**Supplemental Digital Content**

**Inclusions and exclusions at full text level**

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| **St. Louis Group Citations** | |  | **Rationale/comments** |
| ADULTS | Kim YJ, Bridwell KH, Lenke LG, et al. Proximal junctional kyphosis in adult spinal deformity after segmental posterior spinal instrumentation and fusion: minimum five-year follow-up. *Spine (Phila Pa 1976)* 2008;33(20):2179-84. | INCLUDED | * Largest sample, longest follow-up, evaluated confounding factors |
| Kim, Y. J., K. H. Bridwell, et al. Is the T9, T11, or L1 the more reliable proximal level after adult lumbar or lumbosacral instrumented fusion to L5 or S1? *Spine (Phila Pa 1976)* 2007;32(24):2653-61. | Excluded | * Looks like only 2 of 3 groups had fusion of ≥5 segments, shorter f/u than above study, no evaluation of confounding |
| Glattes RC, Bridwell KH, et al. Proximal junctional kyphosis in adult spinal deformity following long instrumented posterior spinal fusion: incidence, outcomes, and risk factor analysis. *Spine (Phila Pa 1976)* 2005;30(14):1643-9. | Excluded | * Smaller series from same underlying population; lower power |
|  | Kim YB, Lenke LG, et al. Surgical treatment of adult scoliosis: is anterior apical release and fusion necessary for the lumbar curve? *Spine (Phila Pa 1976)* 2008;33(10):1125-32. | Excluded | * Does not refer to PJK |
| Ped/Adolescent |  |  |  |
|  | Kim YJ, Lenke LG, et al. Proximal junctional kyphosis in adolescent idiopathic scoliosis after 3 different types of posterior segmental spinal instrumentation and fusions: incidence and risk factor analysis of 410 cases. *Spine (Phila Pa 1976)* 2007;32(24):2731-8. | INCLUDED | * Largest series |
|  | Kim YJ, Bridwell KH, et al. Proximal junctional kyphosis in adolescent idiopathic scoliosis following segmental posterior spinal instrumentation and fusion: minimum 5-year follow-up. *Spine (Phila Pa 1976)* 2005;30(18):2045-50. | Excluded | * Earlier, smaller series–likely same population |
| **New York Group (Boachie-Adjei senior author) citations** | |  |  |
| ADULTS | Kim HJ, Yagi M, et al. Combined anterior-posterior surgery is the most important risk factor for developing proximal junctional kyphosis in idiopathic scoliosis. *Clin Orthop Relat Res* 2012;470(6):1633-9. | INCLUDED | * Larger series; use of multivariate methods |
|  | Yagi M, King A, et al. Incidence, risk factors and clinical outcome of proximal junctional kyphosis for patients with adult idiopathic scoliosis: Minimum five-year follow-up. *Spine J* 2011;11(10):20S-21S. | Excluded | * Smaller series in same population |
| **OTHERS** | |  |  |
| Adults | Mendoza-Lattes S, Ries Z, et al. Proximal junctional kyphosis in adult reconstructive spine surgery results from incomplete restoration of the lumbar lordosis relative to the magnitude of the thoracic kyphosis. *Iowa Orthop J* 2011;31:199-206. | INCLUDED | * Appears to meet definition; binary logistic regression used |
|  | Hyun SJ, Rhim SC. Clinical outcomes and complications after pedicle subtraction osteotomy for fixed sagittal imbalance patients : a long-term follow-up data. *J Korean Neurosurg Soc* 2012;47(2):95-101. | Excluded | * N = 13, 6 of which had PSO for post-traumatic kyphosis; sample size too small to allow meaningful evaluation; no comparison between those that did and did not develop PJK |
| Ped/Adolescents | Wang J, Zhao Y, et al. Risk factor analysis of proximal junctional kyphosis after posterior fusion in patients with idiopathic scoliosis. *Injury* 2010;41(4):415-20. | INCLUDED | * Used Glattes’ definition * Mean # fused levels not reported – appears that 27/123 (22%) had fewer than 6 levels fused, but unknown # with fewer than 5 –have included provisionally |
| 10 degree – but 2 levels above not specified, number of fused levels not specified | | | |
| Scheuermann’s | Denis F, Sun EC, et al. Incidence and risk factors for proximal and distal junctional kyphosis following surgical treatment for Scheuermann kyphosis: minimum five-year follow-up. *Spine (Phila Pa 1976)* 2009;34(20):E729-734. | INCLUDED | * PJK >10° for PJ angle and >10° than corresponding preop * # fused levels not reported but assumed to be >5 |
| Scheuermann’s-ped/adolescent | Lonner BS, Newton P, et al. Operative management of Scheuermann’s kyphosis in 78 patients: radiographic outcomes, complications, and technique. *Spine (Phila Pa 1976)* 2007;32(24):2644-52. | INCLUDED | * PJK >10° measured from 1 segment cephalad to UIV end * # fused levels not reported; assumed to be >5 * Limited evaluation of risk factors |

**List of other excluded studies (definition other than 10 degrees / 2 levels above**

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|  |  | **Definition** | **Reason for exclusion** |
| Adults | Kim YJ, Bridwell KH, et al. Sagittal thoracic decompensation following long adult lumbar spinal instrumentation and fusion to L5 or S1: causes, prevalence, and risk factor analysis. *Spine (Phila Pa 1976)* 2006;31(20):2359-66. | * Sagittal thoracic decompensation as a progressive kyphotic deformity of the thoracic spine without pseudarthrosis after a long lumbar fusion | * Different definition vs. others – cannot draw conclusions across populations/papers with different definitions * Concerns regarding overlap with other papers from same group |
|  | Kim JH, Kim SS, et al. Incidence of proximal adjacent failure in adult lumbar deformity correction based on proximal fusion level. *Asian Spine J* 2007;1(1):19-26. | * Local kyphosis of more than 10 measured from consecutive 3 segments or more of a vertebra as kyphosis * Describe adjacent segment failure/degeneration | * Does not evaluate risk factors for PJK * Number of fused levels not given |
|  | Sethi RK, Patel M, Geula D, et al. Proximal junctional kyphosis above fusions to the thoracolumbar spine for adult scoliosis: fate and predictive factors. *J Orthopaedics* 2011;8(4):e14. | * Kyphosis progression >5° | * Number of levels fused not clear * Web page says Journal indexed in CINAHL, but citation not found in this database |
| Scheuermann’s | Lowe TG, Kasten MD. An analysis of sagittal curves and balance after Cotrel-Dubousset instrumentation for kyphosis secondary to Scheuermann's disease. A review of 32 patients. *Spine (Phila Pa 1976)* 1994;19(15):1680-5. | * Definition not provided | * Definition not provided * Number of fused levels not described |
| Peds/Adolescent | Helgeson MD, Shah SA, et al. Evaluation of proximal junctional kyphosis in adolescent idiopathic scoliosis following pedicle screw, hook, or hybrid instrumentation. *Spine (Phila Pa 1976)* 2010;35(2):177-81. | * 2 standard deviations * Above the mean as being “abnormal” we are redefining abnormal PJK as any increased postoperative kyphosis of 15° or more | * Number of fused levels not given |
|  | Hollenbeck SM, Glattes RC, et al. The prevalence of increased proximal junctional flexion following posterior instrumentation and arthrodesis for adolescent idiopathic scoliosis. *Spine (Phila Pa 1976)* 2011;33(15):1675-81. | * Definition of “increased proximal junctional flexion” or increased “proximal junctional angles” not provided | * Number fused levels not provided |
|  | Lee GA, Betz RR, et al. Proximal kyphosis after posterior spinal fusion in patients with idiopathic scoliosis. *Spine (Phila Pa 1976)* 1999;24(8):795-9. | * >5° above summed normal angular measurement | * Number fused levels not provided |
| Adults | Sacramento-Dominguez C, Vayas-Diez R, et al. Reproducibility measuring the angle of proximal junctional kyphosis using the first or the second vertebra above the upper instrumented vertebrae in patients surgically treated for scoliosis. *Spine (Phila Pa 1976)* 2009;34(25):2787-791. |  | * Study of measurement reproducibility * No evaluation of PJK risk factors |

**Critical appraisal and level of evidence (LOE) for included studies**

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| --- | --- | --- | --- | --- | --- | --- | --- |
| **Methodological principle** | **Kim YJ**  **(2008)** | **Kim HJ (2011)** | **Mendoza-Lattes (2011)** | **Denis (2009)** | **Lonner (2007)** | **Kim YJ (2007)** | **Wang (2010)** |
| Study design |  |  |  |  |  |  |  |
| Prospective cohort study |  |  |  |  |  |  |  |
| Retrospective cohort study | + | + | + | + | + | + | + |
| Case-control study |  |  |  |  |  |  |  |
| Cross-sectional study |  |  |  |  |  |  |  |
| Case-series |  |  |  |  |  |  |  |
| **COHORT STUDIES** |  |  |  |  |  |  |  |
| Patients at similar point in the course of their disease or treatment | + | + | + | + | + | + | + |
| Complete follow-up of > 80% |  |  |  | + |  |  |  |
| Patients followed long enough for outcomes to occur | + | + | + | + | + | + | + |
| Accounting for other prognostic factors\* | + | + | + |  |  |  | + |
| **CASE-CONTROL STUDIES** |  |  |  |  |  |  |  |
| Incidence cases from defined population over a specified time period |  |  |  |  |  |  |  |
| Controls represent the population from which the cases come |  |  |  |  |  |  |  |
| Exposure precedes an outcome of interest |  |  |  |  |  |  |  |
| Accounting for other prognostic factors |  |  |  |  |  |  |  |
| **CROSS-SECTIONAL STUDIES** |  |  |  |  |  |  |  |
| A representative sample of the population of interest |  |  |  |  |  |  |  |
| Exposure that precedes an outcome of interest (e.g., sex, genetic factor) |  |  |  |  |  |  |  |
| Accounting for other prognostic factors |  |  |  |  |  |  |  |
| For surveys, a return rate of > 80% |  |  |  |  |  |  |  |
| **Evidence class** | **III** | **III** | **III** | **III** | **III** | **III** | **III** |

**Overall body of evidence summary**

The following overall summary of the available evidence focuses on findings across multiple studies to the extent possible.

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| Baseline quality: HIGH = majority of article Level I/II. LOW = majority of articles Level III/IV.  UPGRADE: Large magnitude of effect (1 or 2 levels); dose response gradient (1 level)  DOWNGRADE: Inconsistency of results (1 or 2 levels); indirectness of evidence (1 or 2 levels); imprecision of effect estimates (1 or 2 levels) | | | | | |
|  | **Strength of evidence** | **Conclusions/Comments** | **Baseline** | **UPGRADE (levels)** | **DOWN-GRADE**  **(levels)** |
| Question 1a. What is the reported risk and timing of PJK development? | | | | | |
| * **Cumulative risk** | **Moderate** | * Cumulative risk ranged from 17%-39% across studies, but based on studies in which loss to follow-up could not be determined. | * Low | * Yes – 1 level; consistently high risks | * No |
| * **Timing** | **Low (adults, adolescents)**  **Insufficient (Scheuermann’s)** | * Four LOE III studies, 2 in adults, 2 in adolescents suggest that the majority PJK development or greatest increases in PJ angle may occur relatively early in the postoperative period. * Not reported in studies of Scheuermann’s kyphosis. | * Low | * No | * No (adults & adolescents) * YES – Scheuermann’s |
| Question 1b. What factors are associated with PJK development | | | | | |
| * **Patient factors** (age, sex, Risser sign) | **Low (adults, adolescents)**  **Insufficient (Scheuermann’s)** | * **Adults:** In multivariate analysis (2 studies) neither age nor sex were significant; older age conferred higher risk of PJK based on crude estimates in one study. * **Adolescents:** No association with age in two studies. No association with sex in multivariate analysis but increased risk in males based on unadjusted risk ratio. In the study using a multivariate model, Risser sign was associated with PJK but no association was found in a second study. * **Scheuermann’s:** Not reported in studies of Scheuermann’s kyphosis. | * Low | * No | * No (adults & adolescents) * YES – Scheuermann’s |
| * **Surgical Factors** | **Low** | * **Adults:** Fusion to S1did not increase risk but combined anterior and posterior approach was associated with increased risk based on adjusted estimates (2 studies). * **Adolescents:** Number of fused vertebrae did not increase PJK risk. Thoracoplasty associated with increased PJK risk, as was use of screws vs. hooks in both studies. Wide confidence intervals for some multivariate estimates suggest instability. * **Scheuermann’s**: Two studies suggest increased risk of PJK with shorter fusions with results statistically significant in one. Wide confidence intervals suggests some instability in estimates and neither adjusted for potential confounding factors. | * Low | * No – although the effect sizes in one study were big, the wide CI suggests estimate instability | * No |
| * **Radiographic findings** | **Low (adults, adolescents)**  **Insufficient (Scheuermann’s)** | * **Adults:** In multivariate analyses in isolated studies none of the following were associated with PJK: sagittal sacral vertical line, sacral slope, ratio of C7 plumbline: sacral femoral distance, difference between magnitude of thoracic kyphosis and lumbar lordosis Cobb angle measurement or pelvic incidence. Mean proximal junctional angle was significantly different between those who did and did not develop PJK postoperatively in one study. * **Adolescents:** Preoperative thoracic Cobb angle and postural thoracic curvature >40° was associated with PJK. * **Scheuermann’s**: One study reported significant differences in kyphosis pre and postoperatively. | * Low | * No | * No (adults & adolescents) * YES – Scheuermann’s |
| Question 2. Do persons with PJK experience decreased function or quality of life? | | | | | |
| * **SRS scores** | **Low (adults, adolescents)**  **Insufficient (Scheuermann’s)** | * Adults: Scores were similar between those who did and those who did not develop PJK in 2 studies. * Adolescents: Scores were similar between groups in 1 study * Scheuermann’s: No studies were found. | * Low | * No | * No (adults & adolescents) * YES – Scheuermann’s |

**Summary of radiographic angle changes in degrees – Kim 2008 (Adults)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **PJK (n = 62)** | **No PJK (n = 99)** | | **P value†** |
| **Proximal junctional kyphosis angle changes** | | | | |
|  | Mean ± SD | | |  |
| Preop | 3 ± 7.7 | 4 ± 8.8 | | 0.63 |
|  | Mean change score (%)\* | | |  |
| 8 weeks postop – preop | 11 (367%) | 3 (75%) | | <0.0001 |
| Ultimate follow-up – preop | 17 (567%) | 3 (75%) | | <0.0001 |
| Ultimate follow-up – 8 week | 6 (43%) | 0 (0%) | | <0.0001 |
| **Thoracic kyphosis (T5-T12) angle changes** | | | | |
|  | Mean ± SD | | |  |
| Preop | 28 ± 17.7 | 28 ± 18.1 | | 0.90 |
|  | Mean change score (%) | | |  |
| 8 weeks postop – preop | 7 (25%) | 1 (4%) | | NR |
| Ultimate follow-up – preop | 13 (46%) | 4 (14%) | | 0.001 |
| Ultimate follow-up – 8 week | 6 (17%) | 3 (10%) | | NR |
| **Lumbar lordosis (T12-S1) angle changes** | | | | |
|  | Mean ± SD | | |  |
| Preop | 35 ± 24.5 | | 39 ± 25.4 | 0.32 |
|  | Mean change score (%) | | |  |
| 8 weeks postop – preop | 17 (49%) | | 9 (23%) | NR |
| Ultimate follow-up – preop | 12 (34%) | | 8 (21%) | 0.84 |
| Ultimate follow-up – 8 week | -5 (-10%) | | -1 (-2%) | NR |
| **Sagittal vertical axis (cm) changes** | | | | |
|  | Mean ± SD | | |  |
| Preop | 5.1 ± 7.4 | | 4.6 ± 7.5 | 0.65 |
|  | Mean change score (%) | | |  |
| 8 weeks postop – preop | -4.5 (-88%) | | -3.3 (-72%) | NR |
| Ultimate follow-up – preop | -0.9 (-18%) | | -2 (-43%) | 0.53 |
| Ultimate follow-up – 8 week | 3.6 (600%) | | 1.3 (100%) | NR |

\*Difference in mean scores as listed and % change in mean score

†As reported by authors

NS = not significant; NR = not reported or data not provided by the authors from which the change could be calculated

**Summary of radiographic angle changes in degrees – Kim 2007 (adolescents)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | PJK (n = 111) | No PJK (n = 299) | | P value† |
| **Proximal junctional kyphosis angle changes** | | | | |
|  | Mean ± SD\* | | |  |
| Preop | 6 ± 5.7 | | 6 ± 5.9 | 0.86 |
|  | Mean change score (%) | | |  |
| Immed postop – preop | 7 (117%) | 2 (33%) | | NR |
| 2 years postop – preop | 16 (267%) | 2 (33%) | | NR |
| 2 years postop – immediately postop | 9 (69%) | 0 (0%) | | NR |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Proximal thoracic Cobb angle changes** | | | | |
|  | Mean ± SD | | |  |
| Preop | 27.1 ± 8.2 | | 25.6 ± 11.0 | 0.31 |
|  | Mean change score (%) | | |  |
| Immed postop – preop | -9.4 (-35%) | -9.2 (-36%) | | NR |
| 2 years postop – preop | NR | NR | |  |
| 2 years postop – immediately postop | NR | NR | |  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| main thoracic Cobb angle changes | Mean ± SD | | |  |
| Preop | 60 ± 12.3 | | 58 ± 12.1 | 0.10 |
|  | Mean change score (%) | | |  |
| Immed postop – preop | (56%) | (55%) | | NR |
| 2 years postop – preop | NR | NR | |  |
| 2 years postop – immediately postop | NR | NR | |  |

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| --- | --- | --- | --- | --- |
| **T5-T12 sagittal Cobb angles changes** | | | | |
|  | Mean ± SD | | |  |
| Preop | 29 ± 14 | | 22 ± 14 | < 0.0001 |
|  | Mean change score (%) | | |  |
| Immed postop – preop | -9 (-31%) | -3 (-14%) | | NR |
| 2 years postop – preop | -6 (-21%) | 0 (0%) | | NR |
| 2 years postop – immediately postop | 3 (15%) | 3 (16%) | | NR |

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| --- | --- | --- | --- | --- |
| **C7 plumbline to sacrum** | | | | |
|  | Mean ± SD | | |  |
| Preop | -17 ± 34.2 | | -17 ± 34.2 | 0.51 |
|  | Mean change score (%) | | |  |
| Immed postop – preop | 7 (41%) | 11 (65%) | | NR |
| 2 years postop – preop | 19 (112%) | 21 (124%) | | NR |
| 2 years postop – immediately postop | 12 (120%) | 10 (167%) | | NR |

\*Difference in mean scores as listed and % change in mean score

†As reported by authors

NS = not significant; NR = not reported or data not provided by the authors from which the change could be calculated.

**Characteristics of included studies**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Author (year)** | **Population** | **Follow-up** | **PJK Definition** | **Purpose** | **Inclusion/exclusion** |
| **Adults** |  |  |  |  |  |
| **Kim YJ, Bridwell (2008)**  Retrospective prognostic study | N = 161  Female: 87%  Mean age: 45.2 yrs (18.1 – 73.0)  Group 1: PJK (n = 62)  Group 2: Non-PJK (n = 99)  Scoliosis: n = 106  Sagittal imbalance syndrome: n = 55  Previous surgery: n = 67  Patients all had fusion, minimum 5 segments | Mean 94 months (60-238); % NR | “1. Proximal junction sagittal Cobb angle ≥10°. 2. Proximal junction sagittal Cobb angle at least 10° greater than the preoperative measurement.” | “To analyze time-dependent change of, prevalence of, and risk factors for proximal junctional kyphosis (PJK) in adult spinal deformity after long (≥5 vertebrae) segmental posterior spinal instrumented fusion with a minimum 5-year postoperative follow-up.” | Inclusion:  “Age ≥18 years at the time of surgery, adult spinal deformity treated with instrumented segmental posterior spinal fusion with a minimum 5-year follow-up, at least 5 vertebrae fused, and complete radiographic follow-up.”  Exclusion:  “Ankylosing spondylitis, neuromuscular deformity, postoperative pseudarthrosis, postoperative infection, and connective tissue disorder.” |
| **Kim HJ, Yagi (2011)**  Retrospective prognostic study | N = 249  Female: 86%  Mean age: 35 yrs (15 – 62)  Group 1: Non-PJK (n = 207)  Group 2: PJK (n = 42)  Normal bone quality: n = 156  Abnormal bone quality: n = 93  Osteopenia: n = 16  Osteoporosis: n = 77  Mean levels fused: 10.64  Fusion to S1: n = 57  Thoracoplasty: n = 75  Anterior surgery: n = 14  Posterior surgery: n = 147  Anteroposterior surgery: n = 88  Hook/hybrid: n = 182  Pedicle screw: n = 40  Vertical body screws: n = 25  Wires: n = 2  UIV T1-T3: n = 83  UIV T4-T12: n = 163  UIV L1 or below: n = 3  Patients all had fusion, mean 10.64 ±3.64 segments | Mean 48 months (18-108); 74% (249/336) | “1. Proximal junction sagittal Cobb angle of 10° or greater. 2. Proximal junction sagittal Cobb angle of at least 10° greater than the preoperative measurement.” | “[To identify] risk factors for PJK in idiopathic scoliosis and determine their relative risks in a predictive model.” | Inclusion:  “All age groups with the diagnosis of idiopathic scoliosis”.  Exclusion:  “Patients who did not have complete charts, including a preoperative dual-energy x-ray absorptiometry (DEXA), radiographs, and Scoliosis Research Society-22 (SRS-22) questionnaire scores [1] from the pre- and postoperative periods.” |
| **Mendoza-Lattes (2011)**  Retrospective prognostic study | N = 54  Female: 83%  Mean age: 59.3 ± 10.3 yrs  Group 1: Non-PJK (n = 35)  Group 1: PJK (n = 19)  Patients all had fusion, number of segments NR | Mean 26.8 months (12-42); % NR | “1. Proximal junction sagittal Cobb angle ≥10°. 2. Proximal junction sagittal Cobb angle of at least 10° greater than the preoperative measurement.” | “To identify predictors for this complication, [PJK] with particular emphasis on the contribution from spinal-pelvic alignment resulting after surgical reconstruction, as measured in standing films at four-to-six weeks postoperatively.” | Inclusion:  “At least one of the following criteria: Coronal Cobb angle measurement of >30°, lumbar lordosis Cobb angle <30°, thoracic kyphosis Cobb angle >60°, sagittal imbalance (C7 plumbline > 5cm from the sacral endplate), coronal imbalance (C7PL: >5 cm from the center sacral vertical line).”  Exclusion:  NR |
| **Scheuermann’s** | | | | | |
| **Denis (2009)**  Retrospective prognostic study | N = 67  Female: NR  Mean age: 37 yrs (16-51)  Group 1: PIV = PEV (n = 40)  Group 2: PIV = Short of PEV (n = 27)  Hyperextension < 50º treated with posterior-only surgery: n = 15  Anterior/posterior surgery: n = 52  Scoliosis > 20º: n = 11  Lumbosacral spondylolysis: n = 6  Thoracolumbar type Scheuermann’s with apex at T10/T11: n = 6  T7/T9: n = 51  Patients all had fusion, minimum 6 segments | Mean 73 months (60-164); 89% (67/75) | “Proximal junctional angle greater than 10° and at least 10° greater than the corresponding preoperative measurement.” | “To analyze the incidence and risk factors associated with proximal junctional kyphosis (PJK) and distal junctional kyphosis (DJK) in patients undergoing  instrumented spinal fusion for Scheuermann kyphosis.” | Inclusion:  “Patients who had undergone surgical treatment for Scheuermann kyphosis from 1986 to 1996.”  Exclusion:  “Patients with a neuromuscular disorder, post-traumatic kyphosis, collagen vascular disease, tumor, or infection.” |
| **Lonner (2007)**  Retrospective prognostic study | N = 78  Female: 32%  Mean age: 16.7 yrs (9-27)  Group 1: Anterior-posterior surgery (n = 42)  Group 2: Posterior arthrodesis (n = 36)  All patients had fusion, minimum 5 segments | Mean 35 months (24-72); % NR | “Kyphosis measured from 1 segment cephalad  to the upper instrumented vertebra (EIV) to the proximal  instrumented vertebrae with an abnormal value defined as ≥10°.” | “To evaluate correction of sagittal alignment, maintenance of correction, and occurrence of, and etiologic factors associated with, junctional kyphosis in patients managed operatively for Scheuermann’s kyphosis.” | Inclusion:  “1. Diagnosis of Scheuermann’s kyphosis (wedging of 5° of 3 successive vertebrae, with or without endplate irregularities and Schmorl’s nodes).  2. Surgical correction of kyphosis with current generation multisegmental instrumentation.  3. Minimum 2-year clinical and radiographic follow-up”.  Exclusion:  NR |
| **Pediatric/Adolescent** | | | | | |
| **Kim YJ, Lenke (2007)**  Retrospective prognostic study | N = 410  Female: 70%  Mean age: 14.6 yrs (10.6-20)  Group 1: PJK (n = 111)  Group 2: Non-PJK (n = 299)  Mean levels fused: 11.7  Mean Risser sign: 2.9  Main thoracic: n = 195  Double thoracic: n = 76  Double major: n = 51  Triple major: n = 13  Thoracolumbar/lumbar major: n = 31  Major thoracolumbar/lumbar and minor thoracic structural: n = 44  Coronal lumbar A modifier: n = 141  Coronal lumbar B modifier: n = 85  Coronal lumbar C modifier: n = 184  Normal thoracic kyphosis sagittal modifier: n = 285  Thoracic hyperkyphosis sagittal modifier: n = 54  Thoracic hypokyphosis sagittal modifier: n = 71  Thoracoplasty: n = 132  Posterior iliac crest graft: n = 278  Hooks: n = 210  Hybrid: n = 103  Pedicle screws: n = 97  All patients had fusion, minimum 6 segments | 24 months; % NR | “Proximal junction sagittal Cobb angles between the lower endplate of the uppermost instrumented vertebra and the upper endplate of 2 supra-adjacent vertebrae ≥10° and at least 10° greater than the preoperative measurement at 2 years postoperative.” | “[To] determine proximal junctional kyphosis (PJK) prevalence and analyze risk factors associated with PJK in adolescent idiopathic scoliosis (AIS) patients following 3 different posterior segmental spinal instrumentation and fusion surgeries.” | Inclusion:  “All AIS patients treated with instrumented segmental posterior spinal fusion and complete radiographic follow-up with distinct radiographic landmarks and an age range of 10 to 20 at the time of surgery.”  Exclusion:  “Revision or anterior cases.” |
| **Wang (2010)**  Retrospective prognostic study | N = 123  Female: 81%  Mean age: 15.0 (13-16)  Group 1: Control (n = 88)  Group 2: PJK (n = 35)  All patients had fusion, number of segments NR. | Mean 42 months; % not calculable – do not indicate if the 150 were all eligible patients or if they were consecutive  82% were included in study (123/150) | “1. The measured Cobb angle was >10°. 2. Compared to the preoperative angle of that region, the increase >10°.” | “To analyze the incidence of the postoperative proximal junctional kyphosis after posterior fusion to the upper thoracic vertebra in adolescents with idiopathic scoliosis and to explore its risk factors.” | Inclusion:  “1. The type of scoliosis was adolescent idiopathic scoliosis.  2. The surgical approach was simple posterior surgery (including patients who received the thoracoplasty during the same period).  3. The top vertebra was in the upper thoracic region (T1-T7).  4. No intraoperative or postoperative internal fixation-related complications occurred.  5. The proximal junctional vertebra could be identified on the lateral X-rays and the angle measurement was not affected.”  Exclusion:  “Patients receiving revision surgery” |

NR: not reported

**Results of risk factor evaluation**

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| --- | --- | --- | --- | --- | --- |
| **Author (year)** | **Frequency of PJK (time)** | **Factors associated with PJK (significant results)** | **Factors not associated with PJK** | **Time-related changes** | **Other results** |
| **Adults** | | | | | |
| **Kim YJ, Bridwell (2008)**  Retrospective prognostic study | 94 month f/u: 39% (62/161) | * Age   P = 0.007  > 55 years: P < 0.0001   * Thoracic kyphosis   P = 0.001   * Combined anterior-posterior approach   P = 0.032   * Lowest instrumented vertebrae   S1/above: P = 0.009  L5/above: P = 0.059   * Pedicle screw construct   P = 0.041 | * Sagittal vertical axis   P = 0.65   * Lumbar lordosis   P = 0.17 (to outcomes table)   * Hybrid construct   P = 0.33   * Upper instrumented vertebra   P = 0.17   * Comorbidity   P = 0.60   * Osteotomies   P = 0.63 | Proximal junctional angle:  Preop: 3° ± 7.7  8 week postop: 14° ± 6.5  8 week postop – preop change: 10° ± 5. (59%)  2 year postop: 15° ± 6.2  2 year postop – 8 week postop change: 1° ± 5.4 (6%)  2 year postop – preop change: 12° ± 6.2 (65%)  Ultimate postop – preop change: 17° ± 6.5 (100%)  Ultimate postop – 8 week postop: 17° ± 5.8 (41%)  Ultimate postop – 2 year postop: 5° ± 5.8 (35%) | SRS-24, 29, 30 overall score:  PJK: 77 ±18.4 (52/62)  Non-PJK: 79 ± 19.3 (82/99)  Follow-up: 94 month (38%) |
| **Kim HJ, Yagi (2011)**  Retrospective prognostic study | 48 month f/u: 17% (42/249) | * Upper Instrumented Level   OR: 2.34 (1.07, 5.12), CI: 95%, P = 0.034  HR: 1.98 (1.05, 3.72), CI: 95%, P = 0.034   * Anterior-Posterior Approach   OR: 3.13 (1.08, 9.05), CI: 95%, P = 0.034  HR: 3.04 (1.56, 5.93), CI: 95%, P = 0.001   * SSVL Difference   OR: 0.99 (0.98, 1.00), CI: 95%, P = 0.004  HR: 0.99 (0.98, 1.00), CI: 95%, P = 0.001 | * Gender   OR: 2.53 (0.67, 9.65), CI: 95%, P = 0.173  HR: 2.36 (0.72, 7.81), CI: 95%, P = 0.159  Age  OR: 0.99 (0.95, 1.03), CI: 95%, P = 0.582  HR: NR   * Osteopenia/Osteoporosis   OR: 1.75 (0.68, 4.46), CI: 95%, P = 0.244  HR: 1.86 (0.98, 3.55), CI: 95%, P = 0.058   * Fusion to S1   OR: 1.52 (0.55, 4.16), CI: 95%, P = 0.419  HR: NR | NR | SRS-22 overall score difference (pre v. postop):  PJK: 3.63 ± 0.54 (42/42)  Non-PJK: 3.75 ± 0.53 (207/207)  Follow-up: 48 month (17%) |
| **Mendoza-Lattes (2011)**  Retrospective prognostic study | 27 month f/u: 35% (19/54) | * Difference between lumbar lordosis and thoracic kyphosis   P = 0.0121   * C-7 Plumbline   P = 0.0055 | * Age   P = NR   * BMI   P = NR   * Pelvic Incidence   P = NR   * Sacral Slope   P = NR | NR | NR |
| **Scheuermann’s** | | | | | |
| **Denis (2009)**  Retrospective prognostic study | 73 month f/u: 30% (20/67) | * Fusion short of the proximal end vertebra   P = NR   * >50% correction   P < 0.05 | * Magnitude of preoperative kyphosis   P = NR   * Amount of correction achieved   P = NR   * Sagittal balance   P = NR | NR | NR |
| **Lonner (2007)**  Retrospective prognostic study | 35 month f/u: 32.1% (25/78) | * Kyphosis follow-up   P < 0.01   * Kyphosis %change   P < 0.01 | * Pelvic incidence   P = 0.62 | NR | NR |
| **Adolescent/ Pediatrics** | | | | | |
| **Kim YJ, Lenke (2007)**  Retrospective prognostic study | 24 month f/u:  27% (111/410) | * Preop thoracic Cobb angle   P < 0.0001   * Postop thoracic Cobb angle change (T5-T12)   P < 0.0001   * Thoracoplasty   P = 0.001   * Gender   P = 0.007 | * Instrumentation   P = 0.058   * Number of fused vertebrae   P = 0.12   * Pre-existing segmental kyphosis   P = 0.17   * UIV   P = 0.75 | Proximal junctional angle:  Preop: 6° ± 5.7  Immediate postop: 13° ± 6.2  2 year postop: 22° ± 6.9  Preop – 2 year postop: 16.7° ± 6.2 | SRS-24 overall score:  PJK: 97.0 ± 11.25 (90/111)  Non-PJK: 95.3 ± 12.1 (246/299)  Follow-up: 24 month (100%) |
| **Wang (2010)**  Retrospective prognostic study | 42 month f/u:  28% (35/123) | * Risser   OR: 1.73 (1.06, 2.81), CI: 05%, P = 0.028   * Preoperative postural curvature angle of thoracic vertebrae >40°   OR: 4.49 (1.06, 19.09), CI: 95%, P = 0.042   * Thoracoplasty   OR: 11.31 (2.48, 51, 5.8), CI: 95%, P = 0.002   * Material of correction (distraction)   OR: 4.30 (1.22, 15.19), CI: 95%, P = 0.024   * Grafting material (allogeneic bone)   OR: 0.04 (0.01, 0.27), CI: 95%, P = 0.001   * Grafting material (biomaterials)   OR: 0.07 (0.01, 0.45), CI: 95%, P = 0.005   * Material used in fixation of upper vertebra (screw)   OR: 19.99 (3.54, 112.98), CI: 95%, P = 0.001 | * Age   OR: 0.94 (0.79, 1.13), CI: 95%, P = 0.518   * Gender   OR: 1.07 (0.24, 4.87), CI: 95%, P = 0.929   * Preoperative postural curvature angle of thoracic vertebrae 30-40°   OR: 0.84 (0.16, 4.50), CI: 05%, P = 0.838   * Fused lumbar vertebra below L2   OR: 1.88 (0.54, 6.50), CI: 95%, P = 0.320   * Number of fused segments 6-8   OR: 0.56 (0.12, 2.50), CI: 95%, P = 0.444   * Number of fused segments ≥8   OR: 0.95 (0.22, 4.07), CI: 95%, P = 0.946 | NR | NR |