IMPORTANCE OF SOFT TISSUES IN THE MECHANICAL STABILITY OF VERTEBRAL FRACTURES

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ABSTRACT:

The evaluation of spinal instability due to vertebral fractures is occasionally troublesome. Ligaments and soft tissues are as important as bony structures in maintaining the stability of adult spinal fractures. In patients with chronic instabilities X-ray pictures in flexion and extension are fundamental. Spinal instability can be evaluated as mechanical and neurological. Ligamentous structures and soft tissues have an important role in the mechanical stability of the thoracolumbar spine. Some spinal injuries with soft tissue component can be miss-diagnosed as stable and they may be treated inappropriately. However, they may become unstable as time progresses. Vertebral fractures with multilevel involvement are usually determined as unstable, however, the surgical treatment of these fractures is not well ascertained. Furthermore, the stability of spinal fractures with more than one segment involvement, needs to be evaluated. Spinal injuries in children may cause neurological problems even a fracture is not present in the X-ray. On the other hand, tumoral metastasis of the vertebral bodies should be differentiated from fractures related to osteoporosis in elderly patients.

Key Words: *Spine, Fracture, Stability.*

The most important issue is the correct determination of stability in the treatment of thoracolumbar spinal fractures. Spinal stability can be evaluated under the title of mechanical, neurological or in combined form (5, 8). The clinical outcome of a mechanically unstable spine will be pain or neurological deterioration. On the other hand, a spinal fracture that is suspected to be mechanically stable may present neurological findings. All mechanical and neurological unstable spines may either improve in stability, or they may progress to instability. Improvement or aggravation of the spinal stability is time dependent. Some mechanical and neurological unstable spines may respond to conservative treatment modalities, whereas surgical intervention in mechanically unstable spines sometimes can not avoid the occurrence of a neurological instability. Therefore, the accurate evaluation of stability is crucial in the accurate treatment of spinal fractures.

Spinal stability is maintained by the bony connections of the vertebrae and the surrounding soft tissues as inter vertebral discs, ligaments and muscles. Almost all classifications of spinal fractures are based on the integrity of the bony structures. This is due to the probability of evaluating the bone much more easier than the soft tissues. Although some authors have stated the importance of soft tissues in maintaining the spinal stability it is seldom emphasized that this has been brought to real life. All the soft tissue structures mentioned above are included in the three-column classification of spinal fractures, however, the evaluation of the intactness of the soft tissues of plain X-rays and computerized tomography (CT) is open to discussion.

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Mechanical Stability

Mechanism of Injury

The cause of instability and the correct way of treatment of spinal fractures can be accurately determined if the mechanism of injury is well known. This will prevent consecutive neurological deterioration and the incidence of residual deformity.

Spinal fractures and dislocations are mainly due to compression, distraction, flexion, extension, lateral and medial rotational forces or to their combination. Ferguson categorized thoracolumbar spinal fractures due to the mechanism of injury (14) (Table 1). The main forces that cause instability are the rotational forces. Instability increases when rotational forces are in combination with other forces. In contrast to cervical spinal fractures, the fractures that occur in the tho-

Table 1. Thoracolumbar Spinal Fractures

Compression - Flexion	Burst Fracture
Distraction - Flexion	Chance Fracture
Lateral Flexion	
Translation	
Torsional Flexion	
Vertical Flexion	
Distraction - Extansion	

Table 2. The Advantages of Computerized Tomography in the Evaluation of Spinal Fractures

The patient is positioned supine on the examination table
Information about the spinal canal
Other organ injuries can be evaluated in the same slices
The degree of instability and the mechanism of injury can be evaluated

Table 3. Systematic Analyses of the Clinical Stability of the Spine

Anatomic evaluation
Biomechanic factors
Clinical evaluation
Tretment modalities
Method of evaluation system
Advised treatment

Table 4. Assessment of the Thoracic and Thoracolumbar Spinal Stability

Criteria of Instability	**Points**
Disruption of the anterior elements	2
Disruption of the posterior elements	2
Sagital translation > 2.5 mm	2
Sagital rotation > 5°	2
Disruption at the spinal cord or cauda equina	2
Costovertebral joint involvement	1
Avoiding himself from excessive loads	1

Table 5. Assessment of Lumbar Spinal Instability

Criteria of Instability	**Points**
Cauda equina lesion	3
Translation more than 25 %	2
Disruption of the anterior elements	2
Disruption of the posterior elements	2
Avoiding himself from excessive loads	1

racolumbar level are caused by flexion-compression

Table 6. Neurological Deterioration Due to Spinal Fractures

Displacement of a fracture or injured intervertebral disc into the canal
Spinal distortion due to segmental displacement
Foreign body penetration
Disruption of the blood wessels of the spinal cord

forces rather then distraction-extension forces. Almost all thoracolumbar fractures are effected by some extend of a flexion force together with a compression force. In other words, pure compression forces are rare and we should better identify them as "flexion compression fractures". The rib cage and the posterior laminae are the main bony structures in maintaining the stability of the thoracic spine. Thoracic spinal fractures mainly arise due to a direct blow to the spine from the posterior direction. This causes a distraction extension type fracture and the soft tissue injury is more apparent then the bone involvement. Due to the narrowness of the spinal canal a predisposition to neurological damage is common and the patient remains usually paraplegic (4, 11, 14, 18, 24). A pure compression type thoracic fractures is seldom and it appears in heavy weight lifters by the protrusion of the inter vertebral disc into the corpus of the vertebra. An isolated fracture of the lumbar spine is also rare. This is due to the compact structure of the vertebra and its strong ligamentous connections. A concomitant thoracic spinal fracture is present in 10-25% of the patients who have a lumbar fracture. Therefore, it is important to evaluate the entire spine if a lumbar spinal fracture is present.

Classification and The Radiological Criteria's of Instability

Thoracolumbar spinal fractures are mainly categorized according to their type or the vectoral forces that cause the fracture. Plain X-ray pictures are the basic tool in the evaluation of mechanical stability. The increase in the interpedincular in the anteroposterior plane may indicate a burst fracture. These fractures are unstable and usually need early surgical intervention. A bony prominence directed into the spinal canal or wedging of the corpus of the vertebral body should be evaluated in the lateral X-ray pictures. Involvement of 50% or more of the vertebral body indicates middle column involvement or posterior column ligementous

disruption. Both severe flexion-compression and burst fractures should be treated as unstable as long as the opposite is proved. In chronic thoracolumbar instabilities dynamic X-ray evaluation is an alternative method to plain X-ray pictures. For the evaluation of lumbar hypermobility the normal ranges of motion at each spinal segment is presented by White and Panjabi (31) and can serve as a base tool. X-ray pictures taken in flexion and extension that present less then 3.5 mm displacement in the sagital plane or 11° of rotation are considered as normal. If the obtained values exceed the above mentioned criteria we may suspect spinal instability (32). Recent progresses in dynamic CT and magnetic resonances (MR) will enable us to evaluate instability more accurately. Three dimensional analyses of the CT and MR data will further improve our knowledge on instability. The striking advantage of MR is its accuracy of the determination of the intactness of soft tissues (30).

The advantages of CT in the evaluation of spinal fractures is presented table 2. Ferguson classified spinal canal involvement into four categories (14). He emphasized that surgical decompression is essential in spinal fractures that comprise 50% or more of the spinal canal even neurological findings do not exist. Nevertheless, it is not clearly defined how spinal canal involvement effects the mechanical stability of the spine. It is well known that any displacement of 10% at the thoracic level may cause a neurological deterioration, whereas a 100% of canal involvement at the lumbar level may not. In cases where the neurological findings are in controversy with the X-ray findings, a computerized tomographic myelography (CT-M) is recommended. Denis divided the spine into three columns where he stated that the intactness of the middle column is the key to stability. He evaluated CT images in establishing this classification. Although he included the soft tissues and ligamentous structures in his classification it is difficult to determine the circumstance of the spinal ligaments in saggital sections.

Bone heals more rapidly then ligamentous structures under optimal conditions. As ligaments and soft tissues heal by scar tissue they are prone to injury in a long time span. Recent studies reveal that soft tissue and ligaments are as important as bone in maintaining the satibility of the spinal column. Roaf, in a biomechanical study, presented that ligaments can resist to compression loads better than bone (28). Korres et al. stated that Chance fractures that involve only the bone are more stable than fractures with soft tissue component (17). With the introduction of the MR into the field of orthopedics and traumatology the importance of the ligaments in the maintenance of spinal stability is confirmed. The intactness of the posterior longitudinal ligament (PLL) is important in the decision of anterior or posterior surgical intervention. This ligament can only be evaluated accurately using MR. The MR evaluation of ligaments necessitate a new classification of spinal fractures (10). Farcy et al. divided Denis'es three columns into two subgroups; one being the soft tissue or ligamentous component and the other one the bony structures (13). According to this method, the injury at the soft tissue level and the bone are evaluated independently. If there is an involvement of soft tissue or the bone at any column, that portion of the spine is stated as unstable. In other words, if there is a disruption in the ligaments and soft tissues in two of the three columns the spine is designated as unstable.

Biomechanics

White and Panjabi described clinical instability as "a spinal column that present a remarkable structural deformity and is ineffective in protecting the spinal cord and nerve roots under physiological loads" (31). According to this classification the X-ray pictures of the injured individual should be carefully evaluated. The criteria for the evaluation of clinical instability according to these authors is presented at table 3 (31). On the other hand, Pope describes instability as the "loss of stiffness of the entire spine" (25). It is well known that the thoracic spine is more stable than the lumbar spine related to the presence of the rib cage and the special structure of the laminae and facet joints. The facet joints of the thoracic spine are the main structures that constrain the anterior translation. In the lower thoracic level facet joints incline to the sagital plane and restrain axial rotation. Therefore, it is concluded that facet dislocations are always in combination with the rotational displacements. Nicoll stated that thoracic spinal fractures without the involvement of the inter vertebral discs, facet joints and interspinous ligaments can be classified as stable (21). Burst fractures, however, are unstable (12). Chance fractures

mainly involve the upper thoracic region. The rate of Chance fracture has decreased with seat belts that span from the shoulder to the contra lateral hip. As we suspect a Chance fracture, the rotational forces that will injure the soft tissues makes these fractures extremely unstable. Experimental and clinical studies revealed that, the forces of the same quantity and same direction do not necessarily cause the same type of fracture. In clinical practice we should know that a flexion-compression type rotational ligamentous injury may spontaneously reduce and can be miss diagnosed during X-ray evaluation. Any plastic deformation of the bony or ligamentous structures of the spine can cause neurological deterioration. In other words, each spinal fracture that cause neurological findings can be described as unstable. However, some neurological findings arise in the limits of elastic deformation. Gosh et al., in an experimental study, presented the possibility of neurological deterioration without any lesion of the bone or ligamentous structure (15).

Fain and deformity are major findings in lumbar spinal fractures. The facet joints play an important role in the maintenance of lumbar spinal stability. Ligamentum flavum is well developed at this spinal region and has a positive effect on stability. Iliopsoas and erector spina muscles are one of the strongest muscles of the human body and add further stability to the lumbar spine (20). White and Panjabi's classification for the clinical stability of the lumbar spine is presented in table 5 (31). According to this classification, any patient who presents five points or more is considered to have an unstable spine. If the posterior elements of the L4 or L5 vertebrae are preserved or a longitudinal fracture is present at this level it is determined as stable. The most important issue in the treatment of these fractures mobilized with an orthosis (12).

Neurological Stability

Forces that cause a fracture or ligamentous rupture in the spine may have some direct or indirect effects on the spinal cord. Direct effect as complete rupture of the spinal cord is rare and may be present in penetrating injuries. The indirect effects of trauma as swelling or the disruption of blood flow of the spinal cord are more common mechanisms of neurological involvement. This kind of deterioration needs early medical or surgical intervention and the results of treatment may be unsatisfactory. Displacement of a fractured bone into the canal may cause a mechanical obstruction that will end with neurological deterioration. These neurological findings will recover as soon as the obstructive fragment is removed. Clinical observations revealed that neurological findings recover even after the fragment is removed within six months of injury. The causes of neuorological involvement following spinal fractures are summarized in table 6. Neurological deterioration is more common in the thoracic spine compared to the lumbar spine (27). If paraplegia is present at the moment of trauma the recovery rate is poor. On the other hand, in the patents with minimal but progressive neurological deficits proper treatment will improve the clinical outcome. The examination at the arrival of the patient is consequential in the diagnosis and the neurological monitoring of the patient. Spinal shock will mask the entire neurological condition. The return of the bulbocavernous reflex indicates the recovery of the spinal shock. If neurological functions do not recover in 24 to 48 hours paraplegia is persistent and the level of involvement should be determined (4). Superficial and deep sensation, pain, cold and worm sensations should be evaluated and compared to the radiological level of the spinal fracture. The presence of pathological reflexes and muscle strengths should also be recorded. Cases with partial or progressive neurological deteriorations should be examined at every 6 or 12 hours. Frankel classification is a good and easy method in the determination of the neurological findings. Nevertheless, it is not precise in the evaluation of conus medullaris lesions. As the spinal cord ends at the same level as of the conus medullaris, neurological findings may either be related to the cord or the nerve roots. The tonus of the anal sphincter, urinary incontinence, and S3-4-5 cutaneal dermatomes should be evaluated precisely. The presence of sense at these dermatomes may indicate a possible recovery of motor functions.

Treatment

The definite treatment of spinal fractures is not well established up to date. Both conservative treatment (19, 29) and surgical modalities (1, 2, 6, 7, 16, 23) have proved to be invaluable. Some authors compared the results of surgery to conservative treatment, and found no difference in the late clinical outcome of

both methods (14, 33). Denis et al. and Osti at al. stated that pain subsidence is less predicted in patients who were treated conservatively (8, 22). The positive correlation between deformity, pain and neurological findings indicate instability and necessitate surgical stabilization.

Early mobilization and rehabilitation of thoracic spinal fractures can be maintained by open reduction and fusion. Decompression of the spinal cord and correction of the spinal deformity are other advantages of surgical treatment. There is a common opinion that surgical intervention does not alter the neurological outcome. Distinct indications for open reduction and spinal fusion can be listed as follows; 1-to maintain the stability of the cases with PLL rupture, 2-bilateral facet dislocations with neurological findings, 3-progressive neurological deterioration or 4-burst fractures where the transverse diameter is decreased to 3 mm. The most common site of spinal fractures is the T12 or L1 level. With transpedicular spinal instrumentation reduction can be utilized by a posterior approach. These instrumentation's allow the patient to mobilize without any external support in the early postoperative period (2, 3, 9, 26, 34). In burst fractures and in case when the PLL is ruptured, anterior decompression is the preferred method of treatment. A bony fragment in the canal can not be reduced by posterior distraction methods if the PLL is ruptured. Furthermore, uncontrolled posterior distraction may impair the neurological findings. The anterolateral approach is preferred in the above mentioned conditions. If posterior distraction is delayed for two or more weeks reduction of the fracture should not be expected. In such cases or in severe kyphosis the anterolateral approach is the choice of treatment. Combined antero-posterior surgery is an alternative method when any of these surgeries are not adequate alone. Modified lateral rhachotomy is another method that allows us to reach the anterior and posterior column by one incision (35). As low lumbar segments are included into the fusion mass, flat back syndrome will be the clinical outcome. Pain and loss of mobility are the main symptoms of this syndrome. Loosening of the spinal implant is usually in combination with pseudoarthrosis. If the clinical and radiological findings of pseudoarthrosis is not present the preferred method of treatment is observation. However, if pain is present and the X-ray pictures present obvious delay in union a second surgery for stabilization and fusion is essential. Spondylarthrosis may be present in one above and one below motor unit of the fusion. Therefore, long fusion is contraindicated.

REFERENCES

1. Aebi M, Etter C, Kehl İ, Thalgott J: Stabilisation of the lower thoracic spine with the international spinal skeletal fixation system. Spine 6: 544-551, 1987.
2. Alıcı E: Omurga Hastalıkları ve Deformiteleri. TC Dokuz Eylül Üniversitesi Yayınları, İzmir, 1991.
3. Alıcı E: Alıcı spinal sistemi. Vertebra (Omurga) (ed. R. Ege) pp 353-370, Türk Hava Kurumu Basımevi, Ankara, 1992.
4. Bohlman HH: Treatment of fractures and dislocations of the thoracic and lumbar spine. J Bone Joint Surg 67-A: 165-169, 1985.
5. Bucholz RW, Gill K: Classification of injuries to the thoracolumbar spine. Orthop Clin North Am 17: 67+73, 1986.
6. Cotler JM, Vernace JV, Michalski JA: The use of Harrington rods in thoracolumbar fractures. Orthop Clin North Am 17: 87-103, 1986.
7. Cotrel Y, Dubousset J: Nex universal instrumentation in spinal surgery. Clin Orthop 227: 10-23, 1988.
8. Denis F, Armstrong GWD, Searls K, Matta L: Acute thoracolumbar burst fractures in the absence of neurologic deficit. Clin Orthop 189: 142-149, 1984.
9. Dinçer D: Cotrel-Dubousset entrümentasyonu. Vertebra (Omurga) (ed. R. Ege) pp 337-352, Türk Hava Kurumu Basımevi, Ankara, 1992.
10. Diren HB: Manyetik Rezonans Görüntüleme. Omurga Patolojileri. Ünal Ofset, Ankara, 1992.
11. Donovan WH, Dwyer AP: An update on the early management of traumatic paraplegia. Clin Orthop 189: 12-21, 1984.
12. Dunn HK: Management of spinal injuries to the toracolumbar spine. Surgery of the Musculoskeletal System. 2. Edition. ed. C.M. Evarts, Curchill Livingstone, New York, pp. 2219-2236, 1990.
13. Farcy SP, Weidenbaum M, Michelsen CB, Hoeltzel DA, Athanasiou KA: A comperative biomechanical study of spinal fixation using Cotrel Dubousset instrumentation. Spine 9: 877-881, 1987.
14. Ferguson RL: A mechanistic classification of thoracolumbar spine fractures. Clin Orthop 189: 77-88, 1984.
15. Gosch HH, Gooding E, Shneider RC: An experimental study of cervical spine and cord injuries. J Trauma 12: 570-580, 1972.

16. Jacobs RR, Casey MP: Surgical management of thoracolumbar spinal injuries. Clin Orthop 189: 22, 55, 1984.
17. Korres DS, Nottis PG, Feroussis JC, Hartofilakidis-Garofalidis GK: The Chance fracture and its variants. Int Orthop 7: 233-238, 1984.
18. Koustik JP: Anterior fixation for fracture of the thoracic and lumbar spine with or without neurologic involvement. Spine 13: 286-293, 1988.
19. Krompinger WJ, Frederickson BE, Mino DE, Yuan HA: Conservative treatment of fractures of the thoracic and lumbar spine. Orthop Clin North Am 17: 161-169, 1986.
20. Leong JCY, Luk KDK, Chow DHK, Woo CW: The biomechanical functions of the iliolumbar ligament in maintaining stability of the lumbosacral junction. Spine 12:669-674, 1987.
21. Nicoll EA: Fractures of the dorso-lumbar spine. J Bone Joint Surg 31-B: 376-384, 1949.
22. Osti OL, Fraser RD, Cornish B: Fracture and fracture dislocation of the thoracic spine. Int Orthop 11: 323-329, 1987.
23. Otani K, Higuchi M, Watanabe T, Nakai S, Fujimura Y, Manzoku S- SHibasaki K: The surgical reconstruction of fractures and fracture dislocations of the thoracolumbar spine. Int Orthop 8: 29-36, 1984.
24. Piepmeier JM, Jenkins NR: Late neurological changes following traumatic spinal cord injury. J Neurosurg 69: 399-402, 1988.
25. Pope M, Panjabi M: Biomechanical definitions of spinal instability. Spine 10 255-256, 1985.
26. Rahmatalia AT, Hastings GW, Dove J, Crawshaw AH: A pedicle screw bridging device for posterior segmental fixation of the spine. J Biomed Eng 13: 98-102, 1991.
27. Riggins RS, Kraus JF: The risk of neurological damage with fractures of the omurgae. J Trauma 17: 126-135, 1977.
28. Roaf R: A study of the biomechanics of spinal injuries. J Bone Joint Surg 42-B: 810-813, 1960.
29. Weinstein JD, Collalto P, Lehman TR: Toracolumbar burst fractures treated conservatively. Spine 13: 33-38, 1988.
30. Weisz GM, Lamond TS, Kitchener PN: Spinal imaging. Will MRI replace myelography? Spine 13:65-68, 1988.
31. White AA, Panjabi MM: Clinical Biomechanics of the Spine. JB Lippincott Co., Philadelphia, 1978.
32. White AA, Southwick WO, Panjabi MM: Clinical instability in the lower cervical spine. Spine 1: 15-21, 1976.
33. Willen J, Lindahl S, Northwall A: Unstable thoracolumbar fractures. SPine 2: 111-122, 1985.
34. Yazar T: Spinal internal fiksatör ve eksternal fiksatör. Vertebra (Omurga) (ed. R. Ege) pp 371-378, Türk Hava Kurumu Basımevi, Ankara, 1992.
35. Yonenobu K, Korkusuz F, Hosono N, Ebara S, Ono K: Lateral rachotomy for thoracic spinal lesions. Spine 15: 1121-1124, 1990.