Cervical instrumentation and fusion in children under 10 years old

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Abstract

Introduction: Over the past decade, instrumentation in children's cervical spine has been gaining momentum. The anatomic and biomechanical differences in cervical spine between children and adults make it necessary for this surgery that is thoroughly planned every time implants designed for adults are used. The aim of this study was to evaluate post-operative results in a series of <10 year-old children subject to instrumented cervical fusion, and describe surgical techniques and complications.

Materials and Methods: We evaluated 28 patients with cervical conditions treated by instrumented fusion using the techniques described by Roy-Camille and Magerl for lateral masses, and by Goel-Harms for C1-C2, as well as occipito-cervical fusions with occipital plates or ball joints. The inclusion criteria were: <10 year-old patients, primary surgery and minimal follow-up of 2 years.

Results: The sample included 17 girls and 11 boys with average follow-up of 3.8 years (ranging from 2 to 10). They averaged 6.1 years old (ranging from 1.6 to 10). The average rate of general complications was 32.1%. The patients who showed most complications suffered: genetic syndromes [6 cases (21.4%)] and skeletal dysplasia [3 cases (10.7%)]. Thirteen were <6 years old, and 7 of them showed complications (53.8%).

Conclusions: Cervical instrumentation in <10 year-old patients proved to be a viable and safe procedure. Vertebral dysplasia, congenital anomalies and patients' genetic syndromes, as well as age (<6 year old) are the main variables when it comes to associated complications.

Key words: Cervical arthrodesis; children; occipito-cervical; cervical instability.
Level of evidence: IV

Instrumentación cervical en pacientes menores de 10 años

Resumen

Introducción: La instrumentación de la columna cervical pediátrica ha ganado terreno en la última década. Las diferencias anatómicas y biomecánicas entre la columna cervical pediátrica y del adulto hacen que la cirugía requiera de una minuciosa preparación toda vez que se utilizan implantes diseñados para adultos. El objetivo de este estudio fue evaluar los resultados posoperatorios en una serie de niños <10 años sometidos a fusión cervical instrumentada, y describir la técnica quirúrgica y las complicaciones.

Materiales y Métodos: Se evaluó a 28 pacientes con patología cervical tratados con fusión instrumentada utilizando las técnicas descritas por Roy-Camille y Magerl para masas laterales, de Goel-Harms para C1-C2, y las fusiones occipito-cervicales con placas occipitales o rótulas. Los criterios de inclusión fueron: pacientes <10 años, cirugía primaria y un seguimiento mínimo de 2 años.

Conflict of interests: The authors have reported none.

Resultados: La muestra incluyó 17 niñas y 11 niños, con un seguimiento promedio de 3.8 años (rango 2-10). La edad promedio fue de 6.1 años (rango 1.6-10). La tasa promedio de complicaciones generales fue del 32,1%. Los pacientes que tuvieron más complicaciones sufrían: síndromes genéticos [6 casos (21,4%)] y displasias esqueléticas [3 casos (10,7%)]. Trece tenían <6 años, 7 de ellos presentaron complicaciones (53,8%).
Conclusiones: La instrumentación cervical en pacientes <10 años demostró ser un procedimiento factible y seguro. Las displasias vertebrales, las anomalías congénitas y los síndromes genéticos, sumados al factor edad <6 años, son las principales variables asociadas a las complicaciones observadas.

Palabras clave: Artrodesis cervical; Pediatría; occipito-cervical; inestabilidad cervical.
Nivel de Evidencia: IV

Introduction

Over the past decade, instrumentation in children's cervical spine has been gaining momentum—this procedure is acknowledged as a more stable fixation method with high fusion rates, a shorter time of external immobilization and low rates of associated complications.

The anatomic and biomechanical differences in cervical spine between children and adults make it necessary for this surgery that it is thoroughly planned, since the implants are designed for adults.

There are numerous occipito-cervical, atlanto-axial and sub-axial arthrodesis surgical techniques,[1,2] but the advent of lateral masses and pedicle screws[4] has outdone the results gotten with the old wiring techniques (Gallie, Sonntag, Brooks).[5,6] However, complications still occur in numerous series, especially in the cases of vertebral dysplasia, poor bone stock, scarce soft tissue coverage and infection. Consequently, cervical instrumentation in children represents a challenge for the spinal surgeon.

There are few reports on pediatric patients with cervical instrumentation.[7] Several publications describe complications associated with the implants in up to 20 year-old pediatric populations.[8-11]

The aim of this study is to describe the instrumentation techniques, the results and the complications in a series of <10 year-old patients treated with cervical instrumentation (bars, screws, and hooks).

Materials and Methods

We carried out a retrospective study in a consecutive series made up of <10 year-old 28 patients who suffered cervical conditions which required instrumentation with hooks and screws, with complete medical and radiographic records, between 2003 and 2013 at a high complexity children's hospital.

The inclusion criteria were: <10 year-old patients with diverse conditions that required cervical instrumentation for the first time, with a minimal follow-up of two years.

The exclusion criteria were: >10 year-old patients, history of cervical spine surgery associated with simple cervical arthrodesis, sub-laminar or inter-spinal wiring, as well as post-laminectomy kyphosis.

All the patients were evaluated with static and functional X-rays, pre-operative CT to detect anatomic anomalies and variability, and also to estimate the size of the C2 and C7 pedicles and that of the C1 through C6 lateral masses, and the width of the occipital skullcap.[12-14]

We carried out routine MRI to assess static compressions and instabilities; magnetic resonance angiography and selective arteriography were used if tumoral involvement of the vertebral artery was suspected, and also to rule out arteries permeability and flow impairment.

Surgical technique

For cephalic positioning and stabilization we used a halo; all the patients were under neurophysiological monitoring since the beginning of anesthesia, and we conducted continuous recording until the patient's final positioning. Afterwards, we carried out radiographic control to evaluate the position of the head and the eyes, to preserve the cervical lordosis and to assess the occipito-cervical angle, what is key in occipito-cervical fusion. In all fusions we used screws, hooks, support plates by anterior approach and cervical bars.

We used the techniques described by Roy-Camille and Maegerl[15-17] to insert the screws in the lateral masses, and that one described by Goel-Harms for C1-C2 stabilization.[1] In occipito-cervical fusions, we used occipital plates or ball joints depending on the size of the patient and the soft tissue coverage.[18] We used local bone graft associated with autologous iliac bone graft and bone bank allograft. All the patients used a hallo-vest for three months after the surgery.

The post-operative follow-up included medical and radiographic checkups six weeks, 3 and 6 months, and one year after the surgery. We evaluated the fusion mass with static X-rays three months after the surgery and, when we could not visualize bone callus, we resorted to CT images before removing the halo. When in doubt, we carried out functional flexion-extension X-rays to rule out mobility at the artrhrodesis focus level. The variables we analyzed are the following: surgical technique, intra-operative complications, and immediately post-operative, mediate and remote complications—vessel injuries, superficial and deep infections, meningeal rupture, cerebrospinal fluid fistula, neurologic complications, delayed union and non-union, bad implant positioning, and complications related to the implants.

Results

We evaluated 28 patients [17 girls (60.71%), 11 boys (29.29%)] subject to cervical instrumented arthrodesis (Table 1), with average follow-up of 3.77 years (ranging from 24 to 120 months). They were 6.1 years old on average (ranging from 1.6 to 10).

The patients' diagnosis were: genetic syndromes—Down syndrome (4 cases), Larsen syndrome (1 case), Apert syndrome (1 case), Klippel-Feil syndrome and VACTERL association (1 case), neurofibromatosis 1 (2 cases), mucopolysaccharidosis type I (1 case), mucopolysaccharisosis type IV (4 cases); skeletal dysplasia—campomelic dysplasia (1 case), achondroplasia (1 case),

Table 1. Demographic data

Patient	Follow-up (months)	Total follow-up	Sex	Age	Fusion levels
1	73	6+1 years	M	1+6 years	8
2	37	3+1 years	F	2+4 years	8
3	6	2+6 years	F	2+5 years	8
4	14	2+2 years	F	4+6 years	4
5	43	3+7 years	F	4+3 years	3
6	24	2 years	M	4 +11 years	3
7	27	2+5 years	F	2+6 years	8
8	5	2+5 years	F	2+11 years	5
9	28	2+4 years	F	4+2 years	3
10	49	4+1 years	F	4+2 years	2
11	50	4+2 years	F	4+2 years	4
12	24	2 years	F	9+7 years	4
13	72	6 years	F	6+5 years	3
14	120	10 years	M	8+3 years	5
15	63	5+3 years	F	5+5 years	5
16	28	2+4 years	M	5+2 years	8
17	71	5+11 years	M	8+9 years	2
18	26	2+2 years	M	9+10 years	3
19	25	2+1 years	F	6 years	4
20	31	2+7 years	M	8+6 years	5
21	30	2+6 years	F	8+6 years	3
22	36	3 years	M	6 years	5
23	34	2+10 years	F	6+4 years	5
24	120	10 years	F	6+11 years	4
25	89	7+5 years	F	7+5 years	2
26	32	2+8 years	M	8 years	5
27	25	2+1 years	M	10 years	4
28	26	2+2 years	M	10 years	2
Percentages	1270/28: 45.35 months	1270/12: 101.83/28:3.77 years	F: 17 M: 11	Ranging from 1.6 to 10 years old; average 6.13 years old	125/28 4.46

ISSN 1852-7434 (online) • ISSN 1515-1786 (printed)

chondrodysplasia punctata (1 case), spinal dysgenesis (2 cases); traumatic causes—fracture by firearm (1 case); tumors—aneurysmal bone cyst (1 case), osteosarcoma metastastasis (1 case); non-progressive chronic encephalopathy (1 case), inflammatory causes—psoriatic arthritis (1 case) (Table 2). Twenty-five out of the 28 patients were operated on by isolated posterior approach; one, by anterior approach; two, by combined approaches, and 19 required spinal decompression associated with arthrodesis.

We carried out 14 occipito-cervical arthrodesis, two atlanto-axial arthrodesis, four cervical sub-axial arthrodesis, three cervico-thoracic arthrodesis, and five occipito-thoracic arthrodesis. The average of fused levels was 4.4 (ranging from 2 to 8), with a consolidation rate of 96%.

Nine patients (32.14%) suffered general complications; those with genetic syndromes [6 cases (21.42%)] and with skeletal dysplasia [3 cases (10.71%)] were the ones who suffered most complications (Table 3).

Thirteen patients were <6 years old; seven out of them suffered complications (53.84%) whereas 15 children were >6 years old, and only two showed complications (13.33%).

Table 2. Percentage of complications by condition and general population

Conditions	Number of patients	% by condition	Global % of complications
Genetic syndromes - Being studied: 1 - Klippel-Feil + VACTERL: 1 - Mucopolysaccharidosis: 4 type IV, 1 type I - Neurofibromatosis 1: 2	15	40%	21.42%
Skeletal dysplasia - Chondrodysplasia punctata: 3 - Campomelic dysplasia: 1 - Achondroplasia: 1 - Spondyloepiphyseal dysplasia: 1 - Spinal dysgenesis: 2	7	42.85%	10.71%
Tumor (aneurysmal bone cyst: 1, osteosarcoma metastasis:1)	2	0%	0%
NPCE (kyphoscoliosis: 1)	1	0%	0%
Cervical traumatism (fracture by firearm)	1	0%	0%
Inflammatory (psoriatic arthritis: 1)	1	0%	0%
Total	28		32.14%

NPCE = non-progressive chronic encephalopathy.

Table 3. Complications by time of onset

Condition	<1 month—Immediate complications	<6 months—Mediate complications	>6 months—Remote complications
Genetic syndromes: 5			
Being studied (Klippel-Feil + VACTERL)			Spinal compression, spinal stenosis by instability
Larsen	Intra-operative lateral mass fracture		
Apert	Post-traumatic loosening		
Down	Infection		
Down	Lateral mass fracture		
Mucopolysaccharidosis:1		Spinal compression by instability	
Skeletal dysplasia: 3 Campomelic dysplasia	Lateral mass fracture		
Achondroplasia	Lateral mass fracture		
Chondrodysplasia punctata			Broken bar, non-union

Six patients required a second surgery—two of them due to adjacent instability, one due to distal kyphoscoliosis, one due to post-traumatic loosening (Figures 1-7), and two due to spinal compression compression caused by tumor recurrence. These two patients were not included in the statistics, because their complications were not directly related to the surgical technique or the material, but they were complications caused by tumor advance. We divided complications into two groups: minor complications (which did not require new surgery), such as superficial infections and wound dehiscence, and major complications (which required another surgery), such as deep infection, distal joint kyphosis, and spinal cord compression.

The intra-operative complications were: changes in the frame due to rupture of the lateral masses or anchoring loss—four cases (2 <3year-old patients); in two patients it was necessary to modify the surgical technique and, in the other two, we inserted sub-laminar hooks; loss of cerebrospinal fluid while inserting the occipital screws (4 cases).

Figure 1. AP and lateral pre-operative X-rays.

Figure 2. CT scan. Atlanto-axial instability.

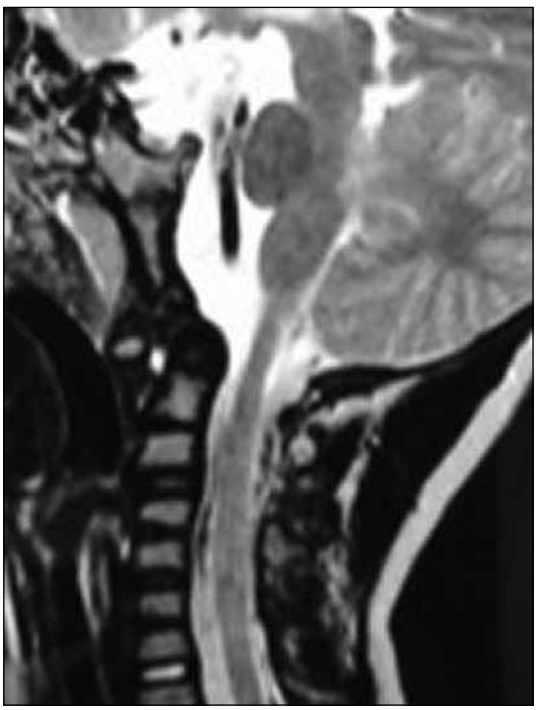
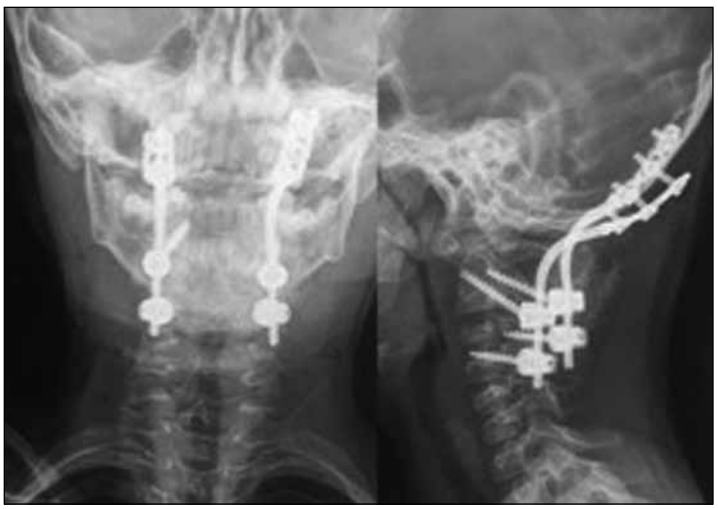


Figure 3. MRI. No evidence of spinal injury.

ISSN 1852-7434 (online) • ISSN 1515-1786 (printed)

Figure 4. CT scan with 2D reconstruction. It shows C1-C2 instability plus odontoid process hypoplasia.

Figure 5. X-ray after fall. It shows occipital screws full out.



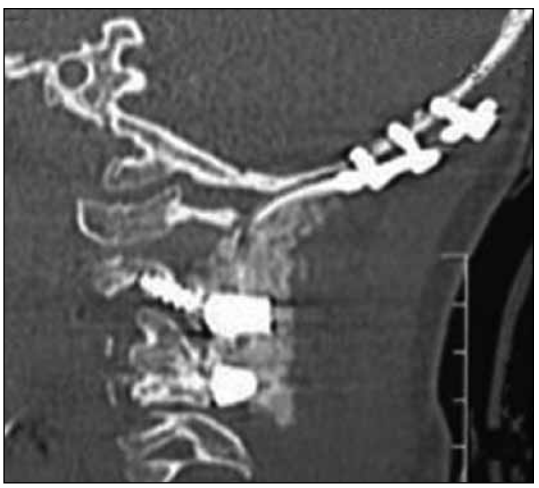


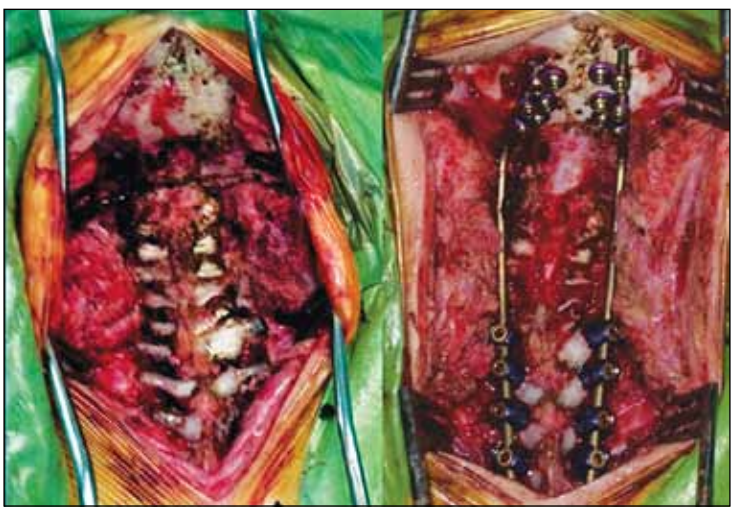
Figure 6. CD scan with 2D reconstruction. Occipital screws full out.

Figure 7. AP and lateral X-rays after revision.

In three patients, cervical instrumentation was difficult due to the degree of dysplasia in the posterior elements [campomelic dysplasia (1 case) and spinal dysgenesis (2 cases)]; therefore, we carried out bridge occipito-thoracic fusion; all the patients were <2 years old (Figures 8-12). One patient suffered surgical wound infection, what required toilet and i.v. plus p.o. antibiotic. The immediately post-operative complication was the anchoring loss of the occipital screws with loosening of the cephalic halo due to traumatism 32 days after the surgery, with consecutive non-union which required a new surgery six months later.

Figure 8. A. AP and lateral cervical X-rays. **B.** MRI. Severe spinal compression and associated myelomalacia.

Figure 9. Intra-operative pictures. Posterior decompression plus posterior instrumented occipito-thoracic fusion.



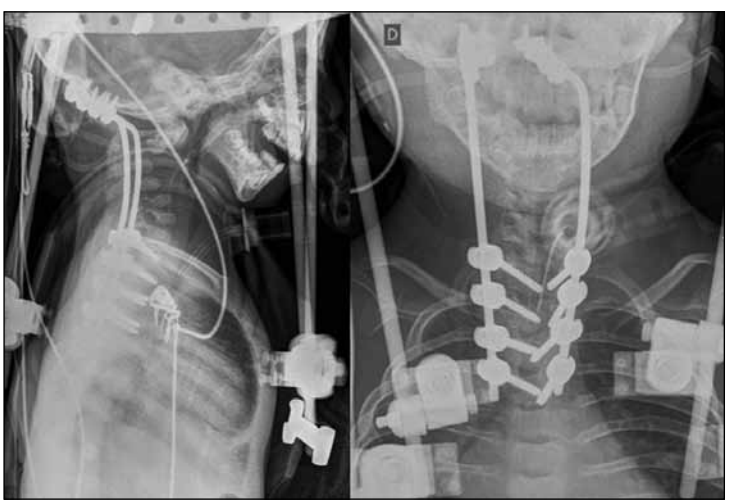


Figure 10. Immediately post-operative X-rays. Occipito-thoracic fusion plus halo-vest.

ISSN 1852-7434 (online) • ISSN 1515-1786 (printed)

Figure 11. X-ray two years after the surgery.

Figure 12. CT scan with 3D reconstruction two years after the surgery.

The remote post-operative complications were: one case of broken bar associated with non-union one year and a half after the surgery in occipito-thoracic fixation in the case of a patient with chondrodysplasia punctata (Figures 13-15); and two cases of spinal cord compression due to adjacent instability and distal joint kyphosis, what required new surgery.

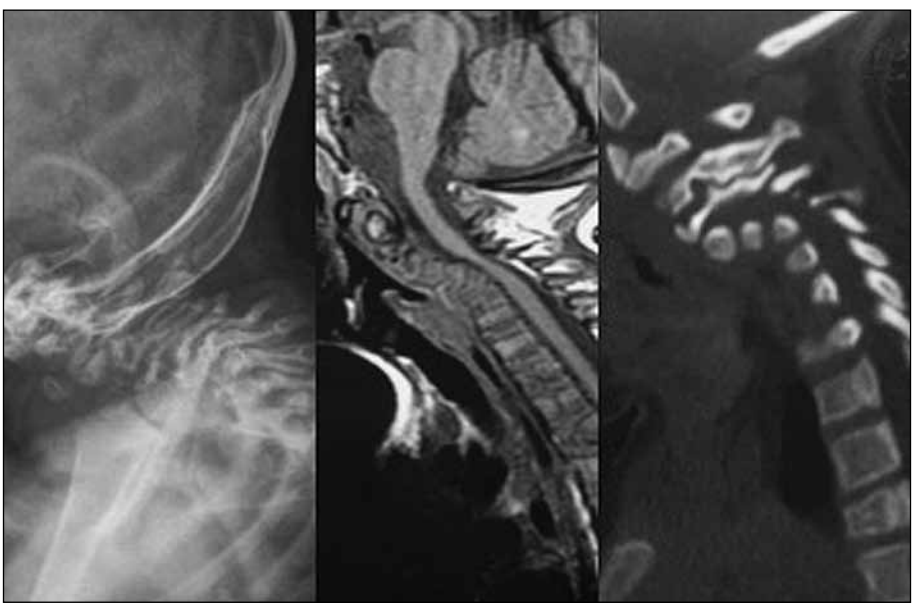


Figure 13. Cervical kyphosis associated with spinal cord compression.

Figure 14. Four months after the surgery, there is posterior instrumented occipito-thoracic fusion.

Figure 15. Eleven months after the surgery. Occipito-C1 non-union associated with no neurological status deterioration.

Discussion

In cervical spine surgery, there are numberless surgical techniques and different types of implants to carry out arthrodesis. Pedicle screws on their own or associated with lateral masses are currently the reference for posterior cervical arthrodesis in adults, because they give safer and more stable fixation, and avoid extended external immobilization.[4] Although there are reports on low numbers of pediatric patients receiving cervical instrumentation for adults, the vast majority of them address isolated cervical conditions in >10-year old populations, and they do not describe all the variables that we analyze in this series. Results seem to be uneven and are particularly focused on the high complication rates that they are associated with (Table 4).[8-11]

The aim of our series was to show instrumentation viability in <10 year-old patients, and also to enumerate

ISSN 1852-7434 (online) • ISSN 1515-1786 (printed)

Table 4. Comparison of results to previous studies

Study	Author	Number of patients	Age (years)	Year	Conditions	Surgical techniques or material	% of complications	Our study
1	Prakash	20	1.4- 18.1	2014	Skeletal dysplasia	Wiring	35%	10%
2	Tauchi	11	4-13	2011	Atlanto-axial instability in any condition	Wiring Screws Hooks	64%	32.14%
3	Ain	25	2-47 9 adults	2006	Skeletal dysplasia	Wiring Screws Hooks	20%	10%
4	Doyle[21]	15	3-53 6 adults	1996	Syndromes (Down)	Wiring	73%	50%

Comparison of complication percentages by the same demography.

the complications associated with instrumentation techniques.

Pediatric instrumentation represents a challenge for the surgeon due to the poor bone stock, the presence of cartilage, the lack of closure in the posterior elements, the immature bone, the anatomic variability, dysplasia, congenital anomalies, and mostly due to the size of the structures in comparison with the implants. However, fusion rates were high (96%) as compared to the ones reported by Tauchi et al.[10] (82%) and by Scott et al.[11] (53%) with wiring and simple fusion techniques.

As far as we know, this series of <10 year-old 28 children with cervical spine instrumentation represents the longest so far.

Thirteen children were <6 years old, and seven of them (53.84%) had complications, whereas 15 children were >6 years old, and only two (13.33%) showed complications, what might mean an increase in complications inversely proportional to age.

The hardware nowadays availabe—3.5 and 4 mm-diameter screws and supra-laminar or sub-laminar hooks, sometimes represent limitations due to the size or the degree of dysplasia in the posterior elements, especially in <6 year-old children. The same occurred with 3.5 mm-diameter and 6-8 mm-length occipital screws, which resulted too long in all patients with intra-cranial invasion, what was associated with craniospinal fluid leak in four cases, but none of them had neurologic complications or fistula; however, bi-cortical anchorage represents a good one for fixation. Therefore, we consider it to be a safe fixation method with no major complications.

When the degree of dysplasia in the posterior elements, fragility and bone size make it impossible to carry out limited instrumentation, we recommend bridge occipitothoracic fusion with or without anterior approach plus structural bone graft. In this series, we carried out five extended fusions with very good results in terms of immediate stabilization, correction of deformity and fusion.

Pre-operative planning with CT assessment of lateral masses, pedicles, and the width of the occipital skullcap[12-14] is key so as to minimize complications and plan the construction we are about to insert.[19]

Leonard and Heuer suggest that a good instrumentation with C1-C2 screws does not require external immobilization.[2,20] On the contrary, we believe that it is necessary to give post-operative protection to the arthrodesis during 6 weeks to 3 months because the length of the screws and the bone stock are never sufficiently stable so as to allow the patient immediate mobility; moreover, it protects him or her against potential falls, quite frequent in children, or frame failure.

In the patients assessed with CT, we found acceptable screw coverage with total bone support within the lateral masses and the pedicles.

There were neither neurologic nor vascular complications associated with the screws.

Conclusions

Instrumentation in <10 year-old patients' cervical spine proved to be a viable and safe procedure which allowed us adequate, stable and immediate fixation, with high consolidation rates in a wide range of conditions.

Vertebral dysplasia, congenital anomalies and patients' genetic syndromes, as well as age (<6 years old) are the main variables when it comes to associated complications.

Although instrumentation implies potential risks in very little patients, adequate imaging studies and pre-operative planning helped to decrease intra-operative complications and gave us medical safety in fusions.

A thorough planning of the screws positioning spots, adequate knowledge of pre-operative anatomic variants, and adequate spinal exposure decrease instrumentation failure to the minimum.

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ISSN 1852-7434 (online) • ISSN 1515-1786 (printed)