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Proximal Junctional Kyphosis in Adult Degenerative Scoliosis - Does the Solution Still Elude Us?

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Abstract

Proximal functional kyphosis (PJK) is a common complication following multilevel instrumented fusion for spinal deformities. Although the exact cause underlying this complication has still remained elusive, multiple clinical and radiological factors have been shown to negatively influence the alignment of spinal segments immediately proximal to the fused segments. The current article comprehensively describes the various factors which may influence the development of this phenomenon.

Abbreviations: PJK: Proximal Functional Kyphosis; UIV: Upper Instrumented Vertebra; SVA: Sagittal Vertical Alignment; LL-PI: Lumbar Lordosis; TK: Thoracic Kyphosis

Introduction

Proximal functional kyphosis (PJK) is a common complication (26-39%) following multilevel instrumented fusion for spinal deformities. It is defined as a focal segmental kyphosis of more than 10 degrees between upper instrumented vertebra (UIV) and 2 levels cranial to UIV (UIV+2); and a focal increase in kyphosis of more than 10 degrees between UIV and UIV+2 [1]. Although the clinical impact of this radiological phenomenon was initially unclear, recent literature has clearly demonstrated it to be the most common cause for revision surgical interventions following spinal deformity correction surgeries [2]. The exact cause underlying this complication has still remained elusive. Nevertheless, multiple clinical and radiological factors have been shown to negatively influence the alignment of spinal segments immediately proximal to the fused vertebrae [3].

Discussion

The etio-pathogenesis of the development of proximal functional kyphosis following long segment instrumented fusion surgeries has remained controversial [4]. It has however, been demonstrated to be an early phenomenon, occurring within the initial 3 months in most situations [5]. Although a majority of patients demonstrating this radiological phenomenon may not manifest with clinically significant symptoms; a subgroup of these patients have a more dramatic condition, known as the proximal functional failure (PJF – 5.6%) which needs revision surgical intervention [6]. It has been broadly debated whether this complication is a result of factors occurring locally at the proximal end of construct or is a more global phenomenon affected by patient-related factors or overall spino-pelvic alignment; nevertheless it seems more often than not to be a combination of both [7].

Local factors

I. Soft tissue integrity at the proximal end of construct: Anderson et al. [8], using in-vitro cadaveric model to demonstrate that extensive dissection of the proximal skeletal tissue at the UIV and removal of supra- and inter-spinous ligaments at this level, leads to significant decrease in the flexion stiffness of the superior adjacent motion segment. Cammarata et al. [3] developed computational musculoskeletal models to demonstrate the role of preserving proximal soft tissues in preventing the development of biomechanical risk factors for PJK. The role of preserving the soft tissue structures at the proximal end of construct in mitigating a failure of posterior tension band at the proximal end cannot be understated. Para-spinal musculature, inter- and supra-spinous ligaments and facet capsules together form a major restraining force against such proximal flexion failures; and a violation of any of these can predispose to this complication [7].

II. Selection of UIV: In long segment instrumented fusion constructs, a careful planning in choosing the UIV at a neutral and stable level needs to be emphasized upon [8]. Stopping

the fusion in the middle of kyphosis can predispose to early failure [9]. Proximal thoracic long instrumented fusions have less incidence of developing PJK, compared to distal thoracic constructs, however such a benefit should be clearly weighed against the morbidity of extending the fusion over such long segments [10].

III. Proximal severe disc degeneration: Whether the phenomenon occurring at the adjacent levels is just an extension of pre-existing degeneration is an issue that still remains controversial. However, when the fusion is stopped at a level just distal to a disc or vertebra which has already degenerated, the degeneration process may continue to progress; and thereby manifest with greater collapse [1,8,9].

IV. Length of transition segment: One major factor which has been purported in the recent past, to predispose to PJK is an abrupt change in biomechanics between rigid instrumented vertebral segments and mobile, non-fused vertebrae [3]. The focus of attention has thus been to widen the "transitional zone" between these biomechanically distinct portions of spine and thereby mitigate the mechanical disadvantage at the functional region [11]. Using less rigid implants at the proximal end of construct including transverse process or laminar hooks or sub-laminar implants [3], novel anchoring devices/ tethers proximal to the fused vertebral levels in order to supplement the posterior tension band [11] or adding less rigid or tapering rods [4] at the proximal end have been proposed to decrease the biomechanical risk factors for PJK by facilitating a broader semi-rigid zone between the rigid and mobile zones.

Global factors

I. Sagittal balance and Correction achieved: Achievement of an appropriate sagittal balance (neither over- nor under-correction) is one of the major recommendations for reducing the incidence of PJK [12]. Pre-operative sagittal balance parameters including increased sagittal vertical alignment (SVA), increased mismatch of pelvic incidence with lumbar lordosis (LL-PI) and high thoracic kyphosis (TK) have been demonstrate to greatly predispose to PJK [7,9]. Patients needing the greatest corrections of sagittal alignments, including the need for pedicle subtraction osteotomies demonstrate higher incidence of PJK [7,12]. It has been proposed that the target lumbar lordosis should be less than PI (PI-9), instead of the traditionally believed PI+/-9 [12]. Sagittal tilt at the UIV also has been proposed by Lewis et al. [13] as a predictive factor for PJK. Achieving an appropriate sagittal balance greatly reduces the stress on the implant construct, especially at the proximal end.

II. Osteoporosis, age and high BMI: The incidence of PJK is influenced by low bone mineral density [14], which can lead to a collapse of the UIV or superior adjacent vertebra. Age >55 years [5] and body mass index >25 kg/m2 [14] are other general patient-related factors which have been associated with PJK.

III. Overall Rigidity of the Construct used: Since PJK seems to be influenced by a sudden transition between rigid and non-rigid spinal segments, reducing the overall rigidity of the fusion construct can smoothen such a transition [11]. Using tapered rods at the proximal end of construct [4], titanium rods (over cobalt-chrome rods) and using hybrid constructs (instead of pedicle-only constructs) [12] can help mitigate the differential stiffness.

Conclusion

Our understanding of this relatively common phenomenon is still far from complete. From the available knowledge, it however, appears that the development of proximal functional kyphosis is multifactorial and is influenced by multitudinous local and global factors affecting the proximal end of long fusion constructs. Careful, meticulous planning of such fusions can definitely reduce, albeit not entirely obviate these disastrous complications. Large scale, multi-centered trials are of utmost relevance in the current scenario in enlightening the medical fraternity upon this unique phenomenon.

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