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An expert consensus on the evaluation and treatment of acute thoracolumbar spine and spinal cord injury in China

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Research Highlights

- (1) The difficult and controversial points of the care of acute thoracolumbar spine and spinal cord injury patients were determined through panel member discussion.
- (2) The development of this expert consensus involved evidence from existing literatures, previous experiences, previous guidelines, and expert recommendations.
- (3) This expert consensus was developed through panel member discussion and vote analysis and the resulting recommendations were graded.
- (4) The contents of this expert consensus are comprehensive and systematic, covering international topics and disputes.
- (5) This expert consensus, with a Chinese perspective, was completed by domestic experts including orthopedists, neurosurgeons, urologists, and rehabilitation physicians.
- (6) The prevention and treatment of major complications focused on the evaluation and treatment of voiding dysfunction, bowel dysfunction, and deep vein thrombosis. This section is clinically oriented and has certain characteristics as a result.
- (7) This consensus is a standard for the management of acute spine and spinal cord injury and was approved by domestic experts. It could standardize the evaluation and treatment of acute thoracolumbar spine and spinal cord injury.

Abstract

This is an expert consensus on the evaluation and treatment of thoracolumbar spinal injury, established from February 2009 to July 2010. The expert consensus consists mainly of six parts with a total of 54 recommendations including the overview (one item); pre-hospital care (one item); evaluation and diagnosis (13 items); treatment (23 items); prevention and treatment of major complications (12 items); and rehabilitation (four items). This is the first time that Chinese experts have published a consensus on spine and spinal cord injury. The expert consensus was established based on Delphi methods, literature analysis, and clinical experiences. Each recommendation is supported by and was interpreted using multi-level evidences. The level of agreement with the recommendation among the panel members was assessed as either low, moderate, or strong. Each panel member was asked to indicate his or her level of agreement on a 5-point scale, with "1" corresponding to neutrality and "5" representing maximum agreement. Scores were aggregated across the panel members and an arithmetic mean was calculated. This mean score was then translated into low, moderate, or strong. After all of the votes were collected and calculated, the results showed no low-level recommendations, 10 moderate-level recommendations, and 44 strong-level recommendations. An expert consensus was reached and was recognized by Chinese spine surgeons. Wide-scale adoption of these recommendations is urgent in the management of acute thoracolumbar spine and spinal cord injury in a broader attempt to create a standard evaluation and treatment strategy for acute thoracolumbar spine and spinal cord injury in China.

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Zhang ZC reviewed the evidence and references, extracted the data, and wrote the manuscript. Li F contributed to the paper's revision and study design. Sun TS is a sponsor and designer of the study. The panel members have carefully discussed and revised the manuscript several times. All authors approved the final version of the manuscript.

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Key Words

neural regeneration; spinal cord injury; expert consensus; thoracolumbar spine and spinal cord injury; guidelines; evidence-based medicine; neurological function; diagnosis; treatment; rehabilitation; grant-supported paper; neuroregeneration

INTRODUCTION

The early management of acute thoracolumbar spine and spinal cord injury is one of the most difficult tasks when treating trauma cases. To standardize the evaluation and treatment of acute thoracolumbar spinal injury, the Chinese Association of Spine and Spinal Cord Injury organized a group of Chinese experts to collectively discuss the draft of "An Expert Consensus on the Evaluation and Treatment of Acute Thoracolumbar Spine and Spinal Cord Injury".

The report is based on a detailed literature search and analysis of evidence-based medicine and clinical experiences. Experts from the Beijing Army General Hospital of Chinese PLA drafted this consensus in February 2010. In May 2010, Professor Shuxun Hou, Chair of the Chinese Association of Spine and Spinal Cord Injury, invited Chinese orthopedic, rehabilitative, and urological experts to discuss and revise the report in Beijing. In July 2010, the consensus was discussed and revised again at the Nanjing Meeting of the Spinal Cord Injury Academic Group. At the Nanjing meeting, all of the recommendations were explained and the categories of recommendations agreed upon by the panel were evaluated. Based on the feedback from the Nanjing meeting, the consensus was revised and discussed again at the general meeting of the Chinese Association of Spine and Spinal Cord Injury at Guangzhou in September 2011. The expert consensus of acute thoracolumbar spinal injury evaluation and treatment is now established and published.

The panel members have carefully considered the best evidence available in reaching a consensus and making recommendations for clinical care in China.

OVERVIEW

(1) The consensus was developed by an expert panel encompassing the myriad disciplines that care for acute traumatic T₁₁-L₂ injury with or without spinal cord, cauda equina, or nerve root injuries. The panel excluded minor injuries; thoracolumbar spinal cord injury without radiographic abnormalities; pathological fracture and dislocation; and ankylosing spondylitis associated with fracture and dislocation.

PRE-HOSPITAL CARE

(2) The spine of any patients with a potential thoracolumbar spinal injury should be immobilized correctly during patient transfer for diagnostic studies and for repositioning to maintain the alignment of a potentially unstable spine. Rapid and safe transport of the spinal injury patients allows for early medical stabilization and potentially improves the neurologic outcome. Fixation and transfer should be performed by at least three persons using correct methods of translation and axial rotation. Patients should be quickly transferred to a second-class or higher hospital. Although not supported by higher levels of medical evidence^[1], this time-tested practice is based on anatomic, mechanical, and clinical considerations, in an attempt to prevent further or new-onset spinal cord injury.

EVALUATION AND DIAGNOSIS

Evaluation

(3) Complete evaluation involves a comprehensive and systematic assessment of thoracolumbar injury morphology, integrity of the posterior ligamentous complex, and neu-

rological function status with history, physical examination, and imaging tests.

History

(4) A detailed medical history should be performed to determine the following: cause of injury; the occurrence and extent of the violence; neurological function; and treatment process and results.

Local examination

(5) Subcutaneous bleeding and thoracolumbar kyphosis should be identified. Palpation of each spinous process and interspinous process spaces should be performed as part of the assessment routine. The gap between spinous processes, widening of the interspinous space, and any steps between spinous processes should be carefully determined.

Neurological function examination

(6) The recommended method for examining neurological function is the American Spinal Injury Association (ASIA) method^[2] and neurological function impairment should be graded according to the ASIA Impairment Scale (Frankel method). Examination of anal sensation and sphincter autonomic contraction should be performed to identify complete or incomplete spinal cord injury as a standard protocol.

This ASIA classification requires a clinical examination with manual muscle testing of 10 key muscles bilaterally; a sensation examination for light touch and sharp/dull discrimination in 28 dermatomes bilaterally; and a rectal examination for sensation and voluntary contraction of the anal sphincter.

The panel recommends the following order for determining the classification of spinal cord injury using the ASIA method: 1) determine sensory levels bilaterally; 2) determine motor levels bilaterally; 3) determine the single neurological level; 4) determine the injury extent (complete/incomplete); and 5) determine the ASIA Impairment Scale grade.

The sensory level describes the most caudal segment of the spinal cord with normal sensory function bilaterally. The motor level describes the most caudal segment of the spinal cord with normal motor function bilaterally and it should be determined according to the level of the lowest key muscle whose strength is a minimum of grade 3, with the key muscles above this level having normal function (grade 5). The neurological level describes the most caudal segment of the spinal cord with normal

sensory and motor function bilaterally.

Incomplete spinal cord injury is defined as the partial preservation of sensory or motor function below the neurological level, including the lowest sacral segment (S₄₋₅). Sensory examination of the sacral spinal cord includes deep anal sensation and anal skin sensation. Digital examination of the anus assesses motor function of the sacral spinal cord by observing the autonomic voluntary contraction of the anal sphincter. The absence of sensory and motor function in the lowest segment of the sacral spinal cord below the neurological level defines complete spinal cord injury.

(7) A comprehensive and detailed neurological examination should be performed, especially for the evaluation of muscle strength. Muscle strength examination should not be confined to the key muscles when applying the ASIA standards clinically. Although some muscles are not key muscles of the spinal cord segments, such as the wrist flexor of the upper limb and sartorius of the lower limb, they can affect the functional recovery of patients. Therefore, muscle strength evaluation should be as detailed as possible^[2].

(8) The panel recommends repeat neurological examinations after transfer and following procedures, such as the application of traction or reduction maneuvers, to determine the progression of neurological deficits. The frequency of repeat neurological examinations should be individualized and based on the clinical status of the patient; however, within the first 3 days of admission, the neurological examination should be performed at least once daily^[3].

Image examination

(9) X-ray and CT (and/or 3D reconstruction) examinations are routinely performed to determine injury morphology and reveal the status of the posterior ligamentous complex indirectly. The degree of vertebral compression, kyphosis angle, and spinal canal invasion should be measured and calculated and the extent of bone fractures in the sagittal and horizontal plane should be determined as well. The relationship between the relative change in position of the disc spaces, interspinous process spaces, pedicle distance, vertebral bodies, and facet joints should be determined.

(10) It is recommended to image the entire spine in a patient with multiple injuries and high-energy injuries (fall injury from higher than 3 meter or motor vehicle accident injury), which can easily lead to multi-segmental spinal

injury^[4]. The entire spine of unconscious patients should also be imaged according to level II evidence, which demonstrates that unconsciousness is an important cause of missed spinal injury^[5].

(11) MRI is recommended for patients with neurological function impairment to observe the status of the spinal cord, cauda equina, and nerve roots. MRI provides excellent soft-tissue and spinal cord imaging, and it is useful in identifying specific soft-tissue injuries accompanying neurologic injury. Often, MRI gives clues to the causes of the neurologic injury, such as spinal cord contusion or stretch, which cannot be illustrated by plain radiography or CT. MRI should be performed in patients who have suspected disc and posterior ligamentous complex injury following X-ray or CT to obtain level I evidence^[6], because MRI can improve the detection rate of disc and spinal ligament injury compared with X-ray or CT examinations.

Comprehensive assessment

(12) According to the Thoracolumbar Injury Classification and Severity Score System^[7], injury morphology can be categorized as follows: compression, burst, rotation, translation, and distraction. AO^[8] and Denis classification^[9] can also be used to classify the injury morphology.

Compression fracture occurs as the result of axial and flexion force, with wedge compression injury of the vertebral body and no posterior wall fracture. Burst fracture occurs with increased force and is identified by posterior wall fracture of the vertebral body without posterior ligamentous complex disruption. Rotational injury is demonstrated by a horizontal rotation of the spinous processes, pedicles and vertebral body, visible on anteroposterior radiographs and axial CT images. Shear forces are primarily responsible for spinal column failure in translation. Anterior-posterior translational instability is usually apparent on the lateral radiograph and sagittal CT reconstructions, whereas mediolateral translational instability is usually apparent on the anteroposterior radiograph and coronal CT reconstructions^[10]. Distraction injury is identified when one part of the spinal column is separated from the other, creating a space between the sections. This can occur through the disruption of the anterior and posterior ligaments, the anterior and posterior bony elements, or a combination of both. The key element in identifying this morphology is that the rostral component of the spinal column becomes disconnected from its caudal component. Among the typical features of distraction injury are posterior ligamentous complex disruption, widening of the interspinous space, facet joint

separation, and widening of the intervertebral space^[10].

(13) The integrity of the posterior ligamentous complex should be categorized as intact, indeterminate, or disrupted. The posterior ligamentous complex has received increasing attention for the independent prediction of thoracolumbar injury stability^[11]. The posterior ligamentous complex includes the supraspinous ligament, interspinous ligament, ligamentum flavum, and the facet joint capsules. This assessment can be made from physical examination, plain film, and CT and MR images. It is typically indicated by widening of the interspinous space, dislocation of the facet joints, and facet perch or subluxation^[12]. Growing indirect evidence of posterior ligamentous complex disruption includes vertebral body translation or rotation, a palpable interspinous gap, and a step sign^[13]. MR scans may improve the diagnostic sensitivity for posterior ligamentous complex injury^[13], especially with fat-suppressed MR scans. When the evidence of disruption is subtle, the integrity of the ligaments is labeled "indeterminate". Posterior ligamentous complex injury is defined mainly as a discontinuity or nonvisualization of the black stripe, representing the supraspinous ligament on sagittal T1- and/or T2-weighted images together with high-signal intensity of the interspinous space on sagittal T2-weighted images^[14].

(14) The evaluation of neurological function status should cover the injury site, extent, and level. Injured sites are classified as spinal cord, cauda equina, and nerve roots. Injury should be classified according to the extent as intact, incomplete, or complete injury. The neurological injury level includes sensory, motor, and neurological function impairment scales.

Diagnosis

(15) The diagnosis of thoracolumbar spinal injury should include spinal column injury site and morphology, neurological injury site, extent, and level. For example, a T₁₂ burst fracture and incomplete spinal cord injury (ASIA scale D) should be diagnosed as 1) T₁₂ burst fracture; 2) incomplete spinal cord injury (ASIA grade D, neurological level L₁).

TREATMENT

(16) Treatment principles: immobilize the spine as soon as possible and transfer patients correctly to avoid secondary spinal cord injury. Adequately relieve compression; rationally reconstruct stability of the spine; perform early rehabilitation; create an appropriate internal and

external environment for the repair of nerve tissue; promote functional recovery; reduce the incidence of complications; and achieve patient reintegration as early as possible.

Drug treatment

(17) High-dose methylprednisolone impact therapy is not recommended as a routine treatment, but can be used as a treatment option.

High-dose methylprednisolone, which was recommended on the basis of the National Acute Spinal Cord Injury Studies (level I evidence)^[15-17], was the only effective neuroprotective agent within 8 hours after sustaining spinal cord injury in these studies. The possible neuroprotective mechanisms of methylprednisolone on spinal cord injury include inhibition of lipid peroxidation, calcium influx, improving blood flow, and anti-inflammatory effects^[18]. The recommended protocol states that methylprednisolone should be given as a bolus dose of 30 mg/kg over 15 minutes, followed by a continuous infusion of 5.4 mg/kg per hour^[16]. However, in recent years, doubt has been raised with respect to the National Acute Spinal Cord Injury studies. These studies were refuted on the basis of the research design, data collection and statistical analysis. Akhtar *et al*^[19] performed a systematic review of animal studies addressing the effects of methylprednisolone administration on the functional outcome of acute spinal cord injury. Sixty-two studies were included, which involved a wide variety of animal species and strains. Overall, beneficial effects of methylprednisolone administration were obtained in 34% of the studies, no effects in 58%, and mixed results in 8%. The results of this study demonstrated the barriers to the accurate prediction from animal studies of the effectiveness of methylprednisolone in the treatment of acute spinal cord injury in humans. In addition, a large number of level I evidence studies^[19-23] revealed that methylprednisolone use has many side effects and the treatment effectiveness is unclear. Therefore, there is insufficient evidence to support the use of high-dose methylprednisolone as a standard treatment in acute spinal cord injury. However, as it is effective for some patients, it can be a treatment option.

(18) The absolute contraindications for high-dose methylprednisolone impact treatment are thoracolumbar spinal injury without neurological deficits, discontinuity of the spinal cord, and more than 8 hours after injury. The relative contraindications are a history of gastrointestinal ulcer or bleeding, existing heart disease, and severe infection.

(19) The time window (< 8 hours) and correct infusion speed should be strictly controlled when using high-dose methylprednisolone, with accurate measurement of body weight and dose. Great attention should be paid to preventing gastrointestinal bleeding and infection, and to controlling blood sugar levels.

(20) The administration of methylprednisolone should be stopped as soon as possible in patients whose prior neurological symptoms have resolved, to reduce deleterious side effects.

(21) Monosialotetrahexosylganglioside sodium, neural growth factor, and other neurotrophic drugs may be used for spinal cord injury patients 48 hours post-injury. Although there is insufficient evidence proving the efficacy, these drugs can serve as treatment options with fewer side effects.

Surgical/non-surgical treatment options

(22) The panel recommends the application of the Thoracolumbar Injury Classification and Severity Score^[10] developed by the United States Spine Trauma Study Group for the selection of non-surgical and surgical treatments. Other classification systems, such as AO, Denis, and Load Sharing^[24], may assist in making a clinical decision.

The Thoracolumbar Injury Classification and Severity Score is based on three major variables: injury morphology, integrity of the posterior ligamentous complex, and neurological function status. According to the state of an injury, a comprehensive injury severity score is calculated from the three major variables to assist in clinical decision making. Injury morphology: compression fracture (1 point); burst fracture (2 points); rotational/translational injury (3 points); and distraction injury (4 points). Integrity of posterior ligamentous complex: intact (0 point); indeterminate (2 points); and disrupted (3 points). Neurological function status: intact (0 point); nerve root injury (2 points); incomplete spinal cord injury (3 points); complete spinal cord injury (2 points); and cauda equina injury (3 points). Treatment recommendations: total score ≤ 3 , nonoperative treatment; total score = 4, nonoperative or operative treatment; total score ≥ 5 , operative treatment^[10].

Non-surgical treatment

(23) Patients with simple compression fractures may be treated with closed reduction, bed rest and back muscle exercises. After 4–6 weeks of bed rest, ambulation may begin with brace protection, which may be removed after

6–8 weeks.

(24) Closed reduction and hyperextension thoracolumbosacral orthosis fixation should be performed for burst fractures with kyphosis $< 25^\circ$ and no neurological deficits. Evidence^[25-26] demonstrates that there are no significant differences between operative and conservative treatment in function and pain for such patients. However, close attention should be paid to observe neurological function status during closed reduction and brace fixation. Plain radiography should be performed to observe vertebral body height and kyphosis deformity. Once neurological deficits occur, the treatment method should be immediately adjusted.

Surgical treatment

(25) The purpose of surgery is to remove neural compression, reduce spine fracture and dislocation, restore alignment, and achieve spinal stability. The operation should be performed when the patient's condition is stable and there are no surgical contraindications.

Timing of surgery

(26) Emergency surgery is recommended for deteriorating incomplete spinal cord and cauda equina injury. Any progressive neurological damage is an absolute indication for surgery^[27-28]. For any progressive neurological injury, decompression could improve neurological function.

(27) Surgery should be performed within 48 hours for patients with spinal cord and cauda equina injury^[27, 29].

(28) When conditions permit, early surgery should be performed in patients without spinal cord and cauda equina injury. Early surgical fixation is associated with reduced complications, shorter hospital stay, and lower overall cost^[30].

Surgical approach

(29) The choice of surgical approach should progress from simple to complex. The surgical aims should be achieved with a single approach when possible based on neurological function, integrity of posterior ligamentous complex, medical equipment, and technical conditions.

(30) A posterior approach is recommended for patients without neurological deficits, whether or not they have a disrupted posterior ligamentous complex.

(31) An anterior or posterior approach may be chosen in neurologically impaired patients without posterior liga-

mentous complex disruption.

(32) A posterior or combined (anterior and posterior) approach is recommended for neurologically impaired patients with posterior ligamentous complex disruption. In this instance, anterior reconstruction may be performed through a posterior approach to reduce the surgical invasion.

(33) A posterior or combined (anterior and posterior) approach is recommended for reduction in patients with definite dislocation^[10].

Surgical decompression, fixation and fusion

(34) Decompression for patients without neurological deficits is unnecessary.

Decompression surgery may increase the surgery time, blood loss, and the risk of iatrogenic nerve injury. When the posterior longitudinal ligament is intact, a fracture reduction procedure, such as distraction, could reduce bone fragmentation that has intruded into the spinal canal due to a burst fracture^[31-32]. Also, with local stability, bone fragments may be resorbed and the spinal canal remodeled^[33].

(35) For patients with neurological deficits, decompression should be accurately performed at the site of compression of the neurological structures. Careful attention should be paid to the structures which are responsible for the stability of the thoracolumbar spine, particularly the facets and capsules of the facet joint.

(36) Thoracolumbar stability should be reconstructed with internal fixation during surgery. Level II evidence^[34] has revealed that most types of fixation, especially posterior short segment fixation, have a tendency to cause the postoperative loss of kyphosis correction. However, this loss has no significant relationship with prognosis and outcomes^[34].

(37) Anterior column support and reconstruction should be performed in patients with burst fracture involving the upper and lower endplate, more severely comminuted fractures in the cross-sectional plane, and in those requiring kyphotic correction $> 10^\circ$ during operation^[24].

The Load Sharing Classification system, implemented by McCormack *et al*^[24], quantifies the vertebral crush degree and kyphosis severity to determine the capability of the vertebral body to bear the axial load. According to the Load Sharing Classification system, anterior reconstruc-

tion should be performed in patients with the above-mentioned conditions (high-level vertebral crush and severe kyphosis).

(38) Spinal fusion should be performed in patients with fracture-dislocation, fracture associated with disc injury and posterior ligamentous complex rupture, and non-reduced dislocation. Level II evidence^[34] has shown that transpedicular vertebral bone grafting cannot effectively prevent postoperative loss of kyphotic correction.

PREVENTION AND TREATMENT OF MAJOR COMPLICATIONS

The prevention of complications is not only an important component in the multimodal management of spinal cord injury, it is also an important part of rehabilitation. This expert consensus mainly covers the evaluation and prevention of common early major complications.

Management of urinary dysfunction in the acute stages

The main purpose of the management of acute stage urinary dysfunction after thoracolumbar spinal cord injury is to prevent bladder overdistention, urinary tract infection, calculus formation, and upper urinary tract damage.

(39) When acute thoracolumbar spinal cord injury leads to urinary dysfunction, immediate indwelling catheterization should be performed and replaced every 1–2 weeks^[3]. If the patient has indwelling catheterization contraindications, such as urethral injury, suprapubic cystostomy should be performed^[3].

Thoracolumbar spinal cord injuries usually lead to neurologic loss of the ability to void. In the immediate period after spinal cord injury, the lower urinary tract demonstrates loss of all reflex function, such that urinary retention is very common, even to very high volumes. Therefore, indwelling bladder catheterization should be carried out no later than the emergency room, and ideally when intravenous fluids are initiated. An indwelling bladder catheter offers the advantages of measuring urine output accurately and preventing overfilling of the bladder, and resolves the problem of bladder voiding.

(40) It is recommended to remove indwelling catheters and begin intermittent catheterization every 4–6 hours once patients are hemodynamically stable, with a balance of intake and output^[35]. Intermittent catheterization should be postponed until all conditions associated with

urethral stricture, bladder neck obstruction, urethral or bladder injury (urinary tract bleeding), bladder capacity less than 200 mL, and cognitive disorders have been addressed^[36].

Intermittent catheterization provides a method of emptying the neurogenic bladder after thoracolumbar spinal cord injury without leaving an indwelling catheter, and lessens the frequency of long-term complications such as hydronephrosis, bladder and renal calculi, and autonomic dysreflexia encountered with other methods of neurogenic bladder management. The normal capacity of the bladder is less than 500 mL. Catheterizing the bladder every 4–6 hours prevents overdistention. If bladder volumes consistently exceed 500 mL, fluid intake should be limited to decrease the urine volume and decrease the frequency of intermittent catheterization^[35].

(41) When residual urine volume is less than 100 mL, intermittent catheterization should be discontinued and reflex-voiding exercises should be performed^[37]. The trigger point for the micturition reflex should be determined by examination, such as tapping the suprapubic area and rubbing the inner thigh, to promote the spontaneous micturition reflex. Once the spontaneous micturition reflex occurs, intermittent catheterization should be discontinued.

(42) Routine urine tests, urine bacterial cultures and drug sensitivity tests should be performed periodically. If urinary tract infection is diagnosed, known sensitive drugs should be prescribed.

Bowel care

A neurogenic bowel after spinal cord injury has the potential to disrupt almost every aspect of life. It is a very important problem after thoracolumbar spinal cord injury, but usually ignored.

(43) Bowel function should be assessed as early as possible. A systematic, comprehensive evaluation of bowel function and impairment should be performed at the onset of spinal cord injury and at least annually in follow-up.

A detailed patient history should be collected covering the following aspects: gastrointestinal function and medical conditions; defecation or assisted defecation frequency, and the duration and characteristics of the stool; and drug use and effect on the bowel program. Abdominal check, rectal examination, and anal sphincter tone testing should be carried out. In particular, feces cha-

characteristics and defecation frequency should be observed. The type of bowel dysfunction (reflexic or areflexic bowel) should be determined. An areflexic rectum results from spinal cord injury above S₂₋₄ with intact defecation reflex such that feces can be defecated through reflex, but without active control. A reflexic rectum results from spinal cord injury below S₂₋₄ (including S₂₋₄) and/or cauda equina injury without defecation reflex.

(44) Reflexic bowel patients can achieve self-reflection defecation through the defecation reflex. Digital stimulation may be performed to evoke reflective peristaltic rushes regulated by the conus medullaris and tapping mid-abdomen may also induce and promote defecation. An areflexic bowel may defecate with suppository administration in the early stages of spinal cord injury. If necessary, manual evacuation should be performed. Oral application of purgatives should be individualized, although long-term use is not recommended^[38].

Deep vein thrombosis

Deep vein thrombosis is a common complication that often occurs within 2 weeks after spinal cord injury. Deep vein thrombus detachment often leads to fatal pulmonary embolism and it is the leading cause of death during this period. Venous autoregulatory mechanisms are disturbed by paralysis and angiogenic activity is reduced after injury, increasing venous blood flow stasis resulting from sympathetic nervous system impairment. The most common location is the calf; however, the most dangerous deep vein thrombosis is in the thigh and groin.

(45) The early application of mechanical compression devices are recommended after injury, such as gradient elastic stockings, plantar venous pumps, and intermittent pneumatic compression devices.

Level I-II evidence^[39-41] has shown that the early application of mechanical compression can increase venous outflow and reduce venous stasis, but that it is relatively ineffective as a single modality in preventing venous thromboembolism in very high-risk patients, such as those with acute spinal cord injury. However, because mechanical compression is safe, it should be applied in all patients with acute spinal cord injury. Care should be taken to prevent skin breakdown under these devices.

(46) Low molecular weight heparin is recommended as prevention once the patient's hemodynamics stabilize. Low-dose unfractionated heparin alone is not recommended in patients with spinal cord injury with an increased risk of bleeding. Intracranial bleeding, perispinal

hematoma, or hemothorax are potential contraindications to the administration of anticoagulants; however, anticoagulants may be indicated when bleeding has been controlled.

Level I evidence^[42] has demonstrated the safety and feasibility of initiating anticoagulant prophylaxis early in spinal cord trauma. In addition, the use of a low molecular weight heparin was associated with a low rate of pulmonary embolism.

(47) Pharmacologic prophylaxis with low molecular weight heparin should be stopped at 24 hours prior to selective surgery. When emergency surgery is unavoidable, the administration of protamine will neutralize unfractionated heparin and partially neutralize low molecular weight heparin. Low molecular weight heparin prophylaxis may be resumed 24 hours postoperatively if bleeding has been controlled^[3].

Pressure sores

(48) It is recommended that physicians educate the patient and family on the importance of vigilance and early intervention in maintaining skin integrity. Skin areas at risk of pressure sores should be assessed frequently and the nutritional status of the skin should be evaluated.

(49) Meticulous skincare should be provided. Repositioning or turning the patient to provide pressure relief should be performed at least every 2 hours while maintaining spinal stability. Pressure reduction equipment should be used rationally and early, such as the use of an air bed^[3]. The skin on the patient's down-side should be kept clean and dry and increased temperature should be avoided. Attention should also be given to prevent skin damage and maintain the integrity of the skin, especially the skin under pressure garments and splints.

(50) Once pressure sores occur, regular dressing or debridement should be performed. Improvement of the nutritional status and various physiotherapy methods may promote healing. Surgical treatment is recommended for stage III/IV non-healing pressure sores, pressure sores associated with bone and joint infections, and those with sinus formation^[43].

REHABILITATION

(51) The purpose of rehabilitation is to prevent complications, maintain the existing function, and promote a smooth transition to the next rehabilitation phase. The

main principles are early, comprehensive, and individual rehabilitation.

(52) Rehabilitation intervention should be performed as early as possible, and may begin when vital signs are stable.

Early intervention from rehabilitation specialists may shorten the length of stay during the acute hospitalization phase by preventing secondary complications and moving the patient more quickly toward discharge to the next level of care. For postoperative patients with internal fixation, when patient conditions allow, ambulation rehabilitation exercises may begin with brace protection 5–7 days after operation to reduce the risk of complications.

(53) Comprehensive rehabilitation is recommended for physical and psychological function, and social adaptation. This includes physical and psychological therapy.

Physical therapy includes posture training, and exercises in range of motion, muscle strength, soft-tissue stretching, sitting up, bed mobility, transfer training, and inclined bed standing. Psychological therapy includes behavioral intervention and psychological support. If necessary, anti-anxiety and anti-depressant drugs may be used under the medical orders of a psychiatrist.

(54) Individualized rehabilitation intervention is recommended. According to the injury site, type, extent, patient's life and career environment, individual rehabilitation measures are selected to meet the actual needs of patients after discharge. For example, axial turn training should be avoided in early stage rotational injury patients.

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