Instrumentation of the paediatric cervical spine

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Abstract

Background:
Paediatric cervical fusion surgery is challenging. Traditional techniques such as external stabilisation, onlay fusions and wiring techniques resulted in unsatisfactory outcomes due to inferior biomechanical stability.

Methods:
A retrospective review was performed of paediatric patients who underwent instrumented cervical fusion surgery under 16 years of age. Fusion rates, blood loss, levels fused, theatre time, technique and complications were assessed.

Results:
An average of 2.5 levels was fused, with an estimated blood loss of 428 ml and surgical duration of 159 min. Anterior procedures had an average of one level fused with blood loss of 117 ml and surgical duration of 98 min. Posterior procedures had an average number of 1.9 levels fused, blood loss of 306 ml and surgical time of 131 min. Combined procedures had an average of 5.5 levels fused, blood loss 810 ml and surgical duration of 241 min. Four surgery-related complications were encountered. These consisted of dural leaks and wound sepsis which were all treated effectively.

All patients achieved radiological fusion.

Conclusion:
The use of modern segmental spinal instrumentation in the paediatric cervical spine is a viable option. Although the study sample was small we are able to demonstrate that no major surgical complications were encountered due to the use of adult cervical spinal instrumentation techniques in the paediatric group.

Key words: paediatric, spine, instrumentation, fusion, cervical

Introduction

Fusion surgery for paediatric cervical instability is challenging due to small anatomical dimensions and largely cartilaginous spinal elements. Traditional techniques such as external stabilisation, onlay fusions and wiring techniques have resulted in unsatisfactory outcomes due to inferior biomechanical stability and resultant loss of reduction post-operatively, especially in the setting of tumour surgery.

There are very few articles published regarding the use of segmental spinal instrumentation in the paediatric population

High fusion rates have been reported using these techniques, but they are cumbersome for both the surgeon and patient,[1-2] and can lead to severe morbidity despite initial surgery. Fixation methods in the adult cervical spine have been well described using a variety of techniques.

Surgeons are well aware of the various fixation points which can be safely employed during surgery of the cervical spine in adults.[3-6] Anatomical studies of paediatric thoracic and lumbar morphology have been performed, but studies specifically pertaining to the paediatric cervical spine anatomy have been scarce.[7-9] There are very few articles published regarding the use of segmental spinal instrumentation in the paediatric population.[10-11]

Materials and methods

Following Institutional Ethics committee approval (HREC 525/2011), a retrospective review of paediatric patients who underwent cervical surgery in our hospital group was performed.

The senior author's database was interrogated for patients who underwent instrumented cervical surgery younger than age 16 years over a 10-year period 2001 to 2011.

Case notes and imaging were reviewed. Demographic data, pathology, surgical technique employed, intra- and post-operative data, and complications encountered were recorded.

Radiographic review was done of all the patients and included pre- and post-operative X-rays as well as CT and MRI scans if performed.

Fusion was assessed by means of X-ray evaluation at regular post-operative intervals. The fusion mass, absence of peri-screw lucency and motion on dynamic views were studied.

Sixteen patients were identified for inclusion in the study. All surgery was performed by the senior author. The median age at surgery was 8 years with a range from 3 months to 16 years. Ten were male and six female.

The underlying aetiology included five acute trauma cases, three spinal tuberculosis, six congenital abnormalities and two tumours (*Table I*). Three anterior and eight posterior procedures were performed, with the remaining five constituting combined procedures. The combined cases were one trauma, one tumour and three for spinal tuberculosis. The average number of levels fused was 2.4 (range 2–5).

Results

With regard to levels fused, there were two five-level fusions, two four-level fusions, one three-level fusion, seven two-level fusions and five single-level fusions.

The average surgical duration was 159 min (range 70–295 min) and blood loss ranged from 50 to 1 300 ml, with an average loss of 428 ml. The two extreme blood losses of 1 300 and 1 200 ml were due to tumour resections.

Anterior-only cases

Three anterior cases were performed due to traumatic conditions. The ages of the patients ranged from 8 and 16 years. Anterior plating was performed utilising the narrow Synthes CSLP plate (*Figure 1*) in two cases and a small fragment screw for a type 2 dens fracture. The average blood loss in the anterior procedures was 117 ml (range 50–250 ml) and surgical time 98 min (range 70–135 min). Autograft was harvested from the iliac crest in two cases.

Table I: Aetiology

Anterior	3	Trauma
Posterior	1 6 1	Trauma Congenital Malignancy
Combined	3 1 1	Tuberculosis Malignancy Trauma

Figure 1: ACDF for unifacet dislocation

Posterior-only cases

Posterior surgery was performed for a variety of disorders. A variety of fixation techniques was utilised as tabulated (*Table II*). For all the cases the Synthes Axon instrumentation was used (*Figures 2–4*). The 3.5 mm polyaxial head screw was used along with the 4 mm rod.

Fixation techniques varied between lateral mass, pedicle, isthmic and translaminar screws. This was largely based on safety with regard to the vertebral artery. Lateral mass was used from C3–6 and pedicle screws in C2 and C7.

Table II: Posterior fixation techniques

Fixation techniques	Total
Occiptocervical	4
Atlantoaxial	2
Subaxial	2

Figure 2: Atlantoaxial fusion for os odontoidum

Figure 3: Posterior instrumented fusion after tumour resection

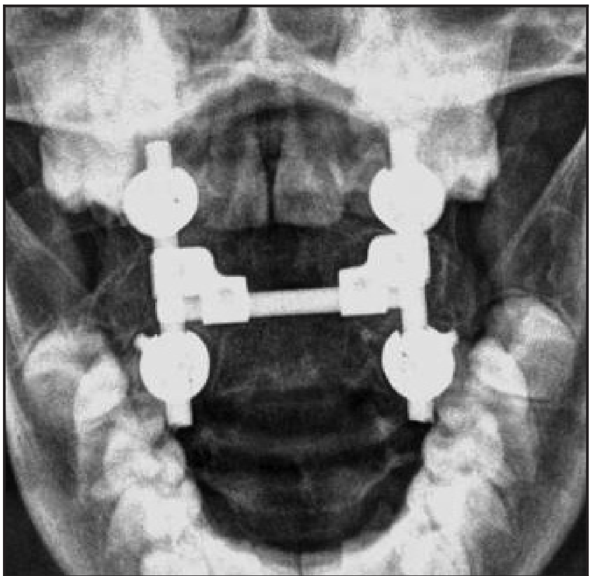

Figure 4: Posterior instrumented fusion after tumour resection

A skull plate was used in the occipitocervical cases.

In six of the posterior cases, autograft was used and in two cases demineralised bone matrix allograft. The average blood loss and surgical time was 306 ml (range 50–1 200 ml) and 131 min (range 75–250 min) respectively.

The average age of patients who underwent posterior surgery was 8.2 years (range 3 months–16 years).

In a 7-year-old with a C7/T1 unifacet dislocation but neurologically intact, a small dural tear was identified on exposure. This was successfully stopped with local measures.

Transcranial motor-evoked spinal cord monitoring (NIM Medtronic) was used when available and deemed necessary. A patient with severe myelopathy due to a congenital occipito-cervical deformity and basilar invagination demonstrated immediate improvement in both conduction velocity and amplitude upon reduction of the dens from the foramen magnum. This was done by means of distraction between the skull plate and C2 screws demonstrating an advantage of secure modular instrumentation.

Anterior and posterior combined cases

Five patients received combined anterior and posterior procedures for a variety of conditions. Ages ranged from 5 to 16 years with an average age of 11 years. Levels fused ranged from two to five levels. All surgery was performed in a single sitting with an average blood loss of 975 ml (range 300–1 300 ml) and surgical time of 248 min (range 210–295 min).

Anterior procedures in the combined group all consisted of corpectomy with fibula allograft reconstruction. In two patients a CSLP plate was used as an adjunctive fixation. All cases were followed by additional posterior techniques varying between lateral mass and pedicle screws using the Axon system as described above (*Figure 5*).

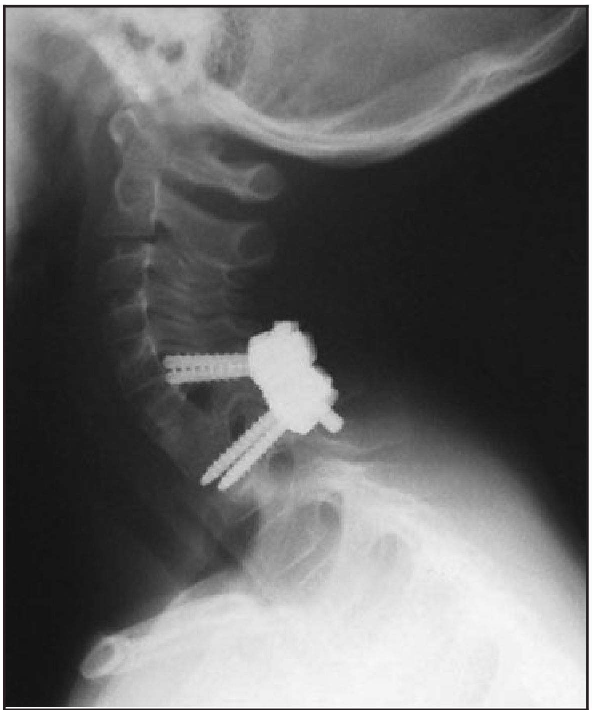

Figure 5: C6–T1 fusion for bifacet dislocation

Complications

There were two unintentional durotomies intra-operatively. These were due to root sleeve injuries while mobilising adherent annulus. Both were managed successfully with Duraseal sealant intra-operatively.

One patient developed a post-operative superficial posterior wound sepsis that resolved with oral antibiotics. Another case presented with a draining sinus in the anterior surgical scar area seven years after the initial surgery. Surgical exploration revealed no connection between the abscess and the plate. The plate was removed anyway and the sepsis resolved with oral antibiotics.

There was one post-operative death. This was a 3-month-old Conradie-Hunerman patient with C1–2 instability and respiratory drive impairment due to severe myelopathy which was initially missed. A posterior C0–3 fusion with skull plate and rods secured with sublaminar sutures (*Figure 6*). The C1 arch was resected. There was some initial improvement in motor function but he remained ventilator-dependent. He died in ICU from a chest infection some 4 months later.

Outcome

All patients achieved radiological fusion by 6 months' follow-up. There was no migration or failure of the instrumentation. Post-operative imaging consisted mostly of X-rays, except when CT scans were indicated to assess instrumentation position or union (*Figure 7*). In the two CT scans, all instrumentation was confirmed to be adequately placed.

No patients or parents reported any complaint with regard to swallowing, dysphagia, dysphonia or any other instrument-related complaints.

Discussion

There is abundant literature available regarding the use of modern segmental instrumentation in the paediatric thoracic and lumbar spine.[10-12] The article published by Hedequist in *Spine* (2008) is the first article to describe the use of modern segmental instrumentation other than transarticular screws in the paediatric population.

Literature has shown that the use of modern instrumentation delivers a more rigid fixation with predictable anatomic reduction and good fusion rate compared to older techniques such as Halo fixation and onlay fusions. The use of segmental spinal instrumentation however has not enjoyed the same popularity in the paediatric cervical spine despite the advantages it has over older techniques. Advantages of increased stability, union rate, and a decreased need for external immobilisation are all factors to be considered when choosing modern implants over older technology.

Early use of transarticular screws in paediatric patients has been described.[13,14] Only one study has studied the successful use of modern segmental instrumentation in the paediatric cervical spine.[11] Hedequist used a variety of pedicle and lateral mass screws, anterior cervical and occipito-cervical plates and modern cages.

Figure 6: Occipitocervical fusion in a 3-month-old patient

Although their study also consisted of a small number of patients it showed that excellent results can be obtained with the use of modern segmental instrumentation while no instrumentation-related complications were encountered.

One of the main factors that prevented the popularisation of the use of segmental instrumentation is the size of the paediatric cervical vertebrae and pedicles. Despite numerous anatomical studies of paediatric thoracic and lumbar pedicle sizes, few articles have been published regarding the cervical pedicle anatomy.[9,15]

Vara and Thompson in 2006 shed light on the morphology and development of the paediatric cervical pedicle using cadaveric specimens.[9] Kanna *et al* performed a radiological study of paediatric pedicle size by obtaining measurements from CT scans of the paediatric cervical vertebrae.[7] Vara looked at five parameters, namely the pedicle axis length (PAL), pedicle length (PL), pedicle width (PW), antero-posterior cervical spinal canal diameter, and interpedicular distance. The parameters measured were performed in the same fashion as in other anatomical studies.[16,17]

Vara found that pedicle axis length was longest at C3, and shortest at C7 for all age groups. Mean pedicle axis length increased with time from 23.6 mm at C3 at 3 years to 33.2 mm at 18 years of age and from 22.4 mm to 32.9 mm at C7 respectively.

Vara also studied the contribution of each component to the overall pedicle axis' length and how this changed by skeletal maturity, expressing it as a percentage. The vertebral body's contribution increased over time from 39 to 45%, the lateral mass remained constant at 29 to 31%, and the pedicle's contribution decreased from 33 to 25%.

Zindrick noted a 70% increase in pedicle axis length between 3 years and skeletal maturity, and that the inter-pedicular distance is 87% of adult size by age 4 years. Minimal growth occurred in the AP diameter after 3 years of age. From this they concluded that the growth of the pedicle was lateral to the spinal canal and did not encroach on the canal itself.[18]

Mean pedicle length increased at C3 from 6.3 mm at 4 years to 7.5 mm by 18 years. The mean pedicle length stayed the same at the level of C7 regardless of age. Pedicle width at C3 increased from 3 mm to 4.3 mm between 3 to 18 years and from 4.3 to 6.1 mm at C7. Kanna *et al*, in their radiological study of paediatric pedicle sizes, found that by the age of 5 years 75% of patients have obtained adult pedicle dimensions.[7]

Antero-posterior cervical spinal canal diameter stayed the same throughout age 3 to 18 years.

There was a statistically significant increase of inter-pedicular distance over time for all vertebral levels. Mean interpedicular distance increased at C3 from 18.1 mm (age 3 years) to 22.3 mm (age 18 years). At C7 this increased from 19.9 mm to 24.9 mm respectively for the same ages.

Wang found that the canal diameter increases at the C2 vertebral level from 12.8 mm at six months to 16 mm at 13 years and remained constant for male patients. For females the values were 12.3 mm and 15.8 mm respectively. At C5 in male subjects the level increased from 12.74 mm to 15.67 mm, and in female subjects from 12.26 mm to 15.22 mm.[15]

The median Torg ratio (ratio of the canal diameter to the vertebral body diameter) at C5 was 1.47 at three months and 1.06 by maturity. In all the studies pedicle width did increase slightly, but no increase in length was noted.

Figure 7: Post-operative CT scan confirms screw position

One can conclude from these studies that if meticulous technique is applied, modern spinal instrumentation can be used in the paediatric cervical spine.

The question of instrumentation removal after successful fusion is vexing. A simplistic answer would be to remove it but in our environment this is logistically challenging. Although we offer to remove the instrumentation once a solid fusion is visible, it is not always done. The advantage is really philosophical in that the child may require further surgery as an adult, when well-buried paediatric instrumentation will be difficult to deal with. We did not see instrumentation migration in our follow-up. We try and avoid cross-links and believe that this allows the instrumentation to move with the slowly expanding anatomical structures.

The use of post-operative supportive orthosis was based on the surgeon's confidence in his fix. Generally it was felt not to be required.

Despite our small sample size it was shown that the use of modern spinal instrumentation in the paediatric cervical spine can be performed safely. No instrumentation-related complications were encountered.

It is the opinion of the authors that it is not mandatory to obtain CT scans pre-operatively to assess if the anatomy is adequate for screw placement. If however CT scans were performed for other indications the anatomy was studied.

In conclusion, the use of modern segmental instrumentation in the paediatric cervical spine is a viable and safe option. However, a thorough understanding of the anatomy and meticulous surgical technique is required to perform the surgery safely.

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