How does age, degeneration and osteoporosis affect fixation method of thoracolumbar fractures?

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Majority of trauma patients are young adults and most of the literature is based on this material. Evidence-based guidelines for treatment of thoracolumbar fractures are still lacking. Osteoporotic non-traumatic or low-energy fractures of elderly people are the second peak of interest in spine fracture literature. Point of interest then is pain relief for patients with multiple co-morbidities. There are very few studies on how to manage traumatic fractures of degenerating and ankylosing spine in active patients over forty years of age. There are no randomized controlled studies comparing operative techniques in treating ankylosed spine. This paper brings up spine conditions and techniques that should be taken into consideration when planning operative treatment of spine fracture in degenerated spine. Spondylarthrosis, ankylosing spondylitis (AS), diffuse idiopathic skeletal hyperostosis (DISH) and osteoporosis are the most common findings affecting decision making in middle aged and elderly Finnish spine trauma population.

High energy trauma patient is typically under 40 year old male. Majority of spine fractures and literature of this injury concentrates on this age group or even younger (1). The other end of spectrum of fractures and research are very low energy osteoporotic fractures. Fracture classifications, for example TLICS, focus on classifying fracture-related findings and directing towards conservative or operative treatment. Comparisons of operative methods consider only fracture morphology and there is no emphasis on pre-trauma conditions of the spine when choosing the method of operative treatment. Overall, there are no evidence-based guidelines for the treatment of traumatic spine fractures and treatment results are quite equal independent of the operative method. So far there is no operative method algorithm to guide through individual variables of fracture morphology, degenerative conditions and patient-related factors. Ankylosing spine conditions and changes in bone mineral density occur in patients over 40–50 years. Randomized, controlled study based knowledge of operative treatment methods in this age group is scarce. Even the adequate extent of posterior instrumentation is based on retrospective descriptive data (2). In case of acute trauma there are very few opportunities to do thorough analysis of the pre trauma condition of spine. Often the operative planning of severely degenerated fractured spine is strongly based on the surgeon's expertise and experience.

Imaging

Suspicion of spine fracture indicates plain x-ray imaging of the affected area. Then computed tomography (CT) can be targeted to the fracture area. After high energy trauma most units scan patients with trauma-CT containing head, neck and torso imaging giving a good view on whole spine. Unnecessary irradiation of the patient should be avoided. Still, if the primary imaging shows widespread degenerative changes in spine, the imaging should be sufficiently comprehensive. Due to pain and fracture morphology in acute trauma patients are imaged supine. Possibility of imaging full spine x-ray in upright position should be considered if

Table 1. Characteristics of diffuse idiopathic skeletal hyperostosis (DISH) and ankylosing spondylitis (AS).

	DISH		AS	
Prevalence	3-25% high: white, caucasian, northeuro-pean. low: east-asian		0.2-1.4 %	
Age	Increasing > 40 years		Incidence peak at 25 y, no new cases > 45 y.	
Male : Female	3 : 2		1:1 Males dominate in severe symp-toms and hospital care.	
Diagnostics	Ossification of ALL in sequential [3] [4] vertebrae in plain x-ray imaging.		Inflammatory > 3 month back pain, morning stiffness, local inflamma-tory tenderness in facet-, SI-joints and ligament insertions	
Background	White, northeuropean, male, obese, hyperuric and -insulinemic (DM2)		95% HLA-B27 positive	
Bone mineral density	Normal, DISH prevalence in osteo-porotic population is low		Osteoporosis and osteopenia common.	
Fracture distribution *	C	60.0%	C	80.0%
	TH	34.5%	TH	10.7%
	L	5.5%	L	7.8%
Neurologic deficit at time of admis-sion (ASIA A-D)	40 %		67 %	

primary imaging shows widespread ankylosis or severe deformity. Magnetic resonance imaging (MRI) is indicated in suspicion of epidural hematoma, traumatic disc hernia and incomplete spinal cord injury when immediate decompression is considered. Combination of neurologic deficit and ankylosed or stenotic spine also indicate MRI. The imaged area should be wide enough to cover all pathology (3). Anamnestic data of spine function, stiffness and deformity before trauma helps planning the adequate level of imaging.

Conditions of spine and surgery

DISH and AS

Golden standard of operative treatment for a thora-columbar spine fracture is short segment instrumentation with either posterior, anterior or combined method. It is most suitable in a flexible spine with healthy adjacent segments. Spondylarthrotic changes increase individually with age affecting the function of adjacent segments to the fracture. Diffuse idiopathic skeletal hyperostosis (DISH) or Morbus Forestier (4,5) has

been diagnosed as a different disease from spondylarthrosis due to successive rightsided formation of anterior osteophytes, spesific predisposing metabolic diseases and genetics. Prevalence of DISH is quite high in caucasian, northeuropean population of over 50 years of age.

Ankylosing spondylitis (AS) or Morbus Bechterew, is more infrequent than DISH, but the patients are younger and meet more problems of ankylosed and osteoporotic spine (Table 1).

These ankylosing diseases put the patient at risk of typical junctional injuries of thoracocervical or thoracolumbar spine. Trauma energy can be very low and injury is often diagnosed with long delay.

A significant part of the patients with severely ankylosed spine and low energy trauma or no clear trauma history at all, have neurologic deficit at the time of admission. Secondary neurological deterioration after treatment is not uncommon and definitive treatment often does not influence the neurological outcome (6). Therefore traumatic lesions, acute or chronic, should be actively diagnosed from patients with ankylosed

Figure 1. Th11-Th12 level fracture and ankylosing spondylitis. Plain x-ray lateral and ap view, CT-reconstruction and long posterior instrumentation of osteoporotic ankylosed spine.

Figure 2. Unstable fracture in DISH-spine. CT and plain x-ray with operative instrumentation. Patient has normal bone mineral density.

spine and new, focal pain. The lesions are often difficult to observe on plain x-rays (Figure 1) and CT or MRI is recommended (Figure 2).

Stiff thorax and problems with ventilation produce most common perioperative problems. DISH-patients have often metabolic comorbidity and obesity. Due to ossification of the ligaments of spine and surrounding tissue the fractures of ankylosed spine tend to be very unstable. Although surgical treatment could be favorable to most of these patients, even half of the patients in literature reviews were treated conservatively. The reason was that the patients were inoperable due to difficult comorbidities and poor ventilation capacity (6).

Spinal deformities and stenosis

The principle of fracture treatment is to restore anatomy and maintain it. Operative treatment preference is often justified by the better long-term correction of kyphosis. If the fractured spine is already kyphotic or scoliotic the surgeon has to consider the equilibrium of normal anatomy and deformity: what is normal in this patient? Baseline of fracture treatment in DISH and AS cases is that fracture treatment restores the pre-trauma anatomy and corrects at least the fracture-related kyphosis. Correction of ankylosed kyphosis adds the risk of further neurologic injury in acute trauma situation and all through the treatment patient positioning should maintain the pre-trauma spine position (7). Correction of coronal deformity is even more
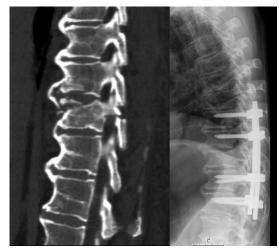
difficult from one single random fracture level. If the deformity has been asymptomatic, fracture treatment should keep that state. Symptomatic, imbalanced deformity correction demands further planning and imaging i.e. bending x-rays and imaging in upright position, which are often impossible to obtain in acute fracture situation. Fracture treatment restores pre-trauma anatomy and after stabilization of the fracture planning of severe symptomatic deformity is done for final second stage deformity correction. Consultation of a deformity specialist in these rare cases before fracture treatment is good practice.

Discovertebral Andersson lesions (8) are most typically associated with AS. Aging patients with severe ankylosing deformity and large coronal curves can also rarely get Andersson lesions. They are often located on horizontal segment of the curve. Aetiology of the discovertebral lesion is not fully understood and it can be the result of inflammation or trauma to ankylosed disc level (9).

Neurology

Neurologic deficit strongly encourages towards operative treatment. Awareness of preceding radiculating pain or spinal claudication is important in evaluating the impact of fracture on neurology. Origin of neurologic deficit can be from the level of the injury, from the level of degenerative disease elsewhere in spine or both. For example, an A-type wedge or burst fracture could be stable enough for conservative treatment,

but can induce acute deterioration of neurology in a symptomatic or asymptomatic pre-existing stenotic level. Thoracolumbar kyphotic fracture can induce symptoms from a low back level with stenosis and degenerative instability due to compensating hyperlordosis. If there is discrepancy between trauma level and neurologic deficit, imaging of all symptomatic areas with MRI or CT is recommended. Neurological diseases (e.g. Parkinson´s disease, axial myopathies, camptocornia-state) or traumatic paraplegia incapasitate the muscular control of spine. This weakening has an effect on the extent of the instrumentation. Neuromuscular diseases can also be associated with secondary osteoporosis due to poor mobility and nutrition.

Osteoporosis

Osteoporosis is common in the aging population. Definition of osteoporosis is age-dependent. Very old women have relatively lower normal bone mineral density (BMD) than young adults whose BMD is the highest. Osteoporotic fractures are more chronic, low-energetic, usually stable and can be managed conservatively. There is time for diagnostics by DEXA and medication unlike with acute unstable fractures demanding operative treatment. An unstable B- or C-type fracture, osteoporotic spine and neurologic compromise is a surgical challenge. The only problem is not the screw pullout. Comorbidities, degenerative ankylosis and stenoses often co-exist (10).

BMD can be enhanced by medication, but the process is very slow. Use of antiresorptive bisfosfonates may retard consolidation of spondylodesis. Anabolic recombinant human parathyroid hormone products, e.g. teriparatide, have been experimentally used in association with osteoporotic spine surgery and may have a positive impact on spondylodesis and fracture healing (11). So far implanted surgery of osteoporotic spine is an off-label use of teriparatide and further research is needed for this indication.

Pathology of AS is excessive bone formation on cortical bone, facets and ligaments and osteoporosis of the vertebral body cancellous bone. AS patients are young and severe forms of the disease affect mostly males. These patients are not typically suspected to have osteoporosis and it is often underdiagnosed. Osteoporosis in AS is not limited to spine and is quite common in nordic AS population (12). DISH does not decrease BMD due to pathogenesis. Ossification of anterior longitudinal ligament (ALL) can give deceptively high values in DEXA-measurement of lum-

bar segments although the true density of cancellous bone is lower. Ankylosis of spine and low exercise can in time result in secondary osteoporosis or normal age-related loss of BMD.

Planning of instrumentation

There are no randomized controlled studies on how many fixation points are enough in ankylosis or osteoporosis. A retrospective review of literature concluded that there were no implant-related problems when three pairs of pedicle screws were used both cranially and caudally to fracture level in fixation of fractures with DISH or AS (2). There is no appreciation how many fixation points are enough in fractures of lesser forms of ankylosis or spondylarthrosis. Four fixation points on both sides of osteotomy is minimum in most reports of deformity surgery. Bone quality is then presumed normal. Planning of instrumentation can be based on fracture morphology. Imaging must give sufficient information to make decisions. Then the first selection is operative or conservative treatment. When operative treatment is chosen, next thing to solve is the approach: anterior, posterior or combined (13). In osteoporotic vertebra the weakest area for instrumentation is the cancellous vertebral body and thus anterior short segment instrumentations are to be used only with contemplation. Comorbidities and respiratory problems often limit the possibility of combined approach. Posterolateral techniques enable achieving posterior and anterior column support with less risk of medical complications (14). The principle of operative treatment of osteoporotic fracture is also reduction, restoration of anatomy and achieving stability (15). Number of needed fixation points is evaluated with list of risks (Table 2). First step is to add one pair of screws to basic short segment instrumentation due to ankylosed adjacent segments. Poor bone quality and severe ankylosis can indicate even eight fixation points on both sides of the fracture. If the instrumentation ends up at the apex of deformity, especially kyphosis, fixing over the deformity should be considered. Fracture in lower lumbar spine may need fixation points to sacrum and pelvis, either S1 and S2 screws or iliac screws or pairs of iliac screws.

Stability can be increased by adding fixation points but also by using screws that are specially designed for osteoporotic bone (augmenting screws with bone cement). To a degree the grip of the pedicle screw can be enhanced by increasing screw diameter. Pull-out force is due to outer diameter of the screw, loosening

Table 2. Preoperative planning check-list for degenerative spine.

Fracture morphology
Bone quality
Adjacent segments: ankylosed or mobile
AS ja DISH
Neurologic deficit: single or multiple etiologies
Deformities and spine balance
Comorbidities

Figure 3. Instrumentation of osteoporotic fracture and destruction of a vertebra. Cannulated, perforated cement-augmented screws and support of anterior column with PEEK-implant, correction of kyphosis by shortening of posterior column.

of the screw due to inner diameter of the screw. Applying the screws with bicortical tehchnique, which also preserves the dorsal cortex increases the pull-out force. The best endurance for axial loading is achieved by placing the screws parallel and close to the superior vertebral endplate. Aiming for the midline gives the best stability (16). Hydroxyapatite coating, enlarging or double pedicle screws decrease pull-out risk and loosening of the screws to some extent compared with plain pedicle screws (17). There are some expandable screw models on market. They can be used alone or with cement augmentation to achieve best possible pull-out resistance. More support can be sought from the laminae which are the strongest part of an osteoporotic vertebra. Sublaminar wires and hooks in clawpairs attached to rods can increase stability in case of osteoporosis (18). Modern version of wires are woven polyethylene tapes with clamps to rods (19). Comparisons of pull-out forces between contemporary screwrod systems are lacking.

Cement augmentation can double the pull-out force of a pedicle screw. It is the best way to ensure screw attachment to osteoporotic bone. All methods of cement augmentation add pull-out strength compared to plain pedicle screws of any design. Polymethylmetacrylate (PMMA) cement is common in orthopaedics. For intravertebral use there are special PMMA products with longer working time, viscosity suitable for injection through cannulae and radiopaque contrast material. In some materials augmenting the screw with assistance of kyphoplasty balloon have given best results (20). Other authors have not found significant differences of screw grip between cementing methods. Variety in screwing and cementing techniques and fracture morphologies can explain this discrepancy. Cement can also be injected with a vertebroplasty needle into a pre-drilled canal before

implanting the screw. There are versions of injection techniques where the screw is implanted in either soft or hardened cement. These techniques are time-consuming and include the risk of cement leakage to spinal canal. Cement injection can be done through cannulated and perforated screws designed for cement augmentation. Variable cement fillings and pull-out results have been achieved. Perforated screws make cement augmenting technically easier and acceptable cement filling is achieved to an osteoporotic vertebra with good cementing technique and suitable cement viscosity (21) (Figure 3). Generally a smaller amount of cement than in percutaneous vertebro- or kyphoplasty is sufficient when augmenting pedicle screws. In many publications 1,5-2 ml volume of cement per pedicle screw is enough to obtain a good pull-out grip and reduce complications due to cement leakage. The volume of pedicle screw and cementing cannula must be taken into count when estimating injected volume. Cement injection is performed in fluoroscopy control with C- or O-arm to confirm good cement spread and to observe leakage to spinal canal. When needed, cement has to be removed from canal and neural structures. Cement leakage can emerge through osteoporortic bone and fracture lines, pedicle canals, or vertebral blood vessels. Cement viscosity and injection pressure have an impact on amount of leakage. Cement particles can be measured from circulation and they can cause pulmonary embolism.

Calcium phospate cement can be used instead of PMMA-cement to augment pedicle screws or to

make vertebroplasty to fractured vertebra. The advantage of calcium phosphate is long operating time, low temperature and resorption of the cement when fracture heals. Injection techniques and the suitable product for vertebroplasty tools or perforated screws are critical but it is possible to achieve equal results to PMMA-cementing (22). The anterior support of the construction can be added with vertebro- or kyphoplasty of the fractured vertebra either with resorbable or PMMA cement.

Decompression

Routine decompression and removal of bone fragments from spinal canal is not recommended if there is no neurological deficit and the patient is ambulatory. Remodelling capacity of the spinal canal is very good. If fracture and spinal stenosis appear at same level, radiological criteria of dural sac area less than 75 mm2 in axial view can be used as a reference in lumbar spine. Lack of cerebrospinal fluid between nerve roots or around spinal cord also indicates considerable stenosis. Medullopathy signs in MRI can be very acute or chronic and in acute cord compression indicate decompression. Decompression and stabilization is recommended if the patient has significantly symptomatic stenotic level before trauma and fracture on the same level. Even stable fracture can make critical symptoms through compression, swelling and epidural bleeding when there is an underlying degenerative stenosis. If the patient is asymptomatic while supine but gets severe symptoms, radiculating pain and claudication, when ambulatory, decompression and most probably instrumentation of acute fracture is indicated. In borderline cases it is good to evaluate which is best for the patient: treatment of the fracture operatively at first stage and possibly decompression at second stage if the patient remains neurologically symptomatic, or operating all at the same time. Patient-related factors help to decide whether two operations or one operation are better tolerated. AS and DISH patients develop epidural haematomas frequently due to instability of the fracture. Neurological deficit is more common at first admission than in other degenerative spine fractures. Decompression is often needed in addition to long instrumented fusion.

Fusion

Role of fusion builds up with degree of degeneration and ankylosis. Non-fusion treatment is suitable for young patients treated with feasibly stable one seg-

ment fractures and with intention to remove the implants (13). When patient has degenerative spine and fracture is located at spinal junctions at spinopelvic, thoracolumbar or thoracocervical areas solid fusion is recommended. Very unstable fractures may also benefit from good fusion regardless of stiff ankylosis. AS produces good bone formation on posterior cortical facets and lack of bone graft is less critical than in other conditions of ankylosed spine. Anterior grafting is seldom needed even if the correction of fracture kyphosis leaves an anterior defect. Bone graft can be harvested from iliac crest if bone quality is good and iliac screws are not needed. Allograft bone and industrial products made of calcium phospates, hydroxyapatite or silicate can be utilized in lack of own bone or in fear of pain at bone harvesting site. Good decortication of the area to be fused is mandatory. Use of osteoinductive bone morphogenic proteins should be limited to special indications.

Conclusions

Medical and degenerative history of patient and the spine have to be regarded when planning surgery of fractured spine.

Surgeons should be alert for typical fractures of ankylosed spine in severe spondylarthrosis, DISH and AS even after non-significant trauma or focal acute pain. Injury of ossified soft tissues in ankylosed spines should be imaged with adequate methods to diagnose unstable fractures.

Despite of numerous comorbidities AS and DISH patient benefits from early diagnostics and operative treatment of unstable fractures and complications are fewer than in conservative treatment.

Best way to increase stability of fixation in deformed and osteoporotic spine is to add on fixation points and augmenting the pedicle screws with cement. Extra stability can be obtained from posterior structures with laminar hooks, wires and tapes.

Osteoporotic elderly patients with acute, unstable fractures with spinal canal compromise can benefit from operative treatment if comorbidities are controlled and good techniques are applied.

Lack of muscular control of the body due to disease or trauma affects the choice of operative method.

Nerve compression symptoms can be due to acute trauma or pre-existing degenerative stenosis or both. Proper imaging results in good operative planning.

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