Surgical treatment of post-traumatic kyphosis in the thoracolumbar spine: indications and technical aspects

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Abstract Indications for correction of post-traumatic kyphotic deformity of the spine and technical aspects of the surgical procedure are reviewed. Surgical correction of post-traumatic deformity of the spine should be considered in patients presenting a local excess of kyphosis in the fractured area superior to 20° with poor functional tolerance. Severe pain, explained by objective factors such as canal or neuroforamen compromise with or without peripheral symptoms, angular deformity, non-union, focal instability, adjacent painful compensatory deformity such as lumbar hyper-lordosis or thoracic hypo-kyphosis or lordosis is a further argument for surgery. More advanced age, litigation, work-related trauma are negative factors. Planning of the surgical procedure includes the choice of the approach(es), the corrective means: subtraction osteotomy or vertebral body reconstruction and the nature and extent of osteosynthesis and fusion. Decision-making factors includes: level of trauma, severity of deformity, history of previous surgery in the area of deformity, bone quality, age of fracture. Corrective surgery of a post-traumatic deformity of the spine is a difficult procedure that should be considered only by an experienced team, after careful consideration of the indication and with the consent of a well-informed patient. Complications do occur and lead to the need of re-intervention in up to 10% of our cases. However, significant complications with lasting consequences did not occur in our experience. The more severe is the deformity, the better are the chances to improve the patient, as long as the surgical goals are fulfilled.

Keywords Spine · Deformity · Post traumatic · Kyphosis · Osteotomy

Introduction

Late post-traumatic kyphosis is often observed to some degree after a spinal fracture. Wedging of the vertebral body associated or not to a damaged intervertebral disc and a torn posterior osseous-ligamentous complex causes the deformity. The contribution of the disc component to the deformity may be visible at the time of the trauma, or later on because of degenerative changes.

Symptoms related to post-traumatic kyphosis are quite variable and are dependent on a number of factors, of which individual nociceptive sensitivity is not the least. Factors contributing to poor tolerance are the severity of deformity, level of deformity, disc degeneration, canal or neuroforamen compromise with or without peripheral symptoms, angular deformity, non-union, focal instability, etc. It is also known that a given degree of post-traumatic kyphosis is less well tolerated in case of a previous surgical treatment that failed to restore the normal anatomy [1].

The level of the lesion is an important factor regarding the tolerance of a given degree of deformity and its influence on the sagittal balance of the spine. Post-traumatic kyphosis in the low lumbar spine is far less tolerated than a similar deformity in the thoracic spine. The impact of the location is quantified by the sagittal index defined by Farcy et al. [3]. It is obtained by the difference in degrees of the kyphotic deformity minus the normal contour in the corresponding area, which is positive in the kyphotic areas of the spine and negative in the lordotic areas.

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If surgery is considered, the surgical planning must take into account the location of the deformity. Four areas of the spine should be considered: the high thoracic spine (T1–T5), the lower thoracic spine (T6–T10), the thoracolumbar junction between T11 down to L2 and the low lumbar spine from L3 to L5. The thoracolumbar junction is most often involved followed by the thoracic spine and finally the low lumbar spine.

Surgery is best indicated when significant pain combined with altered function is reported with a post-traumatic deformity exceeding 20° of sagittal index. Pain may be located about the apex of the deformity, associated or not to painful compensatory hyper-lordosis in the lumbar spine and/or hypo-kyphosis or even lordosis in the thoracic spine, above the lesion. In the absence of compensatory hyper-lordosis, the patient will present with forwards list of the trunk. This is often painful, probably related to muscle spasm. In severe kyphosis, straight vision may even be compromised similar to what happens in Bechterev's disease (ankylosing spondylitis). This situation is particularly poorly tolerated and hence, it is a strong argument in favor of surgery. Pseudarthrosis, severe disc degeneration at the traumatized level, slowly progressive neurological deficit associated with medullary compression on the apex of the deformity (tenting of the spinal cord) are also strong arguments in favor of surgery. Cosmetic concern must also be taken into account. Severe pain with minor post-traumatic deformity and no obvious instability or pseudarthrosis should be considered as a "yellow flag" according to Waddell [11] and be addressed with extreme caution.

Surgical goals

The therapeutic goals in post-traumatic kyphosis include the following:

1. Restore the function by a normal sagittal balance of the trunk, allowing a straight standing position without muscular effort and straight vision.
2. Release the neural structures compromised by:
 - angular kyphosis provoking a tenting effect on the spinal cord or nerve roots;
 - posterior wall receding with stenosis;
 - degenerative stenosis eventually related to instability;
 - foraminal stenosis.
3. Cure the pain related to pathologic curves above and below the deformity, compromised neural structures, local instability and eventual soft tissue tension or even pressure sores about the apex of an angular deformity.

Surgical procedures

Post-traumatic correction of the spine is a technically demanding procedure. Each case is different. The profile, standing full spine radiograph including the hip joints and the base of the skull, must be carefully analyzed. There is no single technique to address all types of sagittal imbalances. The choice of the approach should be directed by the individual situation. An experienced team (surgeon and anesthetist) is mandatory. Optimal equipment is needed: instrumentation, osteosynthesis, cell saver, evoked potentials, scope, and C-arm.

Somatosensory-evoked potentials and motor-evoked potentials are useful in any case and mandatory for corrections in the thoracic spine. An experienced neurophysiologist is as important to pick up early and minor, but significant modifications and differentiate between artifacts, hypotensive-induced modifications indicating the need for an increase in blood pressure, or surgically induced modifications: excessive distention or compression of the neural structures or implant malposition, interfering with the neural function.

Besides the level of the lesion, several clinical situations must be considered for the surgical planning:

- acute or subacute cases of unstable, post-traumatic kyphosis;
- pathological fracture (osteoporosis, plasmocytoma, metastasis...);
- late (over 6 weeks) and fixed post-traumatic kyphosis without previous surgery;
- post-traumatic kyphosis with a history of previous surgery (laminectomy without fusion, posterior fusion or anterior approach).

Several procedures are available. However, in case of previous posterior surgery, a posterior approach is mandatory, eventually associated with an anterior procedure. Indeed, to allow a secure correction of the deformity, the dural sac and the roots must be freed of their adherences to the surrounding tissues.

1. Acute or subacute post-traumatic kyphosis

Acute or subacute cases of unstable fractures with a significant kyphosis are best managed by a posterior approach with instrumentation that corrects the morphology followed, 1 week later, by an anterior reconstruction with a structural graft. Indeed, the anterior surgery in the acute situation may be very hemorrhagic and should only be considered in case of significant neurological deficit with canal compromise.

Vertebroplasty or "kyphoplasty" is contraindicated in acute cases of high-energy trauma. Indeed, the posterior

wall is always disrupted in these cases and the risk of cement leakage in the spinal canal is very high.

In pathological fractures, osteoporotic compression fractures in particular, the indication and the timing for so-called “kyphoplasty” with a deformity corrective goal is a debated matter: significant kyphosis correction with this procedure can only be obtained in the acute phase. Pain relieve is the primary indication of cement injection in a vertebrae and this remains true after several weeks, when deformity correction can no longer be obtained. At that time, simple vertebroplasty without the expensive balloons used in “kyphoplasty”, is as effective. Since most (over 80%) of the osteoporotic vertebral fracture will heal in a few weeks without residual pain, but indeed with a deformity, the question is whether one should treat all the osteoporotic vertebral fractures in the acute phase.

2. Late and fixed post-traumatic kyphosis

- Single level posterior subtraction osteotomy by posterior closing wedge osteotomy initially described by Smith-Peterson et al. [9] and later modified and used by numerous authors [4–6] or transpedicular decancellation [10] is best indicated in low lumbar kyphosis or high thoracic deformities. This technique can be used at all levels but major correction, over 30° is difficult to be obtained in the low lumbar region with decancellation only [7]. Wedge osteotomy with the removal of the pedicles, the correspondent segment of posterior wall and the cephalad disc allows major corrections of 45° or even more in the thoracic spine (Figs. 1, 2).
- Two-staged anterior corpectomy and reconstruction followed by posterior fixation as a second stage can be carried out if there is still significant posterior mobility—an uncommon feature—and no history of previous posterior surgery.
- Simultaneous anterior discectomy(ies) or corpectomy and reconstruction with a segmental allograft [8] or cages associated with posterior fixation in compression is best indicated in the lower thoracic spine and the thoracolumbar junction (Th6–L3). Staged surgery imposes three stages: one for posterior release, a second for anterior release and reconstruction and a third for posterior fixation. Therefore, a simultaneous front and back approach is much preferable.
- An anterior procedure only has been advocated by some authors [2] considering that similar results were obtained when comparing with front and back procedures. It must be noticed in the series of these authors that the deformities that were treated in both groups were mild (mean 23°) and the corrections minor (mean 11°). We have abandoned single anterior procedures in

Fig. 1 Low lumbar post-traumatic kyphosis previously operated and presenting a non-union. Significant pain and impaired function by the deformity

significant, rigid deformities, because of unsatisfactory correction.

Tips and pitfalls

The procedure should follow a number of standardized rules:

Posterior approach

After exposure and meticulous hemostasis, one must carefully prepare the facet joints to be fused. Next, the anchoring implants (screws or hooks) should be inserted. The number of levels to be instrumented will depend on the extent of instability induced to allow the correction of the deformity. If the anterior and posterior longitudinal ligaments must be cut, it is preferable to include in the instrumentation two levels above and two levels below the osteotomy. If only one level above and below are included,

Fig. 2 Correction by posterior subtraction osteotomy. L5 pedicles have been removed

anterior instrumentation is recommended. If the anterior ligament is not severed, posterior instrumentation, one level above and one level below the osteotomy, may be sufficient in healthy bone when associated with transverse connecting devices. This is particularly indicated in the lumbar spine in order to preserve as much motion segments as possible. Three pairs of anchoring points is preferable and should always be used if it interferes less or not with the mobility (thoracic side of a thoracolumbar junction deformity and thoracic spine).

Before attempting to correct the deformity, the soft tissues around the vertebrae and in the spinal canal must be carefully released. Reduction should not induce any traction or elongation of the neural elements. Compression on the nerve roots or impingement of the dural sac at the osteotomy site must be prevented at the time of correction. History of a previous opening of the spinal canal imposes a posterior approach for release, eventually associated with an anterior procedure. Indeed, a previous endocanal procedure will always result in adhesions between the neural structures and the bone. If these adhesions have not been carefully released prior any significant deformity correction, the risk for localized traction on the spinal cord or nerve roots with significant or even catastrophic consequences is very high. This release can only be carried out effectively by a posterior approach.

Following the insertion of the implants and complete release of the soft tissues, the osteotomy and/or discectomy or corpectomy can be carried out. If major instability is expected, a temporary rod contoured to shape the deformity should be inserted for temporary stabilization of the spine. In subtraction osteotomy, the extent of posterior element resection needed to allow correction must be determined on the preoperative planning. This is often somewhere between 2 and 3 cm.

Correction of the deformity should be obtained preferably by external maneuvers, by mobilizing the patient or the operating table. Deformity correction by acting on the anchoring implants should be done only through rods connecting several anchoring points on each side of the osteotomy. Indeed, pulling only one anchoring point on each side of the osteotomy carries a high risk of pulling out the implants, resulting in the need for longer fixation.

Anterior approach

The anterior approach is minimally invasive: it is carried out through a 7–12 cm incision with a muscle splitting technique resulting in minimal morbidity. The use of a powerful distractor to obtain correction in an anterior approach should be very cautious to avoid impaction or fracture of the adjacent vertebral bodies. Ideally, once the spine has been mobilized and the deformity corrected, there should be no recoil into the deformed situation. The osteosynthesis should be constrained only for inducing compression in the osteotomy site and not for providing reduction. This is often not completely obtained. The “reduction” constraints in the construct should be kept to a minimum. If this is not case, further release should be carried out or extra-anchoring implants must be added thus for fusing extra levels.

Solid fusion can only be obtained by strong and self-standing osteosynthesis, together with careful bone preparation and sufficient graft material. We routinely use cancellous, freeze-dried, gamma irradiated allograft mixed with locally obtained autograft chips for the posterior fusion. Anterior reconstruction is carried out with a segmental femoral allograft cut to fit exactly the defect. Its medullary cavity is filled with autograft obtain from the vertebral body or a rib. This yields reliably good results with strong fusion, often demonstrated in case of hardware removal [8].

Properly indicated surgery carried out in an adequate setting gives reliable results with a low rate of complications with lasting consequences. Re-intervention for some type of problem occurs, however, in up to 10% of all of our surgeries for post-traumatic kyphosis. With an increasing experience, the rate has become very low. Over the last 25

cases only one re-intervention for deep infection was required.

The morphological results of this surgery are reliable when a correction of 50–70% of the initial deformity has been announced to the patient.

Neurological recovery in case of preexisting neurological deficit is difficult to predict. A late progressive deficit linked to cord tenting or stenosis is of better prognosis compared with cases with immediate post-traumatic neurological deficit.

Regarding pain relief, the results are rather unpredictable. Not more than 60–70% of the patients are significantly improved. However, the more severe is the deformity, the better are the chances to improve the patient as long as the surgical goals are fulfilled. Minor deformity with severe pain not explained by objective facts is a contraindication for these major procedures. Greater age is also a negative prognostic factor. Work-related accident at the origin of the problem and psychosocial problems have the usually negative influence on the functional outcome. These observations should be clearly explained to the patient prior to obtain his consent for the surgical procedure.

When taking all these elements into considerations, the surgical correction of significant post-traumatic kyphosis in well-selected patients is beneficial and rewarding procedure for the patient with a low rate of significant lasting complications.

Conflict of interest statement None of the authors has any potential conflict of interest.

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