Sagittal profile control in patients affected by neurological scoliosis using Universal Clamps: a 4-year follow-up study

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Abstract

Purpose Patients affected by cerebral palsy often develop progressive scoliosis that can result in trunk instability with an impairment of both coronal and sagittal balance. The aim of this retrospective study was to demonstrate the ability of UC to control the sagittal profile in a consecutive series of patients affected by neurological scoliosis.

Methods From 2006 to 2008, 84 patients (57 F, 27 M) affected by neurological scoliosis were treated surgically. Mean age was 14 years (range 10–17). The etiology was mainly cerebral palsy. The average pre-operative Cobb angle was $73^\circ \pm 16^\circ$. Patients were divided into three groups according to the pre-operative presence of: physiological kyphosis (mean $29^\circ \pm 8^\circ$), thoracic lordosis (mean $10^\circ \pm 6^\circ$) and hyperkyphosis ($51^\circ \pm 8^\circ$). A posterior access was performed in all patients using thoracic UC associated with transpedicular lumbar screws and a conventional claw at the upper extremity of the construct.

Results The average percentage of coronal correction was 72%. In all three groups, we observed a common trend toward maintaining or restoring the physiological values. Mean follow-up time was 36 months. At the 1-year follow-up, the mean loss of correction was $7^\circ \pm 2^\circ$ in the coronal plane and $2^\circ \pm 1^\circ$ in the sagittal plane with no other change thereafter.

Conclusions The hybrid construct using UC appears effective in neurological scoliosis treatment, providing a good correction of the deformity in both coronal and

sagittal planes. In the present series, physiological thoracic kyphosis has been restored in all patients, providing better sitting tolerance in wheelchair-bound patients, and retaining standing and walking abilities in ambulatory patients.

Keywords Neurological scoliosis · Cerebral palsy · Universal Clamps · Thoracic kyphosis

Introduction

Neurological scoliosis is characterized by long collapsing curves, pelvic obliquity and changes in sagittal profile (sometimes increased kyphosis) that affect sitting balance and respiratory function. These patients are often unresponsive to orthotic management. Surgical procedure usually involves long instrumentation and frequently fusion to the pelvis. Furthermore, an increased bleeding, an unsatisfying bone stock, longer fusions and the need for fusion to the pelvis negatively affect operative time. In spinal surgery, as stressed by Winter et al. [1], it is important to consider not only frontal but sagittal correction as well. Recent studies have evaluated the influence of a spinal fusion on both thoracic kyphosis and overall sagittal alignment. Depending on the instrumentation or correction technique used, post-operative thoracic kyphosis could either increase or decrease [2–5]. More specifically, several studies have shown that all-screw constructs have been associated with a significant decrease in thoracic kyphosis, a decrease which cannot be observed using hybrid constructs in matched patients [6]. Supporters of hybrid constructs report post-operative thoracic kyphosis to be of more physiological value to patients than all-screw constructs [6, 7], with a slight difference in coronal or axial correction [1]. Many thoracic anchors could be used to replace the thoracic pedicle screws in hybrid constructs, including hooks, sublaminar wiring,

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intraspinous wiring and soft sublaminar bands [4–9]. We previously published a case-series study on surgical treatment of neurological scoliosis using a hybrid construct consisting of lumbar transpedicular screws plus thoracic sublaminar acrylic loops (Universal Clamp—UC), reporting a good correction of the deformity in the coronal plane ($72 \pm 7\%$) with a reduction in operative time, radiation exposure time and blood loss compared to all-screw constructs [10]. The UC technique has first been described by Mazda et al. [11]. UC combines the initial primary stability of pedicle screws with the straightforwardness and correcting potential of Luque wiring, but with a greater bone contact surface when compared with wires, which allow a higher strength in attraction without risk of laminar fracture. Moreover, it is possible to perform a retensioning and a progressive correction because of the simplicity of the implant and tensioning of the strips, making conventional deformity correction maneuvers easier, including translation, compression/distraction and in situ bending. This is a retrospective study on the ability of UC in controlling the sagittal profile in a consecutive series of patients affected by neurological scoliosis.

Materials and methods

Between January 2006 and December 2008, we treated 84 patients (57 F, 27 M) affected by neurological scoliosis. Data were prospectively collected in all patients. Mean age was 14 years (range 10–17). The etiology was cerebral palsy in 81 cases, Friedreich's ataxia in two cases and Aicardi syndrome in one case. The average pre-operative Cobb angle was $73^\circ \pm 16^\circ$. With regard to pre-operative thoracic kyphosis, we divided the patients into three groups:

Group 1: patients with pre-operative physiological kyphosis (ranging from 20° to 40° : 49 patients, mean $29^\circ \pm 8^\circ$);

Group 2: patients with pre-operative thoracic lordosis ($<20^\circ$, ranging from -15° to 18° in our series: 16 patients, mean $10^\circ \pm 6^\circ$);

Group 3: patients with pre-operative hyperkyphosis ($>40^\circ$, ranging from 43° to 62° in our series: 19 patients, mean $51^\circ \pm 8^\circ$).

On lateral radiographs, thoracic kyphosis was measured from the upper endplate of T5 to the lower endplate of T12. In all patients we performed a posterior access to stabilize each affected level, combining screws (Socore TM spinal assembly), UC and hooks in a hybrid construct. The Universal Clamp is characterized by three components: a woven polyester band (Dacron), a titanium alloy (or stainless steel) clamp and a locking screw (titanium alloy or stainless steel). The surgical technique has already been described in previous study [10].

Peri-operative (30-day) results were evaluated in terms of technical success (deformity correction), operative time and blood loss. Deformity correction has been further evaluated at clinic and radiographic follow-up controls performed at 1, 3, 6 months and 1 year thereafter.

Results

The average percentage of coronal correction was 72% (mean post-operative Cobb angle: $21^\circ \pm 7^\circ$) (Fig. 1). Mean operative time was 240 ± 30 min with mean blood loss of 1200 ± 400 ml. Mean radiation exposure time was 6 ± 1.5 s. We used a mean of six transpedicular screws (range 4–11), seven UC (range 5–9) and five hooks (range 4–6). Results and complications have been described in detail in the previous report [10]. Concerning post-operative thoracic kyphosis, the authors noted that it is not possible to define a clear percentage of correction, in absence of an actual range of “normal value”. However, we observed a common trend to maintain or restore the physiological values in all three groups (Fig. 2). Particularly, our results has been summarized as follows:

Group 1: mean post-operative thoracic kyphosis: $31^\circ \pm 6^\circ$;

Group 2: mean post-operative thoracic kyphosis: $20^\circ \pm 4^\circ$;

Group 3: mean post-operative thoracic kyphosis: $35^\circ \pm 6^\circ$.

In patients with pre-operative thoracic lordosis we performed a progressive translation of the spine in the posterolateral plane toward a square construct created by applying two or three transverse connectors (DTT) to the precontoured rods. Instead, in cases of pre-operative thoracic hyperkyphosis we removed the facets and soft tissue (supraspinous and interspinous ligaments, ligamentum flavum and facet joint capsule) between the posterior elements making a greater compression possible along the length of the posterior column. In the post-operative period a brace has been used for 3–5 months. More specifically, in patients with pre-operative thoracic hyperkyphosis we applied a Milwaukee-like brace. No intra-operative complication occurred. The mean follow-up time was 36 months (range 16–48) after brace removal. At the 1-year follow-up, the mean loss of correction was $7^\circ \pm 2^\circ$ in the coronal plane and $2^\circ \pm 1^\circ$ in the sagittal plane with no other change thereafter. No crankshaft phenomenon was observed. The results are summarized in Table 1.

Discussion

In patients affected by cerebral palsy, most of the neurological curves also include the sacrum; pelvic obliquity and the progression of deformity can result in trunk instability

Fig. 1 Cerebral palsy scoliosis. Optimal deformity correction both in the coronal and sagittal planes using a hybrid system consisting of thoracic Universal Clamp, transpedicular lumbar screws and a conventional claw at the upper extremity of the construct

Fig. 2 Optimal sagittal balance control in patients with pre-operative thoracic kyphosis between 20° and 40° (*Group 1*), pre-operative thoracic lordosis (*Group 2*) and pre-operative hyperkyphosis (*Group 3*)

and it would be difficult to maintain a sitting position in the wheelchair. The aim of surgery in these patients is to restore trunk alignment, improve respiratory function, alleviate the pain caused by the impingement of the ribs

against the iliac crest on the concave side of the curve, provide better sitting tolerance in wheelchair-bound patients, and preserve standing and walking abilities in ambulatory patients.

Table 1 Summary of operative data

Total number of patients	84
Male (%)	27 (32.1)
Female (%)	57 (67.9)
Mean age (range)	14 (10–17)
Pre-operative Cobb angle (mean $\pm$ SD)	73° $\pm$ 16°
Post-operative Cobb angle (mean $\pm$ SD)	21° $\pm$ 7°
% of correction (mean $\pm$ SD)	72 $\pm$ 7
Group 1 pre-op thoracic kyphosis (mean $\pm$ SD)	29° $\pm$ 8°
Group 1 post-op thoracic kyphosis (mean $\pm$ SD)	31° $\pm$ 6°
Group 2 pre-op thoracic kyphosis (mean $\pm$ SD)	10° $\pm$ 6°
Group 2 post-op thoracic kyphosis (mean $\pm$ SD)	20° $\pm$ 4°
Group 3 pre-op thoracic kyphosis (mean $\pm$ SD)	51° $\pm$ 8°
Group 3 post-op thoracic kyphosis (mean $\pm$ SD)	35° $\pm$ 6°
Operative time (minutes; mean $\pm$ SD)	240 $\pm$ 30
Blood loss (ml; mean $\pm$ SD)	1,200 $\pm$ 400
Radioscopy time (seconds; mean $\pm$ SD)	6 $\pm$ 1.5
1 year F-UP loss of correction in coronal plane (mean $\pm$ SD)	7° $\pm$ 2°
1 year F-UP loss of correction in sagittal plane (mean $\pm$ SD)	2° $\pm$ 1°

Restoring the sagittal balance of the spine is still one of the most challenging goals in scoliosis surgery. Numerous studies have shown the efficacy of hybrid constructs in providing a greater post-operative thoracic kyphosis control with a similar result at the coronal level in scoliosis surgery compared to all-screw constructs. Lowenstein et al. [6] observed a trend toward better correction of the main thoracic curve in all-screw versus hybrid hook-screw instrumentation in adolescent idiopathic scoliosis (AIS), but this trend was not significant. Vora et al. [4] observed a lordosing effect in the thoracic spine with posterior pedicle screw instrumentations. Based on a retrospective study of patients with Lenke type 1 AIS, treated with all-pedicle screw instrumentation, Quan and Gibson recently concluded that the greater the coronal plane correction achieved with pedicle screw constructs, the greater was the loss of thoracic kyphosis [12]. In contrast, Clement et al. [13] documented a mean gain of 14° of thoracic kyphosis with pedicle screw instrumentation in patients with severe pre-operative hypokyphosis. Furthermore, Mazda et al., in a retrospective study on comparison of various hybrid systems in AIS surgery, showed that, among hybrid constructs, the results of the UC technique were superior to those achieved with hooks in all three planes, especially the sagittal plane [8]. Moreover, the UC technique is straightforward and safe, reducing both operative time and blood loss. Also Bollini et al., in a recent report on the use of UC in AIS, showed that UC hybrid construct appeared to safely provide satisfying coronal correction while consistently improving thoracic kyphosis in patients with pre-operative hypokyphosis [14].

In our experience, UC provides good deformity correction both on the coronal and sagittal planes and a reduction of the operative time, blood loss and radiation exposure time, with a low rate of peri-operative or late complications. Physiological thoracic kyphosis has been restored in all cases, with a small loss of correction at the 1-year follow-up. In patients with pre-operative thoracic kyphosis between 20° and 40°, the physiological values were maintained. Furthermore, physiological kyphosis was achieved in patients with pre-operative hypo- or hyperkyphosis. Particularly in cases showing pre-operative high thoracic lordosis, the percentage of correction was about 120%. In Group 1 patients, UC translation was performed after compression and distraction maneuvers. In Group 2, we performed an early UC translation just on the precontoured correcting rod before correction maneuvers, and then a progressive translation of the spine in the sagittal plane toward a square construct created by applying two or three transverse connectors (DTT) to the two rods. In Group 3, to reduce hyperkyphosis, we removed the facets and soft tissue (supraspinous and interspinous ligaments, ligamentum flavum and facet joint capsule) between the posterior elements allowing a greater compression along the length of the posterior column. Among the techniques recommended to prevent diminution in thoracic kyphosis, some authors [15] cited contouring kyphosis into the fusion rods, but this could increase the difficulty of bringing the thoracic pedicle screw heads to the rods. Traction of the spine to the fusion rods with the UC and reduction tool remains just as straightforward, regardless of the degree of kyphosis the surgeon decides to precontour into the rods. Moreover, several pedicle screw systems with special translation-mediating screw heads can also improve hypokyphosis in AIS patients [13–16]. The main action of UC is a posterolateral laminar attraction. Its advantage is magnified by an implant density of near 100% on the stabilizing rod. Other advantages of the UC are the very low profile, which is very useful in particular at kyphosis apex in hyperkyphotic patients. Furthermore, the UC permits post-operative imaging (i.e., CT scanning and magnetic resonance) without artifacts and the learning curve is very short. Mazda et al. observed that the main limitation of this technique is a high rate of proximal posterior prominence (14.6%) [8]. As recommended by Mazda et al., we used a conventional claw at the upper extremity of the construct.

Conclusion

The hybrid construct using UC appears safe and effective in neurological scoliosis treatment, providing a good correction of the deformity in both the coronal and sagittal

planes. This system significantly reduces operative time, radiation exposure and blood loss compared to all-screw constructs. Physiological thoracic kyphosis was restored in all patients, providing better sitting tolerance in wheel-chair-bound patients, and retaining standing and walking abilities in ambulatory patients. Moreover, the deformity reduction technique using the UC, progressively translating the spine toward the rods in the sagittal plane, has proved to be effective in controlling sagittal profile in patients affected by neurological scoliosis without major complications at the 4-year follow-up.

Conflict of interest None.

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