Cervical Fusion Related Problems: Malalignment and Nonunions

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Abstract

Two common complications that occur in cervical surgery are malalignment, particularly after multilevel laminectomies, and nonunions. In both clinical situations, prevention and early recognition are critical in its respective clinical management. In postlaminectomy kyphosis, the prevailing cause is an alteration in the normal spinal biomechanics. The exact incidence is unknown; however, when this malalignment occurs, significant morbidity may be inflicted on the patient. Surgical treatment is the mainstay once a patient becomes symptomatic. Anterior cervical procedures are heavily utilized in the correction of the deformity. Like postlaminetomy kyphosis, nonunions can also largely be prevented. The incidence of pseudarthrosis has ranged from 0-50%. With advances in instrumentation and attention to surgical detail, the incidence has decreased. Fortunately, not all nonunions are symptomatic and warrant treatment. If symptomatic nonunion does occur, surgical options exist; anterior, posterior, and combined cervical procedures are viable options depending on the pathology. As the rate of cervical procedures increase in today's population, it is paramount for any spine surgeon to be aware of these complications. Fortunately, if these complications do occur, the surgeon is armed with various methods to treat these deformities.

Postlaminectomy Kyphosis

Normal cervical lordosis ranges from 15-35 degrees[1,2]. This sagittal curve results in preferential load distribution to the posterior elements; however, the vertebral body, facet joints and surrounding capsule, interspinous ligaments, and paraxial cervical spine musculature all contribute to the stabilization of lordosis. In cases where these structures are weakened or disturbed, this critical balance may result in cervical kyphosis.

The causes of cervical kyphosis are numerous, yet a common etiology is via iatrogenic means, particularly due to aggressive facet resections in multilevel laminectomies. Several studies have demonstrated that progressive facet resection results in cervical spine instability[3-6]. For example, Zdeblick et al reported that foraminotomies involving removal of greater than 50% of the facet resulted in segmental hypermobility[5], while Cusick et al found a 32% decrease in flexion-compression strength with unilateral facetectomy[3]. Removal of 50% of the facet capsule alone also results in significant mobility during flexion and extension[7]. Furthermore, disruption of the posterior tension band and denervation of the posterior cervical musculature can result in progressively increasing anterior compression loads that result in deformity, offering an explanation for the incidence of postoperative kyphosis in laminoplasty patients[8,9]. Other risk factors for post-surgical kyphosis include age, preoperative sagittal alignment, intra-operative positioning, anterior graft complications such as extrusion and collapse, and posterior fusion without instrumentation. Regardless of the iatrogenic insult, hypermobility of the spine transfers load to the anterior column often leading to kyphosis. It should be noted, however, that extensive multilevel laminectomies do not immediately destabilize the spine. This article will discuss the specific management for postlaminectomy kyphosis.

The exact incidence of postlaminectomy kyphosis is unknown; however, the incidence has been estimated at 20%[10]. Furthermore, literature suggests that the incidence is higher in the younger population[11,12], likely a result of incomplete bone formation, resultant wedging deformity, and excessive motion of intervertebral spaces with cervical motion[13]. In addition, the pediatric population is exposed to radiation in conjunction with posterior cervical fusion. Radiation can result in bone death and impaired bone growth[14], ultimately leading to kyphosis. In contrast, the adult population typically suffers from diffuse spondylosis, in effect stabilizing the cervical spine and preventing kyphosis[15].

Early recognition of clinical symptoms due to postlaminectomy kyphosis is paramount in treatment. The typical clinical presentation of kyphosis is back or neck pain. Albert and Vaccaro described a “honeymoon” period when patients after laminectomy have transient improvement of neurological symptoms or remain symptomatically unchanged. As sagittal deformity occurs, the head assumes a position over the torso, placing the paraspinal musculature at a disadvantage. Eventually, muscle fatigue, facet joint arthopathy, or radiculopathy due to foraminal compression ensue, and if the deformity continues to progress, neurological symptoms such as myelopathy may appear[16].

If kyphosis is suspected, radiographic evaluation includes static **(Fig 1a)** and dynamic radiographs. The extension radiograph will demonstrate the degree of lordosis that can be obtained. If a fixed sagittal deformity is discovered, a computerized tomography (CT) scan may be necessary for better bony evaluation as well as vertebral artery anatomy, both of which are paramount for surgical planning if a corpectomy is needed. A magnetic resonance image (MRI) is critical as well as this study can determine the cause of neurological symptoms and evaluate for intrinsic abnormalities to the cord that may increase the risk of surgery, such as myelomalacia, syrinx formation, and spinal cord atrophy **(Fig 1b-c)**.

Once symptomatic kyphosis occurs, surgical goals are to correct the sagittal plane deformity, stabilize the spine, and decompress any neural compression. In patients with flexible deformities and no ventral compression of the cord, an isolated posterior spinal fusion may suffice. Intraoperatively, the patient should be placed in a neutral position in a headholder to facilitate exposure and placement of instrumentation. Prior to final tightening of the instrumentation, the head should be extended to achieve lordosis. It should be noted, however, that whenever the cervical spine is extended, iatrogenic foraminal stenosis can potentially occur and should be treated accordingly.

In other clinical situations, an anterior procedure should be included in the treatment plan. Fixed deformities with ankylotic facets should be treated with a posterior release supplemented with anterior correction. In fixed deformities without ankyloses, an anterior corpectomy or multiple level discectomies and fusion can be utilized. Studies, however, have demonstrated that an anterior construct alone increases the graft extrusion rate, so a posterior fusion usually is included as well[15,17-20]. Riew et al reported on eighteen patients with postlaminectomy kyphosis treated with multilevel corpectomies with anterior strut grafting[17]. Nine of the eleven complications were graft-related, resulting in the alteration in treatment protocol to include a circumferential fusion. Moreover, Herman and Sonntag studied twenty patients with postlaminectomy kyphosis in whom the mean kyphosis was 38 degrees. Traction improved the angle by 8 degrees. Open reduction via only an anterior approach and corpectomy improved the mean to 28 degrees[20]. Steinmetz et al achieved on average 20 degrees of correction with the use of only an anterior approach[21]. Multilevel anterior cervical discectomies and fusion provide greater segmental correction in the sagittal plane than corpectomies, yet segmental posterior fixation will also be required for definitive treatment. The authors' preference is if there is ventral spinal cord compression by the vertebral bodies, corpectomies are recommended **(Fig 1d-e).** If, however, the patient does not have myelopathic findings and cord compression, but rather suffers from disc pathology, discectomies are recommended.

In summary, postlaminectomy kyphosis is a problem most spine surgeons will encounter. Various causes exist for this iatrogenic deformity including age, preoperative sagittal alignment, intraoperative positioning, graft complications, and overly-aggressive facetectomies. The main strategy in the treatment of postlaminectomy kyphosis is prevention; however, when deformity occurs, earlier recognition is vital. Surgical correction can be achieved by anterior, posterior, and combined approaches.

Cervical Pseudarthrosis

Anterior cervical discectomy and fusion (ACDF) has been highly successful in the treatment of disc herniation and spondylosis[22]. Despite the popularity of this procedure, the risk of pseudarthrosis after ACDF is an important complication, similar to that seen after lumbar spine fusions. The incidence of ACDF has been reported between 0-50%[23-29]. More specifically, for 1, 2, and 3-level fusion, the fusion rates are 88-90%, 73-80%, and 70%, respectively[30,31]. Rates vary in the literature as there is no one standard radiographic criteria for determining osseous fusion[32]. Fortunately, all pseudarthroses are not symptomatic, and treatment of symptomatic patients yields good to excellent results if fusion is ultimately achieved[33-35]. Studies have demonstrated that 30% of patients with pseudarthrosis may not need surgery[29,35,36].

Patients with persistent or recurrent neck pain after ACDF should be evaluated for pseudarthrosis. Patients may also endorse persistent radicular symptoms[23,37,38]. Radiographs and advanced imaging should be ordered **(Fig 2a-b);** however, the only gold standard is surgical exploration. Radiographic markers that suggest pseudarthrosis include a radiolucent strip at the vertebral body-graft interface, increasing kyphosis, loosening of hardware, and more than 2 mm change in the interspinous process distance during flexion-extension[32]. CT is the preferred method of visualizing the fusion mass and local anatomy, although metal artifact from instrumentation may obscure the images **(Fig 2c-d).**

The goal in treating pseudarthrosis is prevention and achievement of solid fusion. Prevention can be classified into patient and surgeon factors. Patient factors include optimizing diabetic control and eliminating smoking. For surgeons, meticulous surgical technique is the most important factor. To help ensure that adequate discectomy has occurred, the uncovertebral joint serves as the lateral boundary, and the posterior longitudinal ligament depicts the posterior border. Endplate preparation should be meticulous to remove enough cortical bone to yield a flat, bleeding, bony surface. Without this perfusion, bony ingrowth will be limited, increasing the risk for pseudarthrosis. In addition, if instrumentation is used, traction should be reduced by 5 pounds prior to screw placement. The authors' preference is to use a 3 mm burr to create perforating holes in the endplate to promote vascularity and healing. One central hole is preferable to multiple smaller holes in the endplate for vascularity of the bone graft because it reduces the surface area exposed to fracture stress in the endplate[39]. The endplates are then distracted 2 mm[40] before inserting the graft, and subsequently are countersunk 2 mm with the cortical surface positioned anteriorly. A bone drill is also utilized to prepare proper application of the plate device to a smooth anterior cervical surface.

To further prevent the risk of pseudarthrosis, variations in graft selection and instrumentation exist. Grafts range from autograft, allograft, and cages with biological factors. Various studies have demonstrated equivalent fusion results between iliac crest autograft, allograft, or cage in combination with plate fixation[41-45]. The downside of autograft is the morbidity associated with iliac crest harvesting[46]. Donor site morbidity has been reported between 10-20%[38,47,48]. Samartzis et al has reported a high fusion rate (97.5%) in tricortical iliac crest allograft and autograft in one level ACDF with rigid fixation[49]; therefore, the authors support allograft fixation as it eliminates donor site morbidity. Others have reported inferior fusion rates with allograft fixation **particularly in multilevel ACDF{Bishop, 1996 #83}{Zdeblick, 1991 #65}{Zhang, 1983 #82}**, however, and the type of allograft utilized and surgical technique might play a factor.

Precise indications for situations when the use of instrumentation is imperative have yet to be defined. **Some** authors suggest that the use of **rigid or semi-rigid** plates **may be** costly and unnecessary for routine use in single-level degenerative ACDF**{Zaveri, 2001 #87}{Samartzis, 2004 #86}{Wang, 1999 #85}{Connolly, 1996 #84}.** Plates, however, allow earlier mobilization, cost-effectiveness, decreased need for external orthosis, a decrease rate of graft dislodgement and migration, superior fusion rates, immediate stabilization, and theoretical prevention of deformity[50-56]. In contrast, plating increases cost, increases operative time, causes greater retraction of midline soft tissues, increases surgical fees, creates the possibility of hardware failure, and does not ensure superior clinical outcomes[57]. **Odom et al** has demonstrated that instrumentation is not imperative. In eighty patients with one-level ACDF, forty-four patients had instrumented fusion and thirty-six had no plating. Plates were found to be safe yet did not decrease the risk of pseudarthrosis or improve clinical outcomes[58]. However, in other studies, instrumentation in one- or two-level ACDF resulted in higher fusion rates and fewer graft-related complications[54]{**Shapiro, 1996 #88}.** Nevertheless, **we** believe that instrumentation should be included after vertebrectomy for tumor, multilevel spondylosis, fracture, soft tissue instability, infection, and if the patient does not tolerate external support.

In addition to conflicting evidence pertaining to the use of instrumentation, the type of instrumentation that should be utilized is also controversial. Instrumentation options range from locked, fixed angle, translational, variable angle, flexible, and rigid plates. Currently, there is no evidence to suggest that one fixation method is superior to the rest in preventing pseudarthrosis; however, theoretical concerns and advantages of different options do exist. For example, fixed angled stiff plates may be too rigid in some cases, resulting in stress shielding of bone and limiting fusion rates[59-61], while translational devices may allow too much settling and lead to impingement and arthrosis of adjacent levels and possible kyphosis.

Graft subsidence is common during healing after ACDF[62,63]. Subsidence is dependent on construct length[64], size of graft[62], and type of graft utilized[65-67]. Dynamic plating, in theory, allows for controlled subsidence and continued contact between graft and endplate, improving the chances of obtaining a fusion[64,68]. It should be noted that even in rigid constructs, the graft does subside but occurs later[69]. The correct balance of the optimal load that needs to be placed on the graft and endplate is unknown; therefore, in one- or two-level ACDF, the type of plate used is the surgeon’s preference.

Multilevel corpectomies increase the risk of pseudarthrosis compared to one- or two-level ACDF. In these situations, in theory, semi-constrained plates might allow controlled subsidence without loosening, but this has not been confirmed clinically. Anterior plating alone in these situations, however, has been associated with high failure rates, suggesting anterior fusion should be supplemented with posterior fusion or halo[70]. To combat the risk of pseudarthrosis in these situations, various hybrid constructs have been tested. Singh et al biomechanically demonstrated in two-level corpectomies, 360 fusion and posterior-only fusion were significantly more rigid than anterior fusion. There was no difference between the 360 fusion and posterior-only fusion. It should be emphasized however that good stable graft-host bone articulation is more paramount[71]. Similar to multilevel corpectomies, multilevel ACDF increases the risk for pseudarthrosis. Rates of pseudarthrosis are higher when three or more interbody grafts are utilized regardless of instrumentation. To minimize the risk, **Singh et al has** utilized hybrid constructs such as a one-level corpectomy and one-level ACDF instead of a two-level corpectomy or three-level ACDF[72].

If symptomatic pseudarthrosis occurs, revision surgery can be approached anteriorly, posteriorly, or circumferentially. In anterior revision surgery, the surgeon must first decide whether to approach the pseudarthrosis on the same side as the original surgery or on the contralateral side. Contralateral surgery minimizes surgical risk by avoiding a fusion bed and scar tissue, but if the history demonstrates recurrent laryngeal or superior laryngeal nerve injury, one needs an otolaryngology consult to prevent possible bilateral nerve injury. The advantages of anterior revision include direct visualization and removal of the pseudarthrosis, direct decompression, and avoidance of posterior musculature stripping. However, anterior revision comes at the expense of neurovascular injury, esophageal or tracheal injury, postoperative dysphagia, graft collapse, instrumentation failure, and hematoma. Published results with anterior revision have been variable. Tribus et al demonstrated 75% improvement in clinical symptoms using an anterior revision with instrumentation and autograft in either one- or two-level pseudarthrosis[35]. Moreover, Zdeblick et al analyzed thirty-five patients with pseudarthrosis that were managed with an anterior revision with autograft. Revision procedures ranged from anterior corpectomy to vertebral-body resection and strut grafting with reduction of the deformity if there was graft migration and kyphosis. Excellent clinical results occurred in twenty-nine patients, good results were reported in one, fair in four, and poor in one. Four complications occurred, including one patient with temporary recurrent laryngeal-nerve palsy. Two had wound draining, and one had a cerebrospinal fluid leak[73]. Coric et al also reported on nineteen patients treated with anterior revision with instrumentation and allograft at one to three levels of pseudarthrosis. Eighteen patients achieved fusion, and two patients experienced transient hoarseness. One died due to cardiac factors[74].

Posterior revision alone or in combination with anterior revision is the authors' preferred treatment in the majority of cases **(Fig 2e-f).** If excessive kyphosis does not exist and the hardware and graft remain intact, a posterior revision alone has been successful in 90-100% of patients. If hardware failure, graft collapse, and kyphosis occur, a combined anterior and posterior revision has shown the highest success rate[33,34,75]. The advantage of the posterior approach is that it avoids scar and fusion bed; however, posterior revisions increase the risk of stiffness and pain secondary to posterior muscle disruption. In a randomized, prospective series, Brodsky et al demonstrated that when comparing anterior autograft revision with posterior fusion without anterior revision, the posterior procedure alone was more effective than anterior revision in regards to fusion and clinical success. The posterior procedure included grafting and wiring while the anterior group did not include instrumentation. A circumferential fusion was applicable if anterior osteophytic neurocompression existed. Eighteen patients had pseudarthrosis at one level, fourteen at two levels, and two at three levels. In the posterior group of seventeen patients, 88% had good or excellent results with a 94% fusion rate. Anterior revision was done in seventeen patients with only 59% having good or excellent results with a 79% fusion rate[33]. Lowery et al also compared anterior revision with posterior procedures. Twenty patients underwent anterior revision with instrumentation – allograft in 65% of patients and autograft in 35% – and seventeen patients were revised posteriorly with articular pillar plating. Circumferential fusions occurred in seven cases when the anterior instrumentation was broken or loose. Six of these circumferential cases included anterior plating. In the anterior revision, 40% of patients felt better, 25% the same, and 35% felt worse. All patients that were worse had confirmed nonunions and underwent additional surgery. In the posterior-only group, 94% achieved fusions, 82% felt better, 12% the same, and 6% felt worse. The one patient who felt worse had a nonunion. In the circumferential group, fusion was achieved in all patients and 71% felt better and none felt worse[75]. Kuhns et al studied thirty-three consecutive patients with symptomatic pseudarthrosis following ACDF. All patients demonstrated solid fusion by an average of 48 months, and all had significant improvement in their symptoms. Seventeen patients underwent a single-level posterior spinal fusion, nine had two levels, six had three levels, and one had a four-level posterior fusion. In addition, there was no difference in patients treated with iliac crest versus local bone graft[76]. Farey et al also demonstrated in nineteen consecutive patients treated posteriorly that eighteen of nineteen patients achieved fusion and clinical symptoms were relieved in seventeen of these eighteen patients. All patients were treated with posterior wiring with foraminotomy and autogenous bone grafting[34].

In summary, pseudarthrosis can occur due to various etiologies. Some factors are patient-related while others have surgeon control. Although the issues pertaining to graft and instrumentation selection are still controversial, meticulous graft preparation is the most important component of minimizing pseudarthrosis. If pseudarthrosis does occur and is symptomatic, patients can be treated by various surgical approaches. With better instrumentation, anterior, posterior, or combined procedures could suffice; however, it is the authors' belief that if kyphosis and graft complications do not exist anteriorly, a posterior approach is a safe and reliable technique to surgically treat symptomatic pseudarthrosis.

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Figure Legend

Figure 1: Postlaminectomy kyphosis. Patient underwent multilevel laminectomy without fusion. Subsequently, patient developed a kyphotic deformity with myelopathic symptoms (a). On MRI, there is evidence of cord compression (arrow) (b-c). Patient was treated with a C4-6 anterior corpectomy with posterior C3-7 lateral mass fixation (D-E).

Figure 2: Pseudarthrosis. Patient with neck pain after C4-6 anterior cervical discectomy and fusion. Radiographs (a-b) demonstrate pseudarthrosis at C4-5, C5-6 (arrow). CT demonstrates nonunion (arrow) at C4-5, but a solid fusion (arrowhead) at the C5-6 (C-D). Patient was treated with posterior C4-C7 fixation (E-F).