MODERN TECHNIQUES OF CERVICAL INSTRUMENTATION IN IMMATURE SKELETON: VIABILITY ASSESSMENT

ABSTRACT

Objective: This study describes the use of materials for modern cervical instrumentation, evaluating its viability in children and adolescents, and the techniques used in different cases. The efficacy of the techniques was analyzed through improvement of pain, maintenance of cervical range of motion, recovery of cranio cervical stability, bone consolidation, and spinal stenosis in the postoperative follow-up. Method: Retrospective study of the clinical and radiological parameters of 27 patients aged two to 16 years with cervical spine diseases. Results: Two patients had chronic dislocation in C1-C2, one had congenital axis spondylolisthesis, two had congenital dislocation in C1-C2, three had tumors, one had kyphosis after laminectomy, one had post-infection kyphosis, one had fracture, 11 were syndromic with instabilities, and five had congenital cervical scoliosis. As to surgical approaches, two patients were transorally operated, three by anterior approach, 15 by posterior approach, two by anterior and posterior approaches, and five were treated in three stages (anterior, posterior, and anterior approaches). Regarding the technique of cervical stabilization, seven patients were treated by Goel-Harms technique, two received Goel’s facet distraction, and three, Wright translaminar screws. There were complications in four cases. Two patients in the instrumentation of C1 lateral mass due to poor positioning, one with cerebrospinal fluid fistula and one with surgical wound infection. Conclusion: Modern cervical instrumentation in pediatric patients is a safe and effective technique for the treatment of cervical instability.

Keywords: Spine; Pediatrics; Instrumentation.

RESUMO

Objetivo: Este trabalho descreve o uso de materiais para instrumentação cervical moderna, avaliando sua viabilidade em crianças e adolescentes e as técnicas empregadas em diferentes casos. A eficácia das técnicas foi analisada através da melhora da dor, manutenção do arco de movimento, recuperação da estabilidade crânio-cervical, consolidação óssea e estenose do canal medular no seguimento pós-operatorio. Método: Estudo retrospectivo dos parâmetros clínicos e radiológicos de 27 pacientes entre dois e 16 anos com doenças da coluna cervical. Resultados: Dois pacientes tinham luxação crônica no C1-C2, um tinha spondylolistese congênita do âxis, dois tinham luxação congênita C1-C2, três tinham tumores, um apresentou fistula de líquido cerebrospinal, um tinha fratura, 11 eram sindrômicas com instabilidades e cinco tinham escoliose congênita. Quanto às vias de acesso, dois foram abordados por via transoral, três por via anterior, 15 por via posterior, dois por via anterior e posterior e cinco foram tratados em três etapas (anterior, posterior e anterior). Com relação à técnica de estabilização cervical, sete foram utilizadas técnica de Goel-Harms, em dois, distração faceta de Goel e em três, parafusos translaminares de Wright. Houve complicações em quatro casos, dois pacientes na instrumentação da massa lateral de C1 por posicionamento inadequado, um com fistula líquida e um com infecção da ferida operatoria. Conclusão: A instrumentação cervical moderna em pacientes pediátricos é uma técnica segura e eficaz para o tratamento de instabilidade cervical.

Descritores: Coluna vertebral; Pediatria; Instrumentação.
INTRODUCTION

Lesions that affect the cervical spine in children and adolescents are relatively rare, however, when present, they pose a challenge due to complexity of the treatment and the possibility of catastrophic complications.

For many years, due to the limited availability of materials and biomechanical knowledge, many lesions were treated conservatively or using in situ arthrodesis techniques or fixations with sublaminar wires, which require the use of complementary techniques, such as external fixation. However, this type of treatment had the following consequences: high rates of pseudoarthrosis, loss of surgical correction with subsequent deformities, as well as additional morbidity attributed to the halo-vest and revision surgeries.1

Pedicle screws are biomechanically superior to other systems of vertebral stabilization and are considered the gold standard for thoracic and lumbar spine stabilization.2 Although the viability and mechanical advantages of pedicle screws in the cervical spine of adults has been demonstrated, their use in the cervical spine of patients with skeletal immaturity has not gained much popularity.3,4 This is due to the small dimensions of the pedicle, the ossification volume, fear of injury to neurovascular structures, as well as the variable anatomy of the vertebra.5

Several biomechanical studies have shown that pedicle screws offer better fixation than lateral mass screws. Their relative pullout strengths in two studies were 1214 N vs. 332 N (13), and 667 N vs. 355 N (14).6 Reduced bone and ligament structures and anatomical variations associated with cervical abnormalities resulting from syndromes complicate the approach and restrict the use of internal fixation. Cervical lordosis in children can limit growth potential and cause secondary deformity.

A broad spectrum of diseases can lead to an indication of cervical arthrodesis in children, whether for instability or compression. Among them, congenital and acquired anomalies stand out. Examples of acquired abnormalities are inveterate cervical dislocation, tumors, post-traumatic and post-infection kyphoses, and Grisel’s syndrome.7

Congenital conditions observed in our study included congenital scoliosis from hemivertebrae, the absence of the posterior arch of C1, and congenital hangman fracture.

Indication for fusion include acute diseases where the disease is at a critical stage and intervention is essential (fractures, luxations, tumors), as well as rapidly progressing diseases, where evolution to instability is unpredictable. All treatments aim to resolve the disease and achieve stabilization of the cervical spine. In tumors, the primary treatment objectives are radical excision and stabilization of the cervical spine. Cervical tumors are less frequent in pediatric patients than in the adult population.

cervical arthrodesis should achieve spinal stabilization in order to prevent both neurological lesions and secondary compensatory deformities.

METHODS

This study was approved by the INTO Institutional Review Board (046/2016). We accessed the Instituto Nacional de Traumatología e Ortopedía database for the previous 10 years, from January 2006 to December 2016, as well as the medical records of external patients, totaling 27 patients. Because this was a retrospective study, the informed consent form was not required. We identified patients who had undergone modern cervical instrumentation during this period and had a follow-up of at least eight years. The inclusion criteria considered were a minimum of two years of follow-up, patients less than or equal to 16 years of age who had undergone modern cervical instrumentation. Exclusion criteria were in situ arthrodesis, use of sublaminar wires, and patients older than 16 years of age.

Our analysis of the medical records yielded 27 patients between two and 16 years of age, with an average age of eight years, 17 of whom were female and 10 of whom were male, with an average follow-up of six years after modern cervical instrumentation. The selection and review of the records was based on the age of the patient and on their having been submitted to modern cervical instrumentation.

Radiographic evaluations included simple AP, lateral, and transoral radiographs of the cervical spine in diseases of the upper cervical spine and AP and lateral radiographs for diseases of the subaxial cervical spine. Computed tomography was used in axial cuts and sagittal and coronal reconstructions to measure the vertebral structures and to analyze the viability of instrumentation, in addition to postoperatively control the correct positioning of the implants.

Angiometroradiographies were used in cases of congenital malformation of the craniovertebral junction to study the path and possible anomalies of the vertebral artery.

Magnetic resonance was used to evaluate cases of malformation, neurological deficit, and tumors.

Posterior approach instrumentation of the subaxial cervical spine was performed using lateral mass screws.

In the upper cervical spine, Goel-Harms techniques were used for the instrumentation of C1 and C2. When the diameter of the lateral mass, pars interarticularis, and of the pedicle of C2 were less than 3.5 mm the progressive pedicle expansion technique using drills and cutters was performed, as is done in the lumbar spine of immature skeletons. In a recent study, Rinella et al. demonstrated in the cadaver of a 9-year-old male pre-adolescent that the pedicle can be expanded using successive pedicle screws reaching diameter of up to 8.5 mm. The interior and exterior diameters of the dilated screws increased the original diameters by 74% and 24%, respectively.8

For the anterior cervical spine, when a corpectomy was necessary, a mesh-type cage with a diameter proportional to the vertebral body of the patient was used for the reconstruction of the anterior spine.

In cases in which complementary stabilization was required, we used adult cervical spine locking plates in children older than 10 years of age. In children less than 10 years of age, or with reduced vertebral latero-lateral diameter, we used mini cranio-maxillofacial osteosynthesis plates. (Figure 1)

For the anterior (transoral) instrumentation of C1-C2 a Harms T-plate, customized for the age of the patient, was used.
At the C2 level, we used laminar screws in some cases, according to the technique described by Wright, in the case of occurrence of a widened artery groove or anomaly of the same. For instrumentation of the occiput, a technique of plates and screws placed in the suboccipital region, similar to that used in adults, was performed. 

Posterior approach cages were used in one patient with Goel C1-C2 facet joint distraction. The diagnoses included were inveterate cervical luxation in two patients, congenital axial spondylolisthesis in one patient, congenital C1-C2 luxation (congenital hangman syndrome) in two patients, tumor in three patients, post-laminectomy kyphosis in one patient, post-infection kyphosis in one patient, fracture in one patient, syndromes with instabilities in 11 patients, and congenital scoliosis in five patients. Neurological status was assessed using the Frankel scale. Of the 27 patients, 24 were evaluated as Frankel E, one as Frankel D, and two as Frankel C. Arthrodesis was performed via transoral approach (two patients), isolated anterior approach (three patients), combined two-stage approach (two patients), and three-stage combined method approach (five patients). In two cases where three-column osteotomy (VCR) needed to be performed, because of deficient bone quality, treatment was supplemented with the use of a halo-vest.

RESULTS

All of the patients evolved without complications of great relevance. The following were considered major complications related to the procedure: stenosis of the spinal canal, deep infection, osteomyelitis, limited range of motion for performing daily living activities, pseudoarthrosis, loss of correction, neurological deficit or worsening of preexisting deficit, and cervical pain. In our case series, complications were observed in four cases. Two patients had poor positioning of the C1 lateral mass screw. In one of the two cases, surgical revision was performed due to occipital neuralgia and in the other case a cervical collar was used until definitive consolidation, with posterior removal of the material. One patient had a cerebrospinal fluid fistula and the other a superficial infection of the surgical wound that was treated with antibiotics.

The radiographic and tomographic postoperative control exams did not exhibit any signs of loosening of the implant, loss of reduction, or signs of reabsorption indicating pseudoarthrosis. Patients with clinical presentation of cervical pain from instability following stabilization and arthrodesis in the craniocervical joint obtained improved VAS scores without affecting the range of motion of the cervical spine. Patients with significant decompensation of coronal balance evolved with compensation after hemivertebra and tumor resection.

In the literature, many authors believe that rigid instrumentation should be used in 10-year-old children, whereas patients around three years old should be treated with sublaminar wires. Among the patients evaluated, the use of modern instrumentation was possible in two-year-old children. Considering the final outpatient visit, all patients showed clinical and radiological improvement. Only one patient with Morquio syndrome underwent surgery for screw repositioning because of C1 bone dysplasia. Limitation of the range of cervical motion, a complication related to C0-C1 and C1-C2 arthrodesis, was not a relevant complaint in our patients, which we believe to be, in part, due to the patients’ capacity for compensatory adaptation.

DISCUSSION

Modern cervical instrumentation in pediatric patients continues to be a controversial topic. Fixation with pedicle screws was first described by Roy-Camille in 1970. He was the first to use these instrumentations in treating fractures. To date, there are no implants of a specific size for use in children. Among the techniques for cervical arthrodesis used in this population, the most frequently used is fixation with transarticular screws described by Margel.

As regards the anatomy of the cervical spine in pediatric patients, there are anatomical differences that make the instrumentation procedures complex and potentially subject to complications, considering the small size of the pedicles and lateral masses.
Treatment of cervical spine instability in children has traditionally been achieved with a combination of posterior wiring and orthosis with external halo techniques. In our study, we described techniques that can be applied in most of the different diseases that evolve with resources, such as computed tomography and magnetic resonance, shown to be possible with greater safety with the evolution of imaging in adults in the study age group.

Our study proved that it is possible to use materials developed for adults but also because of the dysplasias inherent in syndromic patients, because of the reduced dimensions in those with normal anatomy, anatomical difficulties inherent in this class of patients, not only to the technique described by Wright.

For stabilization and atlantoaxial stabilization, we performed instrumentation of the lateral mass of the atlas and of the pedicle of the axis, respecting the anatomical considerations presented above. It those patients if whom instrumentation of the C2 pedicle was not possible, we performed instrumentation of the lamina of C2, according to the technique described by Wright.

In our study, we used plates specially adapted for the reduced size of the vertebral body in two-year-old patients and, in the most recent procedures, instrumentation with anterior cervical plates was described for patients older than 12 years of age. This method was described for patients older than 12 years of age. This method

### Table 1. Patient demographic and surgical data.

| Case No. | Age (years/sex) | Diagnosis                  | Surgery                  | Arthrodesis levels | No. screws | Instrumentation                  | Follow-up |
|----------|-----------------|----------------------------|--------------------------|--------------------|------------|----------------------------------|-----------|
| 1        | 8/M             | Inveterate Grisel          | C1-C2 Arthrodesis        | 1                  | 4          | T-Plate                          | 9 years   |
| 2        | 5/F             | Hemivertebra C3            | HV resection/C2-C3 Arthrodesis | 1                  | 2          | PD(C2)/LM(C3)                    | 11 years  |
| 3        | 7/M             | Congenital Hangman         | C2-C3 Arthrodesis        | 1                  | 6          | Anterior cervical plate          | 4 years   |
| 4        | 12/M            | Post-tuberculosis kyphosis | PA:C3-C5 Arthrodesis/AA: C6-C7 Corpectomy | 1                  | 12         | LM C3-C6                         | 4 years   |
| 5        | 2/F             | Congenital cervical luxation| C6/C7 Corpectomy         | 3                  | 3          | CMF plate                        | 2 years   |
| 6        | 7/M             | Tumor (post-laminectomy kyphosis) | C7 Corpectomy | 12                  | 13         | PD:C3-C4/T1-T9                   | 10 years  |
| 7        | 10/F            | C1-C2 Instability          | C1-C2 Arthrodesis        | 1                  | 4          | LM:C1/PD:C2                      | 6 years   |
| 8        | 11/F            | C3 Tumor                   | C3 Corpectomy/ C2-C4 Arthrodesis | 2                  | 4          | Anterior cervical plate          | 6 years   |
| 9        | 10/F            | Dens/Morquio IV            | C1-C2 Arthrodesis        | 1                  | 3          | Posterior Vertex                 | 8 years   |
| 10       | 9/M             | MPS IV                     | C1-C2 Arthrodesis        | 1                  | 4          | Posterior Vertex                 | 4 years   |
| 11       | 6/F             | MPS VI                     | C1-C2 Arthrodesis        | 1                  | 4          | Posterior Vertex                 | 4 years   |
| 12       | 7/F             | Congenital kyphosis        | Hemivertebrectomy        | 6                  | 12         | Posterior Vertex                 | 4 years   |
| 13       | 6/F             | MPS VI                     | C1-C2 Arthrodesis        | 1                  | 4          | LM C1/PD:C2                      | 8 years   |
| 14       | 8/M             | MPS VI                     | O-C4 Arthrodesis + decompression | 4                  | 10         | Posterior Vertex                 | 9 years   |
| 15       | 10/F            | MPS VI                     | C1-C2 Arthrodesis        | 4                  | 1          | Posterior Vertex                 | 9 years   |
| 16       | 2/F             | MPS VI                     | O-C0 Arthrodesis         | 2                  | 6          | Posterior Vertex                 | 6 years   |
| 17       | 16/M            | Cervical fracture          | C6 Corpectomy/ C5-C7 Arthrodesis | 2                  | 4          | Anterior cervical plate          | 8 years   |
| 18       | 16/M            | MPS I                      | O-C4 Arthrodesis / decompression | 4                  | 12         | Posterior Vertex                 | 4 years   |
| 19       | 12/F            | Inveterate Grisel          | Osteotomy + PA C1-C2 Arthrodesis | 1                  | 4          | Posterior Vertex                 | 5 years   |
| 20       | 5/M             | C6 Cervical hemivertebra   | VCR/ PA/C4-T5/ AA:CMF(2U) | 8                  | 16         | Posterior Vertex                 | 4 years   |
| 21       | 2/F             | Hemivertebra C3            | Resection HV+ C2-C3 Arthrodesis | 2                  | 10         | CMF+ Vertex                      | 8 years   |
| 22       | 7/F             | C6-C7-T1 Hemivertebrae     | C2-T4 Arthrodesis        | 9                  | 12         | Vertex                           | 8 years   |
| 23       | 6/M             | Congenital kyphosis        | C4-T1 Arthrodesis        | 9                  | 12         | CMF+ Vertex                      | 8 years   |
| 24       | 9/M             | C5 Tumor                   | Resection + C4-C6 Arthrodesis | 4                  | 6          | Vertex                           | 6 years   |
| 25       | 5/F             | MPS VI                     | Cervical canal stenosis  | 1                  | 4          | Vertex                           | 4 years   |
| 26       | 5/F             | MPS VI                     | C1-C2 Arthrodesis        | 1                  | 4          | Vertex                           | 5 years   |
| 27       | 5/F             | MPS VI                     | C1-C2 Arthrodesis        | 1                  | 4          | Vertex                           | 8 years   |
was shown to be possible regardless of age, taking into account the disease being treated and the surgeon’s experience with the local anatomy.

We also analyzed 118 of the 161 instrumented screws and we observed that all the screws were completely contained by bone. We also observed in follow-up assessments that the average age was 8.5 years and that all the patients treated had lower visual analog scale scores, suggesting clinical improvement, in addition to the absence of limitations in range of head motion. Tomographic studies also showed that none of the patients evolved with stenosis of the spinal canal.

CONCLUSIONS
Modern cervical instrumentation proved to be safe and effective in patients with skeletal immaturity, its use being recommended from two years of age, with high fusion rates and low complication rates, as long as a local anatomical study is conducted and the appropriate implant and technique are chosen in each case.

All authors declare no potential conflict of interest related to this article.

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