was 7 ± 7.13 days in the early group and 9.8 ± 8.28 in the late group ($p > .05$). Deficiencies of this study included a small sample size, lack of power analysis, lack of statistical analysis, and lack of standardized surgical technique. This study provides level III evidence that motor improvement can occur in both early and late surgery, but that there is no improvement in patients with complete spinal cord injury.

Stahel et al[4] reported a prospective cohort study, which described a "spine damage control" protocol for unstable thoracic and lumbar spine fractures in severely injured patients. In this study, 112 patients were prospectively enrolled with an unstable fracture and with an Injury Severity Score (ISS) ≥15. Forty-two patients underwent surgery within 24 hours (mean = 8.9 hours ± 1.7), while 70 patients had surgery in a delayed fashion (mean = 98.7 ± 22.4 hours). In the early group, patients underwent a staged procedure, with immediate posterior fracture reduction and instrumentation within 24 hours, followed by a scheduled 360° completion of surgery >3 days after trauma. The second-stage surgery may have been performed during the initial hospitalization or during a second elective hospitalization. The late surgery group underwent a single-stage definitive operation at >24 hours. The early surgery group had lower mean length of operative time (24 ± 0.7 hours vs. 3.9 ± 1.3), length of hospital stay (14.1 ± 2.9 days vs. 32.6 ± 7.8), number of ventilator-dependent days (2.2 ± 1.5 days vs. 9.1 ± 2.4), and lower incidence of wound infection (2.4% vs. 7.1%), urinary tract infections (4.8% vs. 21.4%), pulmonary complications (14.3% vs. 25.7%), and pressures sores (2.4% vs. 8.6%; $p > .05$). This study had no follow-up and 2 different types of operative fixation (staged posterior and anterior surgery vs. posterior surgery alone). This study provides level IV evidence that early surgery may decrease postoperative complication rates.

Dvorak et al[5] reported a review of a Canadian spinal cord injury registry to assess the effect of early surgery on motor recovery and length of stay in patients with traumatic spinal cord injury. Of 1410 patients included in the registry that had information regarding time to surgery and length of stay, 120 patients had injuries from T2 to T10, and 151 patients had injuries from T11 to L2. The study showed that patients with cervical, thoracic, and lumbar fractures with spinal cord injuries that were operated on within 24 hours from time of injury had an average motor improvement of 6 points on the ASIA motor impairment scale, over those who had surgery after 24 hours. However, this registry study did not state what type of surgery was performed, and follow-up was only 3 to 6 months. This study provides level IV evidence that early surgery (<24 hours) may lead to improved motor function.

Boakye et al[6] performed an analysis of the 2003 to 2008 California Inpatient Database registry, and using multivariate analysis examined the importance of timing of surgery for complications and resource utilization after surgical treatment of thoracic and thoracolumbar fractures. A total of 1506 patients were included in this retrospective cohort. Surgery <72 hours after injury had statistically less risk of cardiac, pulmonary, and thromboembolic complications. In addition, the length of stay was 10.0 days for early surgery (<72 hours) compared to 15.0 days for late surgery ($p < .001$). Total hospital charges were less in the early surgery group, $213,031 versus $251,151 ($p < .001$). While this study showed that timing to surgery was the strongest predictor of complications, the limits of this study included a heterogeneous patient population, and the type of surgery performed is not specified or known. This study provides level IV evidence that early surgery, <72 hours after injury, may reduce the risk of perioperative cardiac, pulmonary, and thromboembolic complications, and have a lower length of hospital stay.

Gaebler et al[7] performed a retrospective analysis of 88 patients who underwent short segment fixation with transpedicular reduction of patients with thoracolumbar fracture/dislocations between 1985 and 1992 by 12 different surgeons. Average follow-up was 5.6 years (range 1.9–9.3 years). Frankel scores were obtained for group I (operation within 8 hours; n = 26), group II (operation after 8 hours, but within 10 days; n = 50), and group III (operation after 10 days; n = 12). Surgery was performed an average of 13.4 days after injury (range 0–207 days). Neurologic recovery, based on improvement in Frankel scores, was higher in group I than in groups II and III ($p < .001$). All patients with incomplete paraplegia who underwent surgery within 48 hours had improvement of Frankel score by ≥1 grade. Patients with Frankel grades between B and D, and who showed complete improvement to Frankel E were operated on within an average of 36 hours. Patients operated on after >48 hours showed no significant difference in neurologic recovery rates. All patients with incomplete paraplegia who underwent surgery within 48 hours showed an improvement of ≥1 Frankel grade (*p* < .001). This study had a small patient population, a lack of standardized treatment, and a high degree of heterogeneity of the patient population, and it provides level IV evidence that early surgery improves neurologic outcome.

Kerwin et al[8] performed a retrospective analysis of patients enrolled in a trauma registry, which included 361 patients, 158 of which were operated on within 48 hours, while 203 were operated on after >48 hours. The type of surgical procedure was not reported. Outcomes measured included ventilator days, intensive care unit length of stay, hospital length of stay, and mortality. Using chi square analysis, the only difference between the 2 groups was in mortality rate, which was higher in patients undergoing early surgery (7.6% vs, 2.5%; *p* = .0257), and hospital length of stay, which was shorter in the early surgery group (14.42 days vs. 17.64 days; *p* = .025). The shorter length of stay may be related to the higher mortality rate in patients undergoing early surgery. This study did not have a standardized surgical intervention, and also had a heterogeneous patient population. This study provides level IV evidence that early surgery may increase the risk of mortality.

Kerwin et al[9] also reported a retrospective database review of the National Trauma Data Bank in order to determine the breakpoint in reported timing of operative fixation. Of the 16,812 patients who underwent operative fixation for thoracolumbar fractures, 59% were operated on within 3 days of injury. Patients with enough complete data to allow analysis included 497 early (<3 days), which were matched to 374 late (>3 days). Hospital length of stay was shorter in the early group (13.6 days vs. 24.2 days; $p < .0001$). Complications were higher in the late group (30% vs. 17.5%; $p < .0001$). There were 160 different complications in 87 patients in the early group, and 190 different complications in 141 patients in the late group. Mortality was similar in both groups (2.0% vs. 1.9%; $p > .05$). This study provides level IV evidence that patients undergoing surgery within 3 days of injury had fewer complications.

Pakzad et al[10] performed a retrospective review of patients obtained from a multiple-trauma registry database of an academic regional trauma center of 83 patients who suffered spinal fractures requiring stabilization. The study reviewed subsequent in-hospital complications and length of stay. Unfortunately, this study did not state the type of surgical intervention that was performed, other than that surgery was performed by a fellowship-trained spine surgeon at an academic center. Patients were grouped into those having surgery <24 hours after admission to the hospital (time between injury and patient arrival was not recorded), and those >24 hours, although the reason for delay could not be identified. Twenty-nine of 83 patients had cervical injuries. Complications were categorized by severity (no complication, requires minimal treatment, moderate to major complications that require hospitalization and potential for long-term sequelae, and death) and whether the complication was related to recumbency (pneumonia, respiratory failure, deep venous thrombosis, and pulmonary embolus). The patients were divided based upon time to surgery of <24 hours, 24 to 72 hours, 72 hours to 7 days, and >7 days. Patients who had an ISS score of <18 had no difference in the complication rate, but for patients with ISS >18, early stabilization had a lower rate of complications than late fixation. Patients stabilized after 24 hours had an 8-fold greater risk of complications because of recumbency ($p = .007$), and surgery after 72 hours had a negative effect on complication rates. This effect remained significant after multivariate adjustments for age, comorbidity, and ISS. This study provided level IV evidence that stabilization within 24 hours of hospitalization appears to reduce the risk of complications related to recumbency. However, due to the fact that 35% of the patients in this study had cervical injuries and because the study did not separately report results for thoracic and lumbar fractures, it was excluded.

Petitjean et al[11] performed a retrospective analysis of 164 patients who suffered spinal cord injury with other traumatic injuries. Of these, 49 patients had thoracolumbar fractures. Ten patients were operated on within the first 24 hours, undergoing an unspecified open reduction and internal fixation, while 22 underwent surgery >24 hours after injury, at an average of 9 days. Seventeen patients were not operated on. In the early group, 5 of 10 patients were complete and did not recover function. Four of 5 incomplete patients had good neurologic recovery, although this is not categorically delineated. There was no difference in mean ICU stay between the 2 groups. This small study provides level IV evidence that early surgery may improve neurologic recovery for patients with incomplete spinal cord injury, and that neurologic recovery for the patient with a complete injury does not occur, regardless of the timing of surgery.

Park et al[12] performed a retrospective analysis of 166 polytrauma patients, and only evaluated hospital length of stay, ICU length of stay, and ventilator days. Seventy patients underwent surgery within 72 hours, while 96 patients underwent surgery after 72 hours. The late group had higher hospital length of stay (51.14 vs. 36.04 days; $p = .004$). In the early group, of the 18 patients who were intubated, mean ICU stay was 3.84 days and mean ventilator days was 1.53, compared to 5.0 and 2.11 days in the 13 intubated patients in the late group ($p = .044$ and $p =$

.043, respectively). This study had a small number of patients, no follow-up, and the type of surgery that patients underwent was not delineated, providing level IV evidence that early surgery was associated with shorter length of stay, ICU length of stay, and ventilator days than late surgery.

Schinkel et al[13] performed a retrospective review of German National Trauma Database, and reviewed 205 patients with severe thoracic injuries who underwent spinal stabilization, which were divided into early (<72 hours; n = 156) and late (>72 hours; n = 49). The early group had shorter ICU stay (8 days vs. 16 days; p = .001), shorter dependence on mechanical ventilation (2 days vs. 5 days; p = .02), and shorter hospital length of stay (22 days vs. 31 days; p = .048). This study lacked follow-up and standardized surgical intervention. This study provides level IV evidence that early stabilization of thoracic spine injuries may reduce hospital and ICU length of stay, as well as dependence on mechanical ventilation.

Schlegel et al[14] performed a retrospective review of 138 patients who underwent surgery for spinal fractures, which included 40 cervical injuries. Patients were classified based on timing of surgery (<72 or >72 hours from injury), as well as ISS of <18 or >18. Surgery was performed either via an anterior or a posterior approach based on the pathology of the fracture, but the number of each type of surgery was not delineated in the study. Irrespective of the ISS score and associated injuries, fewer perioperative complications occurred in patients undergoing early surgery than late surgery. Surgery >72 hours after injury had a higher risk of pulmonary complications, pressure sores, and urinary tract infection. Those undergoing late surgery had a 4.3 times higher risk of being admitted to the ICU, and 2.8 times higher risk of being on a mechanical ventilator, 12.2 times more likely to develop pulmonary complications, 4.8 times higher risk of developing pressure ulcers, and 3.2 times more likely to develop urinary tract infections. Patients with neurologic injury had increased morbidity, regardless of the timing of surgery. Of the 138 patients in the study, 26 had a change in Frankel grade. Two patients worsened, while 24 patients (all incomplete spinal cord injuries) had an average improvement of 1.2 Frankel grades (19 improved 1 grade, 5 improved 2 grades). There was no correlation between the timing of surgery and improvement in Frankel grade. In patients with isolated spinal fractures, the timing of surgical intervention did not have a statistically significant effect on the neurological outcome. This study had deficiencies that included the lack of follow-up and heterogeneity of surgical treatment. This study provided level IV evidence that early surgery does not improve neurologic outcome, but may reduce perioperative complications. However, in this study, 28% of the patients had cervical spine injuries, and their results were not separately reported from those with thoracic and lumbar spine injuries. Therefore, this study was excluded.

Question

Does early surgical intervention improve outcomes for patients with thoracic and lumbar fractures?

Recommendation

There is insufficient and conflicting evidence regarding the effect of timing of surgical intervention on neurologic outcomes in patients with thoracic and lumbar fractures.

Strength of Recommendation: Grade Insufficient

There is insufficient data in the literature to make a recommendation regarding the timing of surgical intervention in patients with thoracolumbar burst fractures. Some studies suggest that early surgery may be considered to reduce length of hospital stay and complication rate. The literature uses variable definitions of "early," ranging from <8 hours to <72 hours. There is conflicting evidence in the literature with regards to the effect of the timing of surgical intervention on neurologic outcomes in patients with thoracolumbar fracture.

Timing of Surgery

The literature was highly variable with regards to what the definition of "early" and "late" surgery was. Two papers defined early surgery as <8 hours after injury,[2,7] while 4 papers defined it as <24 hours.[3-5,11] One paper defined it as <48 hours,[8] and 4 defined it as <72 hours.[6,9,12,13] Because of the high degree of variability regarding the time to surgery, there is insufficient evidence to determine which cutoff would be an appropriate definition of early versus late surgery.

Neurologic Recovery

Six studies evaluated neurologic improvement in relation to timing of surgery.[2,3,5,7,8,11] One study[8] showed no difference in neurologic recovery between early surgery and late surgery at 48 hours, while 4 studies showed that early surgery may improve neurologic recovery.[2,5,7,11] Two studies[3,11] showed that there is no indication for early surgery in complete spinal cord injury, and Schlegel et al[14] showed that the presence of neurologic deficit increased the risk of morbidity compared to patients who are neurologically intact, although this study included cervical patients. Rahimi-Movaghar et al[3] also showed that neurologic recovery can occur in both early and late surgery (before and after 24 hours).

The inconsistency of data regarding neurologic outcome in relation to timing of surgery in these 7 studies led to the recommendation of insufficient evidence regarding the effect of timing of surgical intervention on neurologic outcome.

Appendix VI shows a summary of the studies above, the number of patients in each study, each study's definition of early versus late surgery, and a brief result.

Recommendation 2

It is suggested that "early" surgery be considered as an option in patients with thoracic and lumbar fractures to reduce length of stay and complications. The available literature has defined "early" surgery inconsistently, ranging from <8 hours to <72 hours after injury.

Strength of Recommendation: Grade B

Length of Stay

Hospital length of stay and ICU stay were reviewed in several studies, as well as the number of days of mechanical ventilation. Five studies showed that early surgery may decrease the hospital length of stay.[2,4,6,12,13] However, none of the above-mentioned studies compared postoperative length of stay. Therefore, one can make the assertion that the longer length of stay in patients undergoing late surgery was directly related to the time of delay between admission and surgical intervention. In other words, for any given patient, a delay of several days between admission and surgery would increase that patient's hospitalization by that amount of time. The more time that the patient is recumbent prior to surgery, the greater the patient's length of stay, and therefore, increase the risk of complications related to recumbency. Kerwin et al[8] showed that patients undergoing early surgery had a higher mortality rate, and in this study, the authors posited that the shorter length of stay was related to those patients who expired in the early surgery group.

Complications

Complications related to recumbency were reviewed in 6 studies.[2,4,6,9,12,13] These studies also showed a correlation between longer length of stay and late surgery. Therefore, one would expect that the increased rate of complications is due to the prolonged recumbency for patients undergoing late surgery, and the increased time of recumbency between admission and surgical intervention for patients undergoing late surgery.

Mortality

Kerwin et al[8] showed that patients undergoing early surgery <48 hours after admission had a higher rate of mortality. Although this was a database study from a trauma registry, and patients had other associated sites of injury, the ISS score was similar between the 2 groups (21.6 in the early surgery group, 21.3 in the late surgery group). The groups were delineated by surgery before or after 48 hours. In this study, the mortality rate was 3 times higher in those undergoing early surgery compared to late surgery (7.6% vs. 2.5%; $p = .025$). Those who expired in the early group had a higher ISS score than those who did not (37 vs. 29). However, when the patients with cervical injuries were excluded, there was 1 death in the early group for patients with thoracic injuries, and 1 for patients with lumbar injuries. Therefore, when limiting to just thoracic and lumbar fractures, there were 2 deaths in the early group and none in the late group. There is insufficient evidence to conclude that morbidity is higher with early surgery compared to late surgery for those with thoracolumbar fractures.

Future Research

In reviewing the available medical literature, there is a lack of research that adequately compares the timing of surgery to neurological outcome. Even the definition of "early" and "late" surgery varies considerably in the currently available literature. However, the nature of traumatic injuries does not lend itself to RCTs. The fact that many patients with thoracolumbar fractures also have concurrent multisystem injuries makes it difficult to parse out confounding factors that could also influence the relationship between timing of surgery and neurologic outcome. Future trials or the implementation of prospective registries are needed in order to ascertain a relationship between the timing of surgical intervention and neurologic outcome for patients with thoracolumbar fractures.

Conclusions

The available medical literature is inconsistent in determining a definitive correlation between timing of surgical intervention and its effect on neurological outcome. The data suggest that early surgery reduces the length of hospitalization, and therefore may reduce the risk of complications related to recumbency. Surgery may be performed as early after injury as medically feasible in order to reduce the length of stay and complications related to recumbency for patients with thoracolumbar fractures. The available literature has a highly variable definition of what is considered “early” surgery, ranging from <8 hours to <72 hours after injury.

Potential Conflicts of Interest

The task force members were required to report all possible conflicts of interest (COIs) prior to beginning work on the guideline, using the COI disclosure form of the AANS/CNS Joint Guidelines Committee, including potential COIs that are unrelated to the topic of the guideline. The CNS Guidelines Committee and Guideline Task Force Chairs reviewed the disclosures and either approved or disapproved the nomination. The CNS Guidelines Committee and Guideline Task Force Chairs are given latitude to approve nominations of Task Force members with possible conflicts and address this by restricting the writing and reviewing privileges of that person to topics unrelated to the possible COIs. The conflict of interest findings are provided in detail in the companion introduction and methods manuscript.

Disclaimer of Liability

This clinical systematic review and evidence-based guideline was developed by a multidisciplinary physician volunteer task force and serves as an educational tool designed to provide an accurate review of the subject matter covered. These guidelines are disseminated with the understanding that the recommendations by the authors and consultants who have collaborated in their development are not meant to replace the individualized care and treatment advice from a patient's physician(s). If medical advice or assistance is required, the services of a competent physician should be sought. The proposals contained in these guidelines may not be suitable for use in all circumstances. The choice to implement any particular recommendation contained in these guidelines must be made by a managing physician in light of the situation in each particular patient and on the basis of existing resources.

Disclosures

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REFERENCES

1. Ransohoff DF, Pignone M, Sox HC. How to decide whether a clinical practice guideline is trustworthy. Jama. Jan 09 2013;309(2):139-140.

2. Cengiz SL, Kalkan E, Bayir A, Ilik K, Basefer A. Timing of thoracolomber spine stabilization in trauma patients; impact on neurological outcome and clinical course. A real prospective (rct) randomized controlled study. Archives of orthopaedic and trauma surgery. Sep 2008;128(9):959-966.

3. Rahimi-Movaghar V, Niakan A, Haghnegahdar A, Shahlaee A, Saadat S, Barzideh E. Early versus late surgical decompression for traumatic thoracic/thoracolumbar (T1-L1) spinal cord injured patients. Primary results of a randomized controlled trial at one year follow-up. Neurosciences (Riyadh, Saudi Arabia). Jul 2014;19(3):183-191.

4. Stahel PF, VanderHeiden T, Flierl MA, et al. The impact of a standardized "spine damage-control" protocol for unstable thoracic and lumbar spine fractures in severely injured patients: a prospective cohort study. The journal of trauma and acute care surgery. Feb 2013;74(2):590-596.

5. Dvorak MF, Noonan VK, Fallah N, et al. The influence of time from injury to surgery on motor recovery and length of hospital stay in acute traumatic spinal cord injury: an observational Canadian cohort study. Journal of neurotrauma. May 01 2015;32(9):645-654.

6. Boakye M, Arrigo RT, Hayden Gephart MG, Zygourakis CC, Lad S. Retrospective, propensity score-matched cohort study examining timing of fracture fixation for traumatic thoracolumbar fractures. Journal of neurotrauma. Aug 10 2012;29(12):2220-2225.

7. Gaebler C, Maier R, Kutscha-Lissberg F, Mrkonjic L, Vecsei V. Results of spinal cord decompression and thoracolumbar pedicle stabilisation in relation to the time of operation. Spinal cord. Jan 1999;37(1):33-39.

8. Kerwin AJ, Frykberg ER, Schinco MA, et al. The effect of early surgical treatment of traumatic spine injuries on patient mortality. The Journal of trauma. Dec 2007;63(6):1308-1313.

9. Kerwin AJ, Griffen MM, Tepas JJ, 3rd, Schinco MA, Devin T, Frykberg ER. Best practice determination of timing of spinal fracture fixation as defined by analysis of the National Trauma Data Bank. The Journal of trauma. Oct 2008;65(4):824-830; discussion 830-821.

10. Pakzad H, Roffey DM, Knight H, Dagenais S, Yelle JD, Wai EK. Delay in operative stabilization of spine fractures in multitrauma patients without neurologic injuries: effects on outcomes. Canadian journal of surgery. Journal canadien de chirurgie. Aug 2011;54(4):270-276.

11. Petitjean ME, Mousselard H, Pointillart V, Lassie P, Senegas J, Dabadie P. Thoracic spinal trauma and associated injuries: should early spinal decompression be considered? The Journal of trauma. Aug 1995;39(2):368-372.

12. Park KC, Park YS, Seo WS, Moon JK, Kim BH. Clinical results of early stabilization of spine fractures in polytrauma patients. Journal of critical care. Aug 2014;29(4):694.e697-699.

13. Schinkel C, Frangen TM, Kmetic A, Andress HJ, Muhr G. Timing of thoracic spine stabilization in trauma patients: impact on clinical course and outcome. The Journal of trauma. Jul 2006;61(1):156-160; discussion 160.

14. Schlegel J, Bayley J, Yuan H, Fredricksen B. Timing of surgical decompression and fixation of acute spinal fractures. Journal of orthopaedic trauma. 1996;10(5):323-330.

Appendix I: Literature Searches
Search Strategies
PubMed

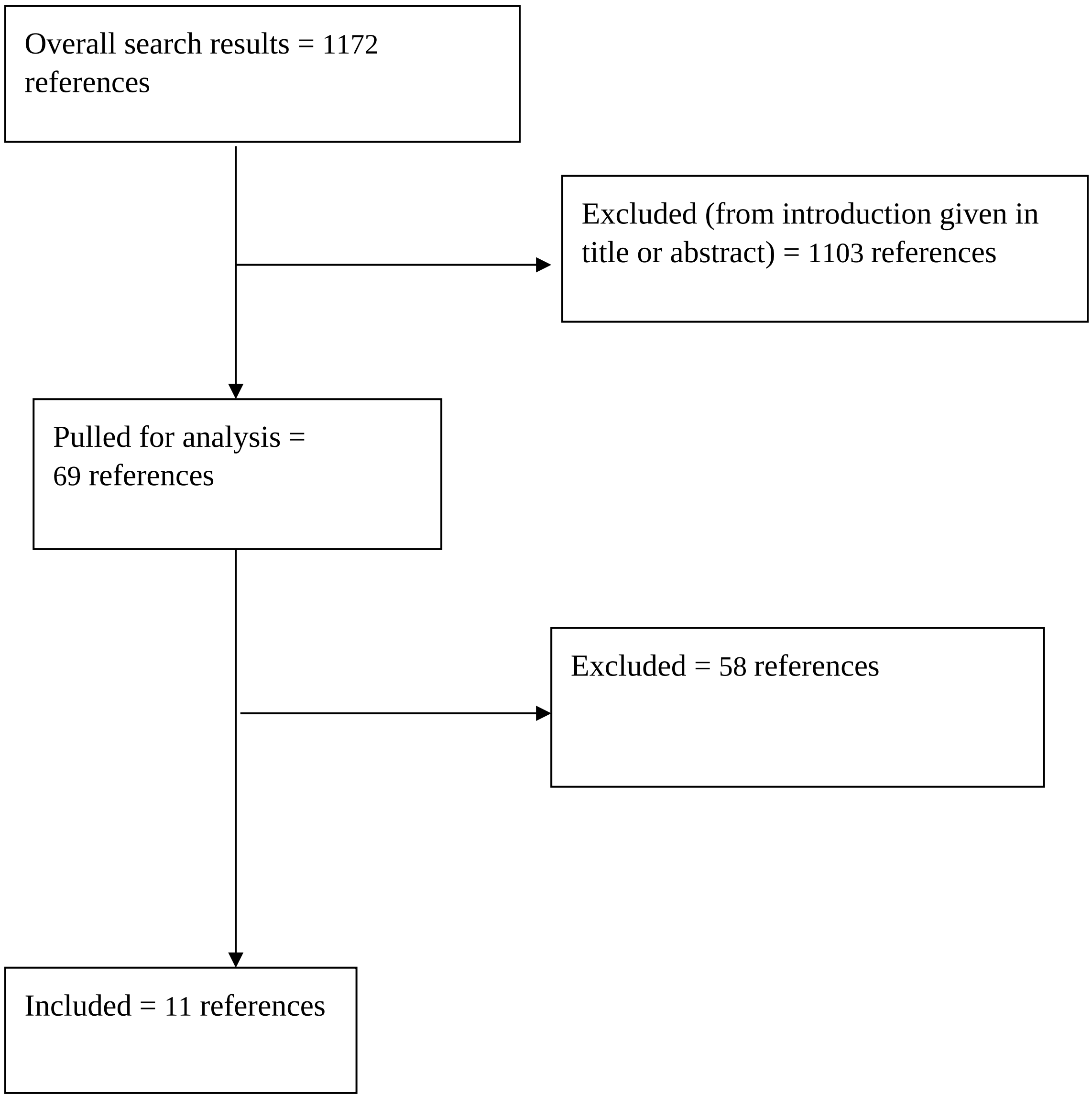
1. Lumbar vertebrae [MeSH] OR Thoracic vertebrae [MeSH]
2. Spinal Injuries [MeSH] OR Spinal Cord Injuries [MeSH]
3. #1 AND #2
4. Thoracolumbar [TIAB] OR thoraco-lumbar [TIAB] OR thoraco lumbar [TIAB] OR burst [Title]
5. Injur* [TIAB] OR trauma* [TIAB] OR fractur* [TIAB] OR dislocation* [TIAB]
6. #4 AND #5
7. Lumbar vertebrae/injuries [MeSH] OR Thoracic vertebrae/injuries [MeSH] (3150 results)
8. #3 OR #6 OR #7
9. Orthopedic Procedures [MeSH] OR Neurosurgical Procedures [MeSH] OR Decompression, surgical [MeSH] OR Orthopedic Fixation Devices [MeSH] OR surgery [SH] OR instrumentation [SH]
10. surgery[tiab] OR surgical[tiab] OR operati*[tiab] OR repair*[tiab] OR stabiliz*[tiab] OR fixation[tiab] OR reconstruct*[tiab] OR fusion[tiab] OR decompress*[tiab] OR spondylodes*[tiab] OR spondylosyndes*[tiab] OR arthrodes*[tiab] OR laminectomy[tiab] OR discectomy[tiab] OR diskectomy OR “percutaneous vertebral augmentation”[tiab] OR “bone screw”[tiab] OR “bone screws”[tiab] OR “bone plate”[tiab] OR “bone plates” [tiab] OR “pedicle screw”[tiab] OR “pedicle screws”[tiab]
11. #9 OR #10
12. Time Factors [MeSH]
13. Time OR Timing OR early OR earli* OR late OR later OR delay* [TIAB]
14. #12 OR #13
15. #11 AND #14
16. #8 AND #15
17. (animal [MeSH] NOT human [MeSH]) OR cadaver [MeSH] OR cadaver* [Titl] OR comment [PT] OR letter [PT] OR editorial [PT] OR addresses [PT] OR news [PT] OR “newspaper article” [PT] OR case reports [PT]
18. #16 NOT #17
19. osteoporosis [MH] OR osteoporotic fractures [MH] OR osteoporo* [TITLE] OR spinal neoplasms [MH] OR tumor* [TITLE] OR tumour* [TITLE] OR malignan* [TITLE]
20. #18 NOT #19
21. #20 AND English [Lang]

Cochrane Library

1. Lumbar vertebrae: MeSH descriptor, explode all trees
2. Thoracic vertebrae: MeSH descriptor, explode all trees
3. #1 OR #2
4. Spinal Injuries: MeSH descriptor
5. Spinal Cord Injuries: MeSH descriptor
6. #4 OR #5
7. #3 AND #6

8. (Thoracolumbar OR thoraco-lumbar OR thoraco lumbar OR burst) NEAR/4 (Injur* OR trauma* OR fractur* OR dislocation*):ti,ab,kw
9. Lumbar vertebrae/injuries: MeSH descriptor, explode all trees
10. Thoracic vertebrae/injuries: MeSH descriptor, explode all trees
11. #9 OR #10
12. #7 OR #8 OR #11
13. mh osteoporosis or mh osteoporotic fractures or mh spinal neoplasms
14. osteoporo* or tumor* or malignan*:ti
15. #13 OR #14
16. #12 NOT #15

Appendix II: Article Inclusions and Exclusions
Included and Excluded Articles Flowchart



Appendix III: Rating Evidence Quality

Levels of Evidence for Primary Research Question[a]

Types of studies				
	Therapeutic studies – Investigating the results of treatment	**Prognostic studies – Investigating the effect of a patient characteristic on the outcome of disease**	**Diagnostic studies – Investigating a diagnostic test**	**Economic and decision analyses – Developing an economic or decision model**
Level I	• High-quality randomized trial with statistically significant difference or no statistically significant difference but narrow confidenceintervals • Systematic review[b] of level I RCTs (and study results were homogenous[c])	• High-quality prospective study[d] (all patients were enrolled at the same point in their disease with ≥80% follow-up of enrolled patients) • Systematic review[b] of level I studies	• Testing of previously developed diagnostic criteria on consecutive patients (with universally applied reference “gold” standard) • Systematic review[b] of level I studies	• Sensible costs and alternatives; values obtained from many studies; with multiway sensitivity analyses • Systematic review[b] of level I studies

Level II	• Lesser quality RCT (e.g., ≤80% follow-up, no blinding, or improper randomization) • Prospective[d] comparative study[e] • Systematic review[b] of level II studies or level I studies with inconsistent results	• Retrospective[f] study • Untreated controls from an RCT • Lesser quality prospective study (e.g., patients enrolled at different points in their disease or ≤80% follow-up) • Systematic review[b] of level II studies	• Development of diagnostic criteria on consecutive patients (with universally applied reference "gold" standard) • Systematic review[b] of level II studies	• Sensible costs and alternatives; values obtained from limited studies; with multiway sensitivity analyses • Systematic review[b] of level II studies
Level III	• Case control study[g] • Retrospective[f] comparative study[e] • Systematic review[b] of level III studies	• Case control study[g]	• Study of non consecutive patients; without consistently applied reference "gold" standard • Systematic review[b] of level III studies	• Analyses based on limited alternatives and costs; and poor estimates • Systematic review[b] of level III studies
Level IV	Case series[h]	Case series	• Case-control study • Poor reference standard	• Analyses with no sensitivity analyses

RCT, Randomized controlled trial.
[a]A complete assessment of quality of individual studies requires critical appraisal of all aspects of the study design.
[b]A combination of results from ≥2 previous studies.
[c]Studies provided consistent results.

[d]Study was started before the first patient enrolled.
[e]Patients treated one way (e.g., instrumented arthrodesis) compared with a group of patients treated in another way (e.g., unsintrumented arthrodesis) at the same institution.
[f]The study was started after the first patient enrolled.
[g]Patients identified for the study based on their outcome, called “cases” (e.g., pseudoarthrosis) are compared to those who did not have outcome, called “controls” (e.g., successful fusion).
[h]Patients treated one way with no comparison group of patients treated in another way.

Appendix IV: Linking Levels of Evidence to Grades of Recommendation

Grade of Recommendation	Standard Language	Levels of Evidence	
A	Recommended	Two or more consistent Level I studies	
B	Suggested	One Level I study with additional supporting Level II or III studies	Two or more consistent Level II or III studies
C	is an option	One Level I, II or III study with supporting Level IV studies	Two or more consistent Level IV studies
Insufficient (Insufficient or Conflicting Evidence)	Insufficient evidence to make recommendation for or against	A single Level I, II, III or IV study without other supporting evidence	More than one study with inconsistent findings*
*Note that in the presence of multiple consistent studies, and a single outlying, inconsistent study, the Grade of Recommendation will be based on the level of the consistent studies.			

Appendix V. Criteria Grading the Evidence

The task force used the criteria provided below to identify the strengths and weaknesses of the studies included in this guideline. Studies containing deficiencies were downgraded one level (no further downgrading allowed, unless so severe that study had to be excluded). Studies with no deficiencies based on study design and contained clinical information that dramatically altered current medical perceptions of topic were upgraded.

1. Baseline study design (i.e. therapeutic, diagnostic, prognostic) determined to assign initial level of evidence.
2. Therapeutic studies reviewed for following deficiencies:
    - Failure to provide a power calculation for an RCT;
    - High degree of variance or heterogeneity in patient populations with respect to presenting diagnosis/demographics or treatments applied;
    - Less than 80% of patient follow-up;
    - Failure to utilize validated outcomes instrument;
    - No statistical analysis of results;
    - Cross over rate between treatment groups of greater than 20%;
    - Inadequate reporting of baseline demographic data;
    - Small patient cohorts (relative to observed effects);
    - Failure to describe method of randomization;
    - Failure to provide flowchart following patients through course of study (RCT);
    - Failure to account for patients lost to follow-up;
    - Lack of independent post-treatment assessment (e.g., clinical, fusion status, etc.);
    - Utilization of inferior control group:
        - Historical controls;
        - Simultaneous application of intervention and control within same patient.
    - Failure to standardize surgical/intervention technique;
    - Inadequate radiographic technique to determine fusion status (e.g. – static radiographs for instrumented fusion).
    - If an RCT fails criteria specific to RCT (such as method randomization reported or improper, no power, greater that 20% crossover, if there is or is not post treatment assessment, inappropriate statistics, no baseline data, small cohorts, etc.), then it will be initially assigned to level II. Only if it further fails additional evaluation, can it be downgraded further to a level III.
3. Methodology of diagnostic studies reviewed for following deficiencies:
    - Failure to determine specificity and sensitivity;
    - Failure to determine inter- and intra-observer reliability;
    - Failure to provide correlation coefficient in the form of kappa values.
4. Methodology of prognostic studies reviewed for following deficiencies:
    - High degree of variance or heterogeneity in patient populations with respect to presenting diagnosis/demographics or treatments applied;
    - Failure to appropriately define and assess independent and dependent variables (e.g., failure to use validated outcome measures when available).

Appendix VI. Summary – Timing of Surgery

Author, Year (Level of Evidence)	+ or -	Number of Patients	Timing	Results
Cengiz, 2007 (III)	Positive	27	+ 8 hours	Early surgery may improve neuro recovery Early surgery may decrease LOS and complications
Rahimi 2014 (III)	Negative	35	+ 24h, 24-72h	Motor improvement can occur in early and late surgery No improvement in patients with complete spinal cord injury
Stahel 2012 (III)	Positive	112	+ 24 hours	Early surgery has decreased LOS and complications for high ISS patients
Dvorak 2015 (IV)	Positive	271 (db)	+ 24 hours	Early surgery can improve ASIA Motor by avg. 6 pts
Boakye 2012 (IV)	Positive	1506 (db)	+ 72 hours	Early surgery has less cardiac, pulmonary, VTE complications Early surgery has lower LOS and costs
Gaebler 1999 (IV)	Positive	88	<8h, 8-48h 48h-10 days	Early surgery had better neurologic recovery
Kerwin 2007 (IV)	Negative	361 (db)	+ 48 hours	No difference between early and late surgery Early surgery had higher mortality
Kerwin 2008 (IV)	Positive	871 (db)	+ 72 hours	Late surgery was associated with increased complications
Petitjean 1995 (IV)	Positive	49	+ 24 hours	Early surgery has no indication in complete SCI Early surgery should be considered in incomplete spinal cord injury
Park 2014 (IV)	Positive	166	+ 72 hours	Late surgery has increased LOS and complications

Author, Year (Level of Evidence)	+ or -	Number of Patients	Timing	Results
Schinkel 2006 (IV)	Positive	205	+ 72 hours	Early surgery has decreased hospital and ICU LOS, less complications
Schlegel 1996 (IV)	Negative	138	+ 72 hours	Timing of surgery did not change neurological outcome Presence of neurological deficit increased morbidity vs. intact patients
Summary				
Positive for Early Surgery	2 Level III papers 7 Level IV papers			
Negative for Early Surgery	1 Level III paper 2 Level IV papers			

Abbreviations: db—database or registry study

Appendix VII. Evidence Table

Author, Year	Level of Evidence	Task Force Conclusions relative to question and rationale for evidence grading
Cengiz ~~~~~~~~~~~~~ 2007	III	This paper provides evidence that: While it is an RCT, only has 27 patients, and only looked at ASIA and LOS.
Dvorak ~~~~~~~~~~~~~ 2015	IV	This paper provides evidence that: Early surgery < 24 hours after injury can improve ASIA motor score by an average of 6 points
Rahimi-Movagher ~~~~~~~~~~~~~ 2014	III	This paper provides evidence that: Small initial results of RCT showing that motor improvement can occur in both early and late surgery, no improvement in complete SCI.
Boakye ~~~~~~~~~~~~~ 2012	IV	This paper provides evidence that: Surgery less than 72 hours may reduce risk of cardiopulmonary and thromboembolic complications, as well as lower length of stay, and lower costs.
Gaebler ~~~~~~~~~~~~~ 1999	IV	This paper provides evidence that: Supports early surgery improves neurological recovery in small patient population.
Kerwin ~~~~~~~~~~~~~ 2007	IV	This paper provides evidence that: Does not support early vs. late surgery.
Petitjean ~~~~~~~~~~~~~ 1995	IV	This paper provides evidence that: Early surgery has no indication in patients with complete paraplegia. It can be considered in patients with incomplete injury if other injuries do not preclude surgery.

Author, Year	Level of Evidence	Task Force Conclusions relative to question and rationale for evidence grading
Park ~~~~~~~~~~~~~ 2014	IV	This paper provides evidence that: Delayed surgery > 72 hours may correlate with increased complications, longer LOS.
Kerwin ~~~~~~~~~~~~~ 2008	IV	This paper provides evidence that: Late surgery for spinal fractures may be associated with increased complications.
Stahel ~~~~~~~~~~~~~ 2012	IV	This paper provides evidence that: Early surgery may correlate with decreased LOS and complications in selected patients.
Schinkel ~~~~~~~~~~~~~ 2006	IV	This paper provides evidence that: Early surgery for thoracic injuries may reduce LOS and ventilator time.