Operative Timing and Management of Spinal Injuries in Multiply Injured Patients

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Abstract

Spinal injuries occurring in polytrauma patients are caused by high impact trauma. Due to high velocity mechanism, trauma of the vertebral column may be accompanied by injuries of adjacent body cavities such as thorax, abdomen, and pelvis. Neurologic examination is mandatory and has to be documented preferably using the ASIA/IMSOP-classification. Clinical symptoms may point towards spinal injury. However, absence of clinical symptoms is not sufficient to rule out spinal injuries. Two diagnostic pathways may be followed to assess the spine: (1) Conventional X-ray diagnostics of the entire spine followed by selective CT scanning of suspected lesions and CT scanning of the upper cervical spine region C0–C3 in unconscious patients. (2) Whole body polytrauma-multislice-spiral-CT scanning from head to pelvis without conventional X-ray playing the key role in the algorithm of modern ER management. In this study, 287 polytrauma patients with associated spinal injuries were analyzed prospectively from a cohort group of 731 polytrauma patients treated from 2002 to 2004 in our institution. Indications for surgery include neurologic deficit, instability, as well as malalignment and dislocation. In polytraumatized patients, indication for primary surgery is given in complex spinal injuries with associated vascular, neurologic, or organ injuries as well as multilevel spinal fractures or unstable spinal injuries. In patients with unstable spinal injuries cardio-pulmonary instability and life threatening intracranial pressure are contra – indications for immediate spinal surgery. On the day of injury ventral spondylodesis of unstable cervical spine fractures of C3–C7 and dorsal spondylodesis of unstable thoraco-lumbar fractures using internal fixator are the standard procedures. Polytrauma patients benefit from early stabilization of spinal fractures including reduction of ventilation and ICU treatment, pneumonia rate, general complications, as well as hospital stay. However, it is controversial if mortality rate and neurologic outcome are affected by the time point of operative stabilization.

Key Words
Spine · Poly trauma · Spine surgery

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Introduction

Approximately 25% of all relevant spinal injuries affect the cervical spine, 75% the thoracic and lumbar spine. In spinal injuries with traumatic plegia the rate of cervical spine injuries is increasing up to 40%. Ten percent of patients present with two level injuries of the vertebral column. Predominately, patients aged 20–30 suffer from spinal injury due to multiple trauma.

Predominate injuries of the upper cervical spine are odontoid fractures with 55%, followed by hangman fractures with 20% and axis ring fractures with 17%. In the lower cervical spine, segments C5/C6 and C6/C7 are affected in two out of three cases. In the thoracolumbar spine the junction and therefore segments T11–L2 is the predilection point and demonstrates the majority of fractures (62%).

These data originate form prospective analysis of 731 polytrauma patients treated in our institution from 2002 to 2004. In this cohort group, 287 patients (39%) presented with associated spinal injuries.

Mechanisms of Injury

Spinal injuries occurring in polytrauma patients are caused by high velocity and high impact trauma such as

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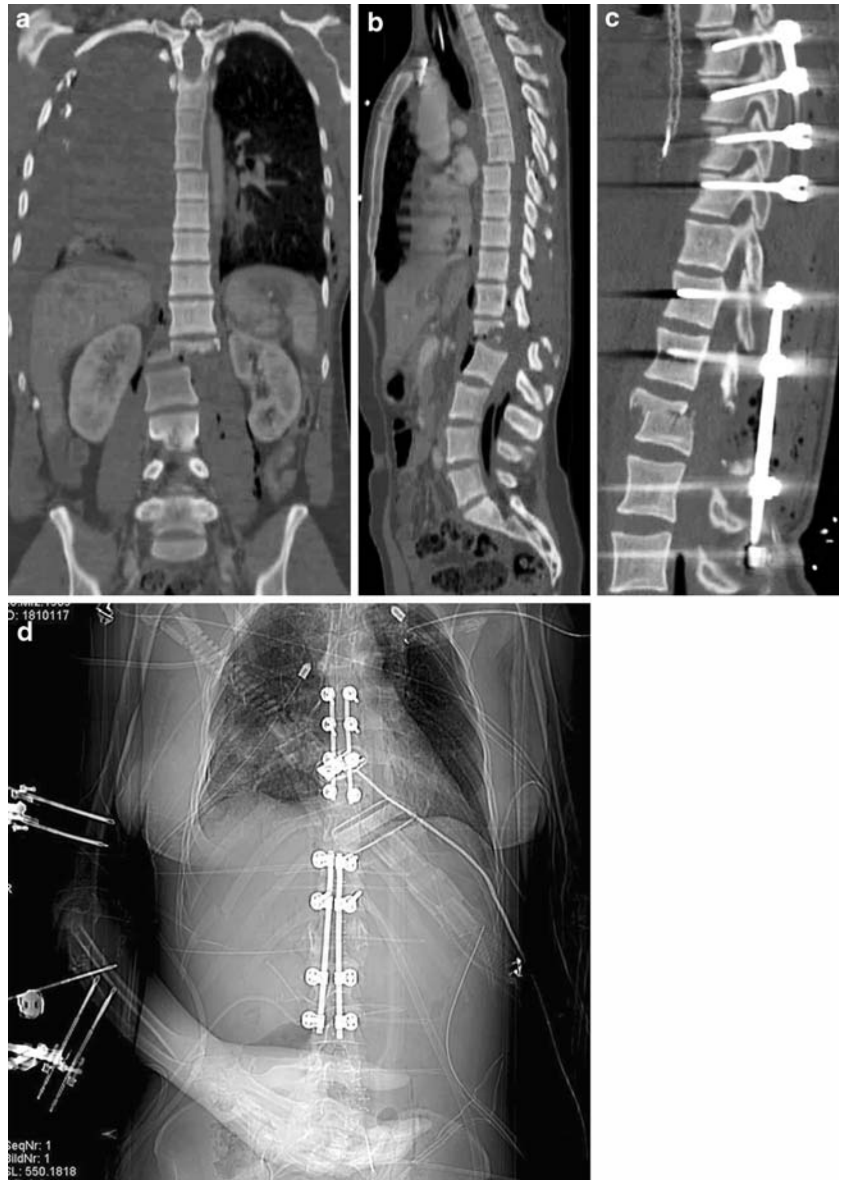


Figures 1a to 1c. a, b) Polytrauma with multi level spine injury including dislocation fracture T 7/8, and T12/1 with paraplegia at the level of T7, pulmonary trauma including bilateral hemato-pneumothorax, bilateral pulmonary contusion, and rib fractures, abdominal trauma including spleen and liver ruptures, right elbow fracture, and right pilon fracture. c, d) Operative treatment including extended, multilevel spinal stabilization with dorsal spondylodesis from T 6/7 to T 8/9, and T 11/12 to L 2/3, bilateral chest tubes, laparotomy with spleenectomy, and surgical hepatic hemostasis, temporary external fixator stabilization of upper and lower extremities fractures.

motor vehicle or motorbike accidents (50%), fall from big height, pedestrians hit by a car, sports injuries, and suicides. Alcohol and drugs predispose for these injuries. Spinal injuries are significantly correlated with head injuries specifically if Glasgow Coma Scale (GCS) is falling below 8. Predominate mechanisms of injury include axial compression as well as forced extension and flexion of the vertebral column. In motor vehicle passengers, deceleration differences between the core body that is firmly attached to the car seat by the seat belt, and the unsupported head is the critical pathomechanical factor.

Due to high velocity mechanism, trauma of the vertebral column may be accompanied by injuries of adjacent body cavities such as thorax, abdomen, and pelvis. Thoracic spine injuries are predominately combined with pulmonary contusion, rib fractures and hemato-pneumothorax (Figure 1). In the abdomen, the typical combination of injuries is the chance fracture accompanied by visceral injuries, specifically small intestine in restrained car passengers. In blunt high-speed trauma, parenchymal organs including spleen, liver, and kidney in decreasing order may be injured (Figure 1).

Diagnostics

Clinical

In conscious patients, motor function and sensatory response have to be evaluated. Dorsal tenderness and pain over head and core body may be indicative of spinal injuries. In addition, contusion of head, back, thorax, and abdomen may be found following spinal trauma. The specific examination of the spine includes inspection over bruises and hematoma, as well as palpation to detect discontinuation and dislocation of spinous processes as well as gaps over affected segments. Tenderness on palpation, distraction, or motion as well as fixed mal-alignment are additional signs of spinal injuries.

Neurologic examination is mandatory and has to be documented preferably using the ASIA/ IMSOP-classification specifically if neurologic deficits are observed. In unconscious patients, flaccid muscle tonus specifically of the anal sphincter, absence of pain reaction, exclusive abdominal breathing, and priapismus are indicative of plegic lesions.

Two studies that evaluated clinical presentation of patients with thoracolumbar fractures reported that specificity of symptoms such as tenderness on palpation over the head or vertebral column, pain with distraction or motion, palpable deformities and muscle lacerations was calculated 3.9%. The positive predictive value was 6.6% the negative predictive value and sensitivity was 90–100% [1, 2]. According to a study performed by Gonzalez [3] sensitivity of symptoms listed above is 91% for injuries of the cervical spine.

In summary, clinical symptoms may point towards spinal injury. However, absence of clinical symptoms is not sufficient to rule out spinal injuries.

Imaging Studies

In general, assessment of spinal injuries in severely traumatized patients can be performed using conventional or CT scanning imaging studies.

Conventional X-Ray Imaging

Recent standard includes conventional X-ray imaging of the spine antero-posterior (a.p.) and lateral followed by selected CT scanning. X-ray of the cervical spine using a.p. and lateral as well as odontoid views have absolute priority. The following qualitative criteria have to be met:

- On the lateral view all spinous processes of C2–T1 must be visible.
- Assessment of lateral masses C1 and C2 must be possible on the odontoid view.
- Additional imaging such as 45° oblique view for evaluation of C7/T1 alignment, swimmer view or similar views are facultative due to limited additional information and lengthy imaging technique.
- Functional X-Ray to assess inter-segmental instability of unconscious patients using the C arm must always be performed by a physician. Sensitivity in conscious patients was 92% with a specificity of 99% [4].

Unrecognized musculo-skeletal injuries in polytraumatized patients occur in approximately 12% affecting predominately the cervical spine and are caused by poor imaging technique, missing imaging studies or inconsistent diagnostic work flow. Therefore, in unconscious patients it is preferable to evaluate the upper cervical spine C0–C3 by CT scanning. In polytrauma patients missed injuries result in prolonged hospitalization time and consecutive operations. It is recommended to routinely evaluate the entire vertebral column. Specifically in blunt high-speed trauma and fall from heights, multilevel fractures may occur with a frequency of 10%. Therefore, thoracic and lumbar spine should always be evaluated by X-ray imaging a.p. and lateral.

Computed Tomography (CT) Scanning

Spinal injuries require a CT imaging study on day of trauma since in 70% of cases conventional X-ray imaging is not sufficient to adequately assess spinal fractures. In 20% spinal fractures are not recognized and in 40% not completely evaluated.

In the majority of cases (60%) additional information is provided by CT scanning. Specifically rotationally unstable fractures require a thorough CT evaluation. It is not advisable to operate on spinal injuries without CT assessment. Whole body multislice spiral CT scanning from head to pelvis without conventional X-ray studies is preferred to assess spinal injuries in polytrauma patients.

CT scanning is performed rapidly and provides increased diagnostic safety. In addition, it is associated with less discomfort for the patient and may reduce costs [5]. The wide-spread availability renders the CT scan the diagnostic tool of choice in diagnosing and assessing spinal injuries in polytrauma patients during the emergency room (ER) phase [6].

CT Scanning of Cervical Spine

Conventional X-ray has been described as not sufficient in diagnosing cervical spine injuries and therefore, CT scanning is recommended specifically in polytrauma patients [7, 8]. Compared to conventional X-ray, spiral CT imaging was superior in diagnosing cervical spine injuries in polytrauma patients demonstrating increased sensitivity of 90 versus 60%, specificity and positive predictive value of 100 versus 100% and negative predictive value of 95 versus 85%. In addition, studies have suggested that with increasing Injury Severity Score (ISS) and decreasing GCS, risk of not diagnosing or miss-diagnosing cervical spine injury using conventional X-ray is augmenting [9–12].

CT Scanning of Thoracic and Lumbar Spine

In a retrospective study, fractures of the thoracic spine were missed in 22% of polytrauma patients using conventional X-ray and therefore immediate CT imaging was recommended [13]. Similar to CT evaluation of cervical spine, CT scanning of thoracic and lumbar spine following multiple injury is beneficial and demonstrated superior results compared with conventional X-ray diagnostics: sensitivity 97 versus 58%, specificity 99 versus 93%, positive predictive value 95 versus 64%, negative predictive value 99 versus 92% [14]. In addition, duration of performing conventional X-rays was significantly longer than CT scanning in this study. Fracture classification using CT scanning was more precise than conventional X-ray and did not expose the patient to higher radiation dose.

CT Assessment of Additional Injuries: Head, Thorax, Abdomen

For assessment of the vertebral column and additional injuries following multiple trauma a whole body multislice-spiral CT from head to pelvis is initially performed. Computing and reconstructions require approximately 20 min.

Combined trauma of head and cervical spine injuries require immediate CT scanning upon admission. Following thoracic spine trauma, CT diagnostics of the thorax is also recommended due to the high incidence of associated thoraco-pulmonary injuries [15]. Lumbar spine injuries with additional contusion and hematoma of the abdominal wall following seat belt injury may be indicative of intra-abdominal lesions and are best assessed using CT scanning [16]. Transverse process fractures of the lumbar spine also point towards an intra-abdominal lesion [17, 18]. Specifically in patients with combination of spinal and abdominal injury, one step CT assessment is beneficial to plan and perform multi-discipline operative interventions without time delay.

Magnetic Resonance (MR) Imaging

Neurologic deficits caused by spinal cord lesions (Figure 2), disc pathology or ligamentous injuries are the

Figure 2. MR imaging of spinal cord lesion with complete tetraplegia following fracture dislocation C5.

major indications for MRI scanning. MRI scanning of polytrauma patients during the ER phase is of less importance since logistic reasons such as accessibility, ferrous objects, time, and availability render MRI scanning not practible.

In the consecutive hospital course, MRI is indicated to evaluate neurologic lesions and has also replaced functional X-ray studies, e.g. in hangman fractures. False negative results occur rarely however, specificity is poor [4].

Diagnostic Pathway

In summary, in severely traumatized patients it is important to diagnose or exclude spinal injuries following successful circulatory stabilization and prior to transfer of the patient to the Intensive Care Unit (ICU). Depending on the infrastructure of the admitting hospital two diagnostic pathways may be followed to assess the spine [19]:

(1) Conventional X-ray diagnostics of the entire spine followed by selective CT scanning of suspected lesions. CT scanning of the upper cervical spine region C0–C3 in unconscious patients.
(2) Whole body polytrauma-multislice-spiral-CT scanning from head to pelvis without conventional

X-ray playing the key role in the algorithm of modern ER management.

In conclusion, whole body multislice CT scanning is the gold standard for assessment of severely traumatized patients in the ER. Simultaneous CT assessment of vital organs and accompanying spinal injuries is beneficial for multi-disciplinary approach in the treatment of polytrauma patients.

Table 1. Advantages of early operative stabilization of spinal injuries in polytrauma patients.

Stability for patient positioning for ICU treatment
No "second hit" by delayed stabilization
Reduction of "antigenic load" mediated by thrombogenic substances,
Soft tissue necrosis, and persistent fracture hemorrhage
No delay in rehabilitation
Prevention of secondary neurologic damage caused by instability
Prevention from secondary complications
Reduction of ICU treatment and hospital course

Therapy

In patient cohorts suffering from spinal fractures without additional injuries, rate of operative treatment is approximately 66% and of conservative treatment 33%. In our study on polytrauma patients, operative treatment of spinal fractures was 72% and conservative treatment 28% indicating that in severely traumatized patients increased severity of fracture patterns require more likely operative stabilization.

Indications

Indications for surgery include:

- Neurologic deficit,
- Instability,
- Malalignment and dislocation

Predominate operative goals in the acute phase are:

- Reduction of dislocation
- Effective decompression of the spinal canal
- Stabilization of injured segments

Specific indications for operative intervention include atlanto-occipital dislocation [20], unstable Jefferson- and odontoid fractures (specifically type 2) [21], ''hangman'' fracture [22], and type A3, B and C fractures of C3–C7, as well as of T1–L5. In open spinal fractures immediate surgery is indicated [23].
Reconstruction of the ventral column of the thoracic and lumbar spine should be performed electively, e.g. with a time interval of days or weeks.

Indications in Polytrauma patients

Priority of treatment following polytrauma have life saving operations of body cavities and the head, followed by primarily emergent procedures such as stabilization of long bone fractures and thirdly stabilization of the spine. In patients with spinal cord injuries, spinal stabilization has priority over long bone stabilization [24].

In polytraumatized patients indication for primary surgery is deducted from the following classification:

(1) Complex spinal injuries associated with vascular, neurologic, or organ injuries of thoracic or abdominal cavity, as well as multi-level spinal fractures.
(2) Unstable spinal injuries since conservative and functional treatment may result in significant axis deviation and neurologic deficits.

Both complex and unstable spinal injuries require early operative stabilization [25]. If no contra-indications for surgery exist, early operative stabilization on day of trauma is advantageous (Table 1). Polytrauma may render a spinal injury a complex injury as suggested by a study that found prolonged hospitalization time and increased rate of operative interventions in polytrauma patients with spinal injury. In addition, increased morbidity, mortality, and disability were observed [26].

Neurologic Deficits

Additional therapeutic goals of primary operative stabilization in unstable fractures with diagnosed or suspected neurologic deficits include amelioration or prevention of neurologic impairment, as well as stabilization for safe patient positioning during intensive care treatment. Indication for surgery to avoid neurologic damage in unstable fractures without neurologic deficits is undisputed. Similarly, in unstable spinal injuries with associated thorax trauma requiring intermittent patient positioning, primary operative stabilization may be indicated to avoid secondary neurologic damage. However, it is controversial if primary stabilization of spinal fractures with injury of the spinal cord is beneficial for the patient compared with secondary stabilization [27].

Experimental studies have suggested that early fracture stabilization may be advantageous for outcome of neurologic deficits [28, 29]. Similarly, a meta-analysis recently performed by La Rosa [30] demonstrated a benefit from early compared to late decompression or conservative treatment. In the early decompression group amelioration of neurologic deficit in patients with complete deficit by 42% and in patients with incomplete deficit by 90% was observed. Following late decompression amelioration was 8% and 59%, respectively, and in the conservative group 25% and 59%, respectively. However, several clinical studies did not demonstrate a significant correlation between time point of surgery and neurologic outcome [31–34].

Associated Injuries

Various studies have reported additional beneficial effects from early fracture stabilization (within 3 days following trauma) in thoracic spine fractures associated with polytrauma [average Injury Severity Score (ISS) 24] including reduced duration of ventilator and ICU treatment, reduced rate of pneumonia and pulmonary complications, as well as reduced overall cost of treatment [35–39]. Similarly, Johnson et al. [40] found a reduced rate of adult respiratory distress syndrome (ARDS) in polytrauma patients treated with early stabilization of unstable spinal fractures. In patients with hematothorax and intrathoracic bleeding, early fracture stabilization of thoracic spine fractures is indicated [41]. Similarly, Petitjean et al. [42] recommended early fracture stabilization in patients with associated severe thorax trauma including pulmonary contusion.

In patients with spinal fractures and associated abdominal injury, laparotomy is required in approximately 38% of cases [9]. Following abdominal surgery, indication for subsequently immediate spinal stabilization has to be re-evaluated.

Indications for surgery listed above require detailed and complete assessment of polytrauma injuries during the ER phase. Prerequisites for operative stabilization of spinal injuries are cardio-pulmonary stability and exclusion of hemorrhage. Preferentially, additional vital parameters such as intracranial pressure, body temperature, and hemostasis should be within normal range. As mentioned above, these polytrauma patients benefit from early spinal stabilization to ensure safe patient positioning on the ICU. In addition, "second hit" impairment of immune system by post primary procedures as well as increased "antigenic load" mediated by instability of core body fractures is reduced.

If primary reduction, decompression, and stabilization of a spinal fracture risk life-threatening aggravation of general condition, spinal stabilization is viewed as a relative contra-indication and should be postponed (Table 2).

Table 2. Relative contra-indications for operative stabilization of spinal injuries in polytrauma patients.

No adequate CT – diagnostics available
Unstable cardio-circulatory condition
Hypothermia
Coagulopathy, thrombocytes < 90.000 μl
Mass transfusion > 10 erythrocyte units
Glasgow Coma Scale < 8 or intracerebral hemorrhage
Multiple long bone fractures
Estimated operating time > 6 h

In conclusion, polytrauma patients benefit from early stabilization of spinal fractures including prevention and reduction of general complications, and prolonged hospital stay. However, neurologic outcome may not be affected by the time point of operative stabilization.

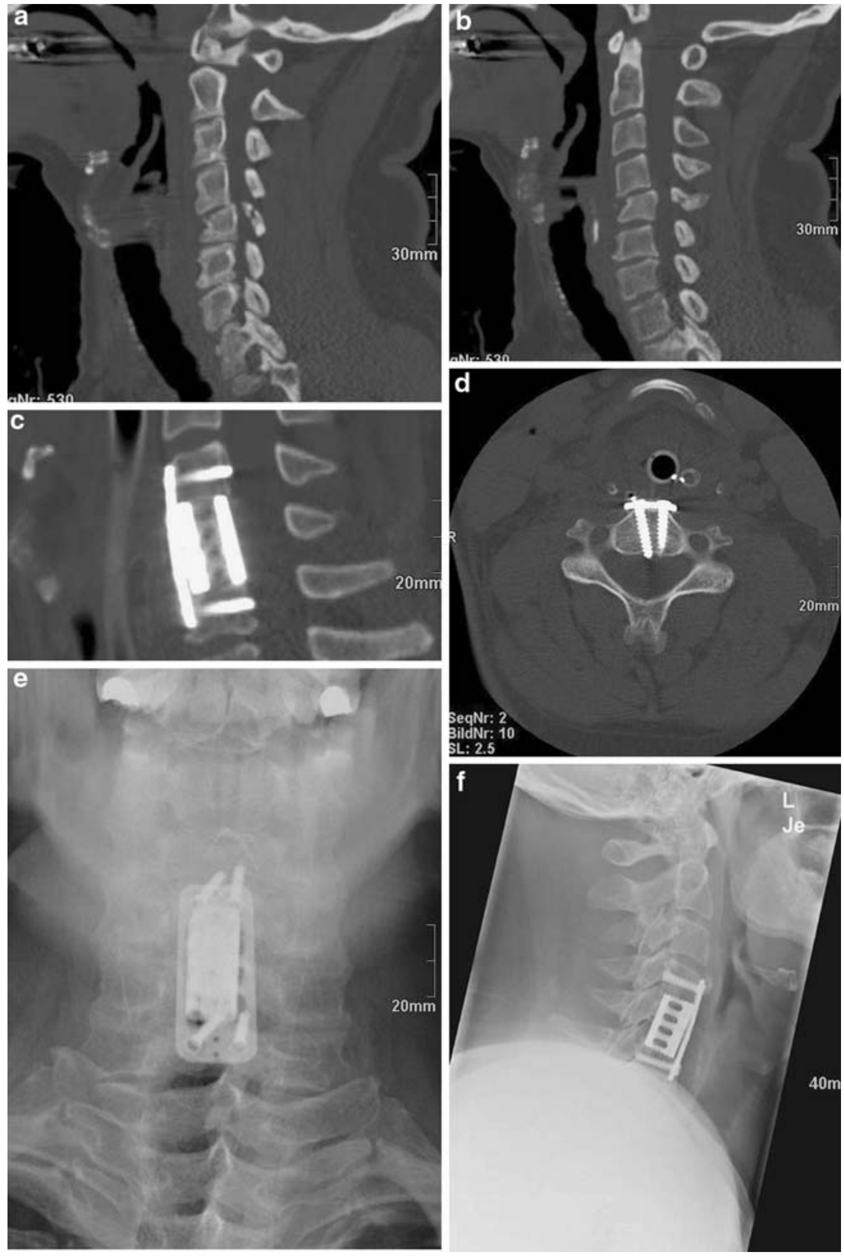
Cortisone Therapy

Three independent, randomized studies have suggested that application of methylprednisolon within 8 h following spinal trauma may improve neurologic outcome compared to placebo. The recommended i.v. dosis was Methylprednisolon 30 mg/kg body weight over 15 min within the first 8 h followed by 5.4 mg/kg body weight every hour for 23 h ("NASCIS-protocol" – National Acute Spinal Cord Injuries Study). Consecutive application over 48 h did not improve outcome and was only recommended for patients with a delay in cortisone treatment of three or more hours [43].

In neurologic deficits, both diagnosed or suspected, and CT morphologic evidence of compression of the spinal canal, early application of NASCIS protocol is indicated and may reduce time of rehabilitation [44]. In contrast, various studies were not able to prove beneficial effects of cortisone therapy [45, 46] and therefore, did not recommend its application [47]. Moreover, validity of the second NASCIS-Study has been criticized [48] and recent results of cortisone therapy following head injury have questioned its efficacy following spinal cord injury [49].

Although application of high doses of steroids is safe and appears advantageous [50, 51], potential side effects serve as an argument against steroid therapy administered according to the NASCIS protocol in polytrauma patients.

The multiply injured patient is endangered by complications associated with steroid therapy including increased risk of infections [52, 53], and impairment of

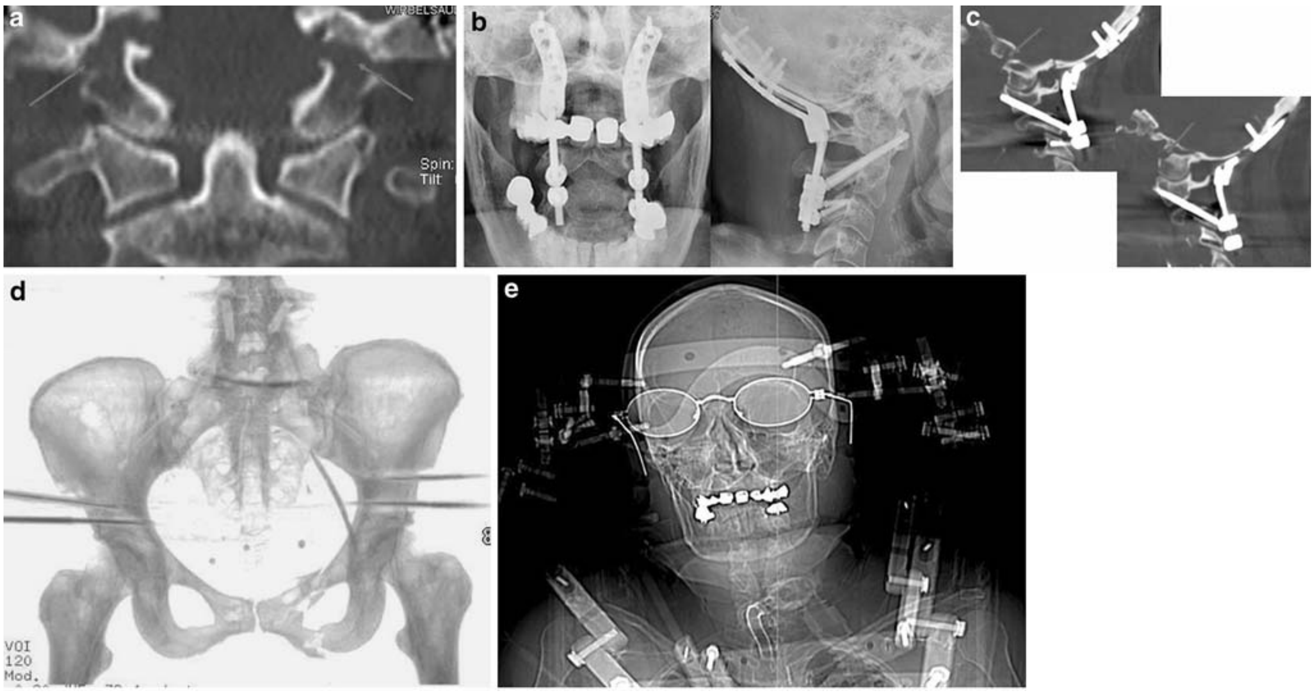


Figures 3a to 3f. a, b) Luxation fracture C5 with complete tetraplegia. c, d) Ventral spondylodesis using corporectomy C5, resection of intervertebral disc, stabilization using cage and caspar plate osteosynthesis. e, f) X-ray control 2.5 years following ventral spondylodesis.

metabolism specifically in combination with i.v. adrenalin [54]. A general recommendation for treatment with i.v. cortisone following spinal injuries is therefore not indicated.

Emergency Treatment of Spinal Injuries in Patients with Cardio-Pulmonary Instability

Hypothermia, mass transfusion, coagulopathy, pulmonary failure, high doses of catecholamines, and life threatening intracranial pressure are contra-indications for immediate spinal surgery. Following a single attempt of closed reduction of severe dislocations, the injuries are treated conservatively including immobilization of the cervical spine using a soft or rigid cervical collar or Halo Fixator. For thoracic or lumbar spine injuries no external fixation is possible and therefore, correct axis alignment and positioning of patients should be ensured.



Figures 4a to 4e. a–d) Polytrauma patient with C0 condyle fracture, intracerebral contusion, pulmonary contusion, multiple rib fractures, unstable pelvic ring fracture with sacral fractures S1–S5, and pubic ramus fractures. Initially, operative stabilization using Halo fixator and supra-acetabular, external fixator (d, e) followed by definitive treatment using dorsal cranio-cervical fusion from C0–C3 as well as dorsal ilio-lumbar transfixation (b, c, d).

Definitive Treatment

Cervical Spine Injuries

Ventral spondylodesis including corporectomy, removal of intervertebal disc, vertebral replacement using cage or autologous bone graft, and plate osteosynthesis is the standard procedure for dislocated fractures of C3–C7 [55] (Figure 3). On day of injury it is recommended to perform ventral spondylodesis of unstable cervical spine fractures instead of dorsal stabilization [56]. Brodke et al. [57] compared ventral and dorsal stabilization of cervical fractures and did not find significant differences for bony consolidation, reduction, neurologic deficit, and long term outcome.

In cases with complex instability dorsal spondylodesis may be indicated. These procedures are complex and time consuming and therefore, are not indicated as an acute phase procedure in polytrauma patients and should be performed electively following stabilization of general condition (Figure 4). Stabilization of fractures of the upper cervical spine using the Halo fixator may be an excellent treatment option for primary stabilization of polytrauma patients (Figure 4). Unstable odontoid fractures are treated secondarily by ventral screw fixation.

Thoracic and Lumbar Spine Injuries

Treatment of choice for thoraco-lumbar fractures is primary dorsal spondylodesis using internal fixator [58, 59]. With this procedure good reduction, decompression, and stabilization is achieved, allowing safe patient positioning during the phase of ICU treatment (Figures 1, 5). Dorsal spondylodesis is recognized as ''damage control'' procedure for spinal injuries in polytrauma patients [60]. In cases with significant compression of spinal canal and traumatic neurologic deficit intraoperative myelography following reposition is performed to verify decompression and unimpaired flow of contrast media in the spinal canal.

If clearance of the spinal canal is not achieved and if neurologic deficit prior to reduction was observed, laminectomy is indicated. Laminectomy may serve as entry point for dorsal decompression and reduction of bony fragments. It is controversial if spinal clearance by direct removal of fragments is beneficial [61–63]. However, laminectomy augments instability.

If ventral fusion of thoraco-lumbar fractures is indicated, it is recommended to perform these procedures electively in the secondary phase of operative

Figures 5a to 5d. a) Polytrauma following crush injury including dislocation fracture of lumbar spine L3–4 with complete plegia at the level of L3, pulmonary injury with hematothorax, and multiple rib fractures, left ilium fracture. b–d) Following open spinal reduction extended, dorsal spondylodesis using internal fixator in addition to plate osteosynthesis of left ilium fracture were performed.

treatment. Ventral spondylodesis may be performed using minimally invasive procedures and thoracoscopic techniques or mini open lumbotomy [64]. Even though performed in minimally invasive techniques, these body cavity procedures require stable condition of patient (Figure 6).

Operating Time

For all operative spine interventions in polytrauma patients, logistics and operating time need to be considered. Table 3 summarizes preparation and operating time for various procedures.

Primary operative procedures of polytrauma patients should be limited to duration of 3 h. Operating time exceeding 6 h is associated with increased mortality [65]. Thus, according to priorities listed above decision has to be taken if spinal stabilization is absolutely necessary, if it has to be included into ''day-one-surgery'', and if it fits into the advisable OR time.

Consecutive Procedures

In general, removal of hardware is not necessarily required following spinal stabilization. Halo Fixation applied for injuries of the upper cervical spine is continued for 6 weeks if no additional internal stabilization was performed. Internal fixators used for dorsal spondylodesis of the cervical spine can be removed, if necessary, after 3–12 months whereas dorsal internal fixators at the thoraco-lumbar spine are re-

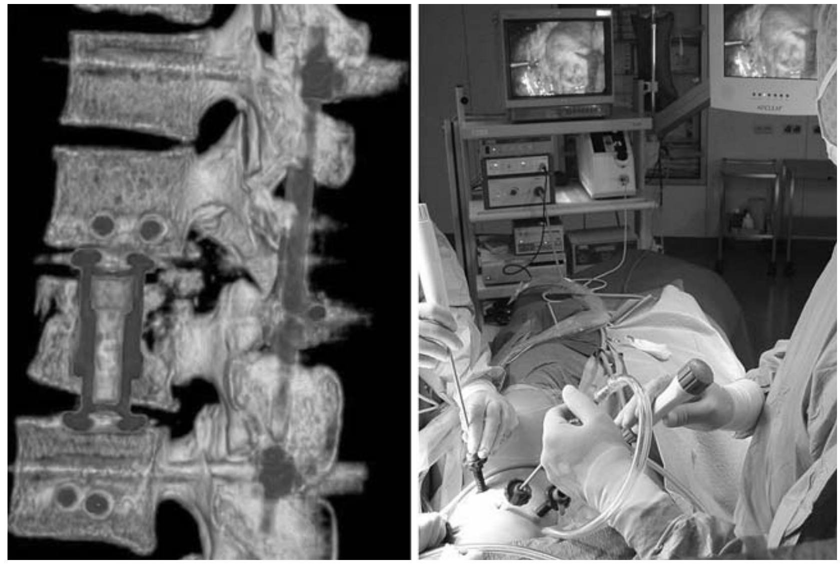
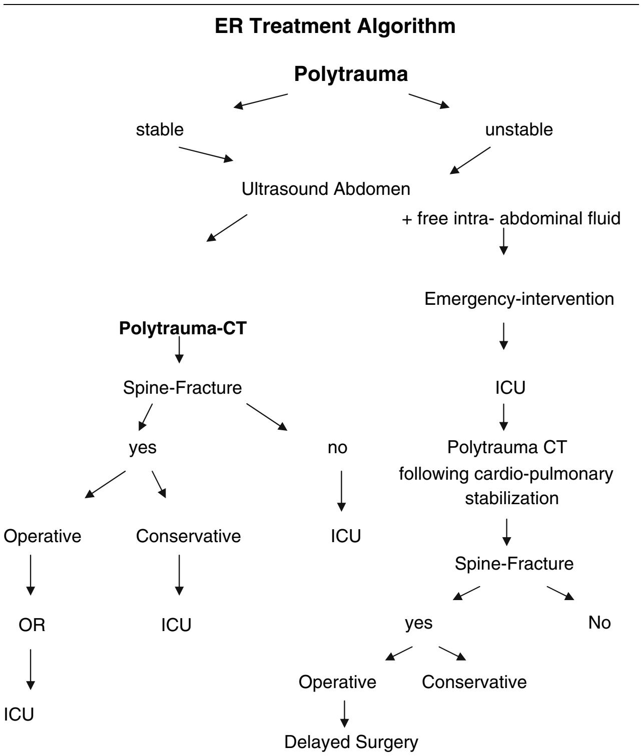


Figure 6. Ventral spondylodesis using minimally invasive, thoracoscopic corporectomy, and stabilization with expandable cage and plate osteosynthesis following dorsal spondylodesis with internal fixator.

Table 3. ER Treatment algorithm polytrauma.



moved after 12 months. If no additional ventral stabilization was performed a loss in reduction has to be expected.

Table 4. Intervention, logistic and technical preparation, operating time.

Intervention	Logistic preparation	Technical preparation	OR time
Halo fixator	Low	Low	1 h
Ventral cervical fusion	Moderate	Moderate	1–3 h
Dorsal cervical spondylodesis	High	High	> 3 h
Dorsal thoracic spondylodesis	Moderate	High	2–3 h
Dorsal lumbar spondylodesis	Moderate	Moderate	1–2 h
Ventral thoraco-lumbar fusion	High	High	2–4 h

Complications

Early Complications

Early complications include infections, hemorrhage, mal-positioning of implants, or injuries of adjacent organs such as the esophagus during ventral spondylodesis. Treatment of these complications follows general surgical principles including debridement and irrigation of infection, surgical hemostasis, and revision of misplaced implants. In esophageal lacerations and fistula, soft tissue coverage of the implant is critical to facilitate surgical or conservative treatment of the fistula.

In the study performed by the German Trauma Association (DGU) on cervical spine injuries, rate of early complications was calculated 10%. The surgical approach may result in nerve lesions and affects predominately the recurrent laryngeal and hypoglossus nerves. Postoperative deterioration of neurologic deficits was found in 3% of cases [66].

Figure 7. a, b) Dorsal stabilization of T11 and T12 fractures using extended spondylodesis with internal fixator at an outside institution. Postoperatively, neurologic deficit with incomplete paraplegia and urinary bladder and bowel dysfunction was noted caused by (c) malpositioning of screws perforating the spinal canal. In addition, implant deviation (d) without nerval damage is observed.

At the thoraco-lumbar spine early complications are predominately caused by deviation of trans-pedicular implants in approximately 10% of cases. Preferably, the nomenclature of implant *deviation* should be utilized if no neurologic deficits are provoked [58] (Figure 7).

The devastating complication of neurologic deterioration following operative stabilization of the spine can be caused by mal-positioning of screws perforating into the spinal canal and causing laceration or destruction of nerval structures (Figure 7). In addition to mal-positioned screws or accidental transposition of traumatized tissue into the spinal canal, impaired perfusion or edema formation may contribute to neurologic deterioration that was observed in approximately 1% of cases [58].

Polytrauma patients with spinal injuries are also exposed to the risk of thrombo-embolic complications including pulmonary embolism specifically in non-operatively treated unstable spinal injuries. If anti-thrombotic medication is not applicable protection may be provided by a removable cava filter [67].

Late Complications

In the continued hospital course, neurologic deterioration may occur as late and significant complication. Loosening and breakage of hardware, progressive compression of the spinal cord due to increasing dislocation or mal-alignment may play a role.

Following removal of hardware specifically of dorsally instrumented internal fixators at the thoracic and lumbar spine, loss in reduction and instability can occur. Instability is often associated with significant pain and indication to perform ventral spondylodesis has to be re-evaluated.

Prognosis

The incidence of spinal injuries in polytrauma patients has been reported in the literature with approximately 30% [68]. Analysis of polytrauma patients in our own institution in the years 2002–2004 revealed a percentage of 39% of associated spinal injuries (287 of 731 patients). Mortality is dependent on the overall severity of injuries as determined by the Injury Severity Score (ISS). In our study, ISS of polytrauma patients necessitating spinal surgery (206 of 287 or 72%) was 28 points and mortality was 5%.

Reduction in mortality to 3% was achieved by early intervention within 24 h following trauma. This cohort group with early intervention consisting of 120 out of 206 patients (58%) with a mean ISS score of 25 points also demonstrated reduced duration of ventilation (average of 13 days) and ICU treatment (average of 16 days). In the cohort group of patients with delayed intervention (in 86 out of 206 patients, 42%) duration of ventilation and ICU treatment was significantly higher with 20 and 21 days, respectively, and mortality increased to 7%. ISS score was significantly elevated with 33 points in this cohort group.

In the combined spine study of the German Trauma Association (DGU), amelioration of neurologic deficits was observed in 10% of cases following cervical spine and in 30% following thoraco-lumbar spine stabilization [59]. In our patient collective with strict adherence to operative treatment priorities discussed earlier, walking mobility following thoracic and lumbar spine injuries was achieved in more than 50% [58]. Undoubtedly, rate of typical complications including pneumonia, thrombosis, and decubitus is reduced by early compared to delayed operative stabilization.

For availability of emergent diagnostics and immediate operative intervention following spinal injuries an area covering network of hospital is required preferentially provided by designated trauma centers. Emergency spine interventions necessitate complex infrastructure and availability of medical staff, instruments, and technical equipment.

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