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Original article

Cervical sagittal alignment in adult hyperkyphosis treated by posterior instrumentation and in situ bending

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ABSTRACT

Background: In the normal adult spine, a link between thoracolumbar and cervical sagittal alignment exists, suggesting adaptive cervical positional changes allowing horizontal gaze. In patients with thoracic hyperkyphosis, cervical adaptation to sagittal global alignment might be different from healthy individuals. However, this relationship has not clearly been reported in hyperkyphotic deformity.
Purpose: The purpose of this study was to identify cervical sagittal alignment types observed on radiographs in young adults with thoracic hyperkyphosis. The relationship between cervical and thoracolumbar alignment as well as the effect of posterior instrumentation and adaptive positional changes of the mobile cervical segment were retrospectively analyzed.
Patients and methods: Twenty-three patients (32.7 years; 5-year follow-up) were included. Full spine radiographic measurements were: T1 slope, T1-T4 kyphosis, T4-T12 kyphosis, L1-S1 lordosis, pelvic incidence, pelvic tilt, sacral slope, SVA C7, SVA C2, lordosis between C0-C2, C2-C7, C2-C4 and C4-C7. A Bayesian model and Spearman correlation were used.
Results: Two alignment types existed: cervical lordosis (group A) and cervical kyphosis (group B). Preoperatively, T4-T12 kyphosis and L1-S1 lordosis were significantly higher in group A: 76.6° versus 59.4° and −72.8° versus −65.8° (probability of > 5° difference $P(\beta > 5) > 0.95$). Pelvic incidence was higher in group A (49.8° versus 44.2°) and C0-C2 lordosis in group B (−29.4° versus −21.6°). A significant correlation existed between: T4-T12 kyphosis and C2-C7 lordosis, L1-S1 lordosis and pelvic incidence, C2-C7 lordosis and T1 slope, C2-C7 lordosis and T1-T4 kyphosis. Postoperatively, T4-T12 kyphosis decreased by 33.1° $P(\beta > 5) = 0.9995$), L1-S1 lordosis decreased by 17.7° ($P(\beta > 5) = 0.961$), T1-T4 kyphosis increased by 14.1° ($P(\beta > 5) = 0.973$). SVA C2 (translation) increased by 13.8 mm. C0-C2 lordosis (head rotation) remained unchanged. Six patients changed cervical alignment. PJK occurred in 15 patients, unrelated to cervical alignment or proximal instrumentation level.
Discussion: Two cervical alignment types, lordotic or kyphotic, were observed thoracic hyperkyphosis patients. This alignment was mainly triggered by the amount of thoracic kyphosis and lumbar lordosis, linked to pelvic incidence. Moreover, the inclination of the C7-T1 junctional area plays a key role in the amount of cervical lordosis. The correction of T4-T12 kyphosis induced compensatory modifications at adjacent segments: T1-T4 kyphosis increase (PJK) and L1-S1 lordosis decrease. Global spino-pelvic alignment and head position did not change in the sagittal plane. The cervical spine tented to keep in its preoperative position in most patients.
Level of evidence: Level IV.

1. Introduction

The indications for surgical treatment in adult hyperkyphosis are not well defined. Surgery might be considered in cases of resistant back pain despite conservative treatment in severe regular kyphosis [1,2]. There is no clear consensus about the surgical procedure. A posterior correction by instrumentation and fusion

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represents the most common technique. It may be combined with posterior Ponte osteotomiesto enhance reduction [3]. A combined approach allows an anterior release first in rigid deformities. Pedicle subtraction osteotomies, opening-closing wedge osteotomies or vertebral column resection may only be considered in selected cases of major angular kyphosis.

In the normal adult spine, sagittal alignment of thoracic kyphosis (TK) is linked to cervical lordosis. A correlation of cervical lordosis with thoracic kyphosis, T1 slope and C7 sagittal vertical axis (SVA) has been reported [4]. Abnormalities of the cervical spinal alignment seem to influence the patient's health-related quality of life [5–7]. Furthermore, the cervical spine might interact with thesubjacent global spinal alignment, as compensatory changes may occur at the lumbar spine, hips (extension) and knees (flexion) to maintain a horizontal gaze [8]. A moderate correlation has been demonstrated between lumbar lordosis and pelvic incidence [9]. The link between pelvic incidence, thoracolumbar and cervical alignment, as well as reciprocal changes, has been investigated in healthy individuals [4,10,11].

In patients with thoracic hyperkyphosis, cervical adaptation to sagittal global alignment might be different from healthy individuals. In patients with global anterior imbalance, cervical lordosis can decrease after surgical correction by osteotomies, suggesting an adaptive role to maintain the head's neutral position [12]. A link between hypokyphosis and straight or kyphotic cervical alignment has also been described in idiopathic scoliosis [13,14]. The relationship between hyperkyphotic deformity of the adult thoracic spine and cervical alignment has not been reported to our knowledge. In practice, different lordotic and kyphotic cervical alignments exist, but their clinical significance remains unclear.

The purpose of this study was to identify cervical sagittal alignment types observed on radiographs in young adults with thoracic hyperkyphosis. The relationship between cervical and thoracolumbar alignment as well as the effect of posterior instrumentation and adaptive positional changes of the mobile cervical segment were retrospectively analyzed.

2. Patients and methods

2.1. Patients

Medical records of 23 consecutive patients followed for thoracic hyperkyphosis and operated between 2002 and 2012 were reviewed. The main inclusion criterion was the presence of a thoracic hyperkyphosis requiring a posterior instrumentation. The cohort included 10 males and 13 females. The average age at surgery was 32.7 (21–37) years and the mean follow-up was 5 (2–12) years. Among the patients, 17 had Scheuermann's disease, 3 hyperkyphosis post laminectomy, 2 Pott's disease and 1rheumatoid polyarthritis. The study is a retrospective radiographic analysis.

2.2. Methods

Surgery was indicated in patients with hyperkyphosis, which led to a mechanical deterioration of the cervical and/or lumbar spine. Clinically, these patients presented with neck and/or back pain. A single posterior instrumentation was performed in 6 patients. In 17 patients, an anterior thoracoscopic release was realized first to improve spinal flexibility in thoracic deformities usually > 70°. A posterior facet release was always performed prior to instrumentation. Hybrid constructs using pedicle hooks at thoracic levels and monoaxial pedicle screws at lower thoracic and lumbar levels were used in all patients. The deformity was corrected by in situ bending of two rods simultaneously [15]. The rods were locked onto a pediculo-transverse or pediculo-laminar claw at the cranial extremity of the construct, while all other implant connections remained unlocked during correction maneuvers.

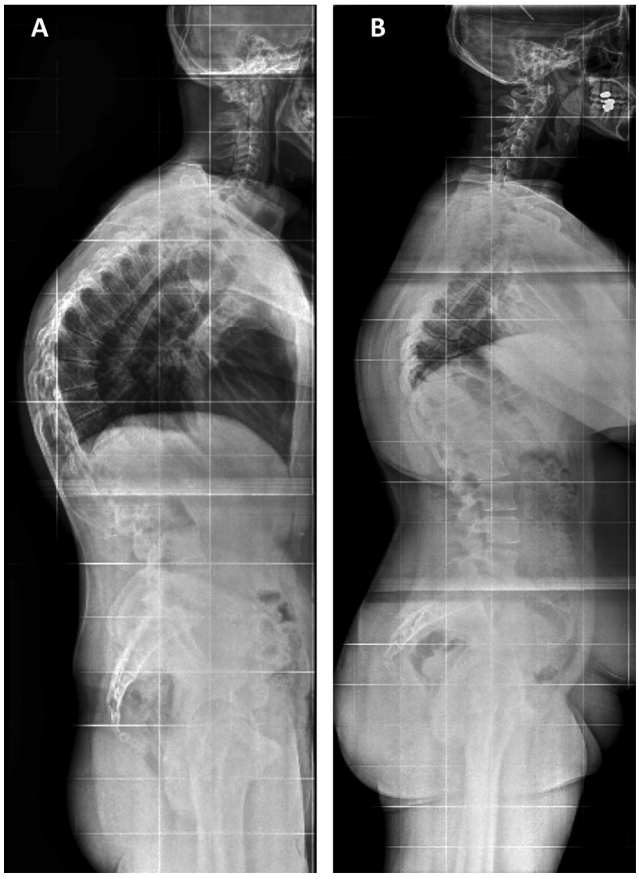

Fig. 1. Sagittal alignment types: lordotic (A) and kyphotic (B) cervical spine.

2.3. Methods of assessment

All radiographs were routinely taken at one radiology department: the patients held their arms forward while holding fixed handles. They were asked to fix one point straightforward at their eyes' height. Preoperative, immediately postoperative, one year and last follow-up full spine radiographs including femoral heads and the external auditory conducts were digitized using an optical scanner (VIDAR TWAIN 32, Vidar systems Inc, Herndon, Virginia). Measurements were performed with Spineview software (Surgiview, Paris, France) [16]. Morphologically, we have distinguished two groups of cervical alignment observed on preoperative radiographs (Fig. 1): cervical spine in lordosis (group A) and cervical spine in kyphosis (group B) according to the criteria of Ohara et al. [17]. Occipito-cervical alignment was assessed using the C0-C2 angle between McRae line and caudal C2 endplate. Cervical lordosis was measured in degrees between caudal endplates of C2 and C7, C2 and C4, C4 and C7. Thoracolumbar alignment was measured by T1 slope, T1-T4 kyphosis, T4-T12 kyphosis and L1-S1 lordosis. Negative values indicated lordosis and positive values kyphosis. The sagittal spino-pelvic balance was evaluated by pelvic incidence, pelvic tilt and sacral slope. The cervical sagittal vertical axes (SVA) were respectively measured in mm between C2 and C7 plumb lines and the posterior corner of the S1 endplate [18–21]. Anterior displacements were expressed as positive value, posterior displacements as negative values. The difference of SVA C2–SVA C7 (Δ-SVA C2-C7) was calculated in mm (Fig. 2).

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