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ORIGINAL ARTICLE

Rigid segmental cervical spine instrumentation is safe and efficacious in younger children

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Abstract

Purpose The utilization of cervical spine instrumentation in the young pediatric patient is not well reported. This study presents outcomes and complications of cervical spine instrumentation in patients who underwent cervical spine fusion surgery before age 10.

Methods Radiographic and clinical data were collected on all patients who underwent cervical spine surgery with instrumentation at a single institution between January 1, 2006, and March 31, 2015. Patients were ≤ 10 years of age at the time of surgery with any cervical spine deformity/injury diagnosis. Patient demographics, details on cervical spine diagnosis, procedural data, imaging data, and postoperative follow-up data were collected.

Results Twenty children met the criteria and were included in the study with a mean follow-up of 10.6 months (3 months–2 years). Initial indication for cervical spine correction surgery included deformity (7 cases), trauma (6 cases), instability (3 cases), stenosis (2 cases), rotary subluxation (1 case), and infection (1 case). Fifteen cases were treated with adult 3.5-mm cervical spine instrumentation, 3 with wiring (1 sublaminar and 2 spinous process), and 2 with cannulated screws. Postoperative immobilization included 16 halo fixation, 3 collars, and 1 CTO. Overall, there were five complications related to the surgery. Two patients who had wiring (1 sublaminar and 1 spinous process) developed a non-union and required revision surgery (1 with cannulated screws and 1 with 3.5-mm segmental cervical spine instrumentation). One patient developed a postoperative infection that required incision and drainage. Five patients developed superficial pin infections for their halo. Two deformity patients experienced neurological complications that were likely unrelated to the cervical instrumentation.

Conclusions Rigid segmental fixation can be safe and efficacious when used in pediatric cervical spine patients. Whether used with halo or orthosis, patients experience minimal to no complications from the instrumentation and achieve successful fusion. Cervical spine wiring had a high risk of non-union requiring revision surgery. The incidence of wound infection was low with one in 20 cases.

Keywords Cervical spine deformity · Cervical spine instrumentation · Pediatric orthopedic surgery · Pediatric spinal implants · Pediatric surgical techniques · Spine fusion surgery

Introduction

Pediatric cervical spine injuries account for up to 80% of pediatric vertebral injuries [1]. Major trauma to the head or neck is the most common mechanism of injury and includes motor vehicle crashes, sports-related injuries, falls, and other sources of blunt trauma [2, 3]. Other conditions may also predispose certain children to cervical spine deformity, including torticollis, down syndrome, Klippel Feil syndrome, neurofibromatosis, and other cervical spine syndromes [4]. Surgical intervention may be required to stabilize the cervical spine [4].

Cervical spinal instrumentation is now commonly used in pediatric spinal deformity correction surgery [4–7]. Despite its widespread use, a paucity of research exists regarding the safety and efficacy of spinal implants in the pediatric population [4–6]. Previously, Hedequist et al. reported on the safety of modern cervical spine implants in children greater than 6 years of age [5]. In a series of 25 cases, three complications

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were reported (1 deep infection, 1 superficial wound infection, and 1 transient radiculopathy) [5]. No implant-related complications were reported and there were no revisions or reoperations related to the implants.

Hwang et al. reviewed literature on pediatric cervical spine fusion and analyzed 914 patients with a mean age of 8.3 years [8]. In 285 occipitocervical fusions, screw instrumentation had a 99% fusion rate, whereas wiring had a 95% fusion rate ($p < 0.05$) [8]. In 181 cervical fusions below the occipitocervical junction, screw instrumentation had a 99% fusion rate and wiring had an 83% fusion rate ($p < 0.05$). Wiring was associated with a higher complication rate in both groups ($p < 0.05$) [8].

Mazur et al. reported on 127 occipitocervical fusions in patients with a mean age of 7.7 years (range 1.2–17.9 years) [9]. Eighty-four percent of the cases achieved successful fusion after one procedure, whereas 15.7% involved surgical failure and required revision surgeries. Four cases involved immediate failure and required immediate reoperation within the first 48 h postoperatively [9].

To date, little literature exists regarding the safety and efficacy of modern spine instrumentation in children younger than 10 years of age. The purposes of this study were to evaluate current surgical techniques used to correct cervical spinal pathologies in the pediatric population and to identify the most common complications associated with cervical spinal implants. The study presents an in-depth analysis of patients' surgical outcomes based on the type of spinal deformity, perioperative and postoperative complications, and loss of correction over time. This institutional review provides new information on the use of spinal implants in the young pediatric population (under 10 years of age) and adds to the evidence in support of the safety of pediatric cervical spinal implants.

Materials and methods

Institutional review board approval was obtained for this study. A retrospective review of all patients who underwent cervical spine surgery with instrumentation at a single pediatric institution between January 1, 2006, and March 31, 2015, was conducted. The electronic medical record system and the ICD-9 codes 733.82, 756.19, 805.00, 805.02, 805.07, 806.00, 839.00, 839.01, and 996.49 were employed to identify eligible patients. Initial indication for cervical spine correction surgery was consolidated into (1) trauma, (2) deformity, (3) rotary subluxation, (4) stenosis, and (5) infection. Patients were ≤ 10 years of age at the time of surgery with any cervical spine deformity/injury diagnosis. Patients who underwent surgery without instrumentation or only in the thoracic or lumbar spine were excluded. The patient demographics, details on cervical spine diagnosis, procedural approach data, fusion levels, size and type of instrumentation, neuromonitoring data, imaging obtained, postoperative immobilization data, and postoperative follow-up data were collected. Reports of complications were collected and included halo pin infections, surgical site infections, instrumentation failure-related complications, and neurological complications. Instrumentation failure-related complications were defined as a complication associated with an implanted screw or wire, such as breakage of wire or incomplete fusion requiring revision surgery. Reports of any failed initial surgery and reoperations were also recorded.

Results

Twenty patients who underwent cervical spine surgery with instrumentation at a single institution between January 1, 2006, and March 31, 2015, were identified. There were 12 female and 8 male patients. Mean age at time of surgery was 5.25 ± 2.47 years (range 1.5–9 years). Initial indication for cervical spine correction surgery included deformity (7 cases), trauma (6 cases), instability (3 cases), stenosis (2 cases), rotary subluxation (1 case), and infection (1 case). The mean follow-up for all 20 cases was 10.6 months (3 months–2 years). Two patients underwent revision surgery, which included repeat cervical fusion with reduction and replacement of screws or wires for breakage.

Procedural data

There were 19 posterior approaches, 1 anterior approach, and 2 combined anterior and posterior approaches. Fifteen cases were treated with adult 3.5-mm cervical spine instrumentation, 3 with wiring (1 sublaminar and 2 spinous process), and 2 with cannulated screws. There were a total of 107 vertebrae fused. The average number of levels fused was 3.6 ± 3.2 (range 1–14); however, the majority of patients (8) had only one motion segment fused and all but 1 patient had ≤ 7 levels fused. The upper instrumented vertebra ranged from occiput to C7 and the lowest instrumented vertebra ranged from C2 to L2 (Fig. 1). Seventeen cases included a decompression. Ten cases included a laminectomy.

Postoperative immobilization included 16 halo fixations, 3 collars, and 1 cervical thoracic orthosis (CTO). The average duration of wear for the halo fixation was 11.8 weeks (range 6–17 weeks). The average duration for the collars was 11 weeks (range 8–13 weeks). The 1 CTO was worn for 6 weeks.

Complication data

In total, there were five complications related to the surgery. Two patients (10%) required a revision surgery, both of which had wiring (1 sublaminar and 1 spinous process) and

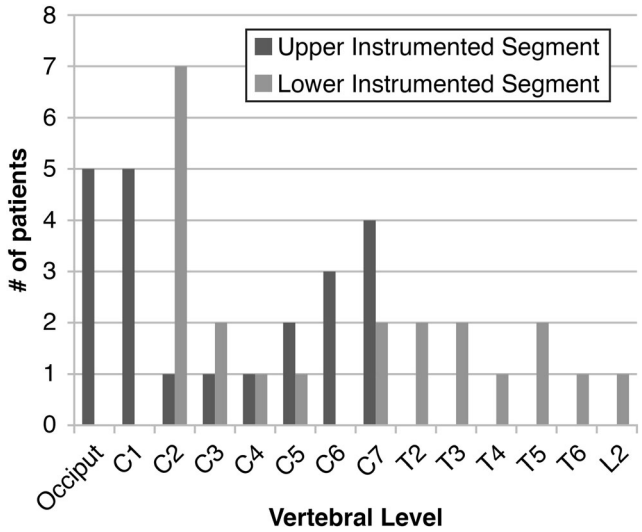

Fig. 1 The upper and lower instrumented vertebra

developed a non-union. One patient developed a postoperative surgical site infection that required incision and drainage. Five patients developed superficial pin infections for their halo.

One deformity patient experienced a perioperative complication that involved a traumatic durotomy. A lumbar drain was placed to manage the CSF leak, CSF cultures were monitored, and the drain was discontinued after 5 days. Another deformity patient who underwent a C7–L2 fusion experienced a postoperative neurologic deficit of no motor or sensory function in the lower extremities. Following revision surgery including thoracic screw repositioning and a wide decompression was performed, and the patient demonstrated recovery with complete resolution of his neurologic deficit by 6 weeks postoperative.

A final neurological complication occurred postoperatively as persistent left arm weakness and loss of finger intrinsic control. This likely resulted from some traction injury to the brachial plexus following correction of a cervicothoracic congenital deformity. There was no indication to suggest this resulted from the cervical spine instrumentation. At 6-month follow-up, the patient was undergoing occupational therapy and wearing a metacarpal phalangeal joint-blocking splint for some improvement in left hand function. Details regarding the procedures and outcomes are found in Table 1.

Discussion

In this report on the safety and efficacy of modern spinal instrumentation in children younger than 10 years of age, the most common indications for surgery were deformity, trauma, instability, stenosis, rotary subluxation, and infection. This was consistent with previous studies that also reported congenital anomalies as the most common surgical indication [4, 8]. Hwang et al. reviewed pediatric cervical spine fusion literature from 2007 to 2011 and reported 55% of cases had congenital abnormality as the indication for surgery [8]. Similarly, Mazur et al. reported congenital spinal anomaly as the most common indication (29.1%) in a study population of 127 occipitocervical fusions [9]. Spine deformity/instability secondary to Chiari malformation was the second most common indication (19.7%), followed by trauma (17.3%), down syndrome (16.5%), skeletal dysplasia (14.2%), and os odontoideum (3.1%). Interestingly, Mazur et al. performed a subgroup analysis and found that congenital vertebral anomaly and skeletal dysplasia patients were at higher risk for instrumentation-related complications and surgical failure [9]. The diversity of diagnoses was also similar to previous studies on pediatric cervical spine instrumentation surgeries [8–11].

In our study of 20 cases, there were five complications related to surgery. Two patients, both of whom had wiring, developed a non-union and subsequently underwent revision surgery. One patient had a surgical site infection requiring incision and drainage, and five had superficial halo pin infections. These findings were consistent with prior studies that reported similar rates and types of complications [5, 8–10]. Hedequist et al. reviewed 25 cervical spine correction surgeries in children greater than 6 years with an average patient age of 12 years and reported complications in 3 cases (1 deep infection, 1 superficial wound infection, 1 transient radiculopathy); no cases of instrumentation failure requiring reoperation were reported [5]. Brockmeyer et al. reported two complications in 24 cases of pediatric cervical spine screw fixation in patients 16 years or younger. One complication involved hardware failure and reoperation [10]. The other complication was a superficial wound site infection that resolved with antibiotic treatment. Hwang et al. reported postsurgical complications in 26% of the 914 patients included in the literature they reviewed [8]. Five percent of the 914 patients had multiple complications.

Hwang et al. also reported surgeries involving wiring were associated with a significantly higher complication rate (50%) than surgeries involving screws (14%) [8]. Menezes reported no harmful effects and a 98% fusion rate in pediatric patients with craniovertebral junction instability who were treated with rigid instrumentation [7]. This was consistent with our data, as both patients who had instrumentation failure and required repeat operation had wiring placed in their initial surgery.

A limitation of this study was the lack of consistent long-term follow-up. One patient transferred care to a different pediatric hospital in the immediate postoperative period and did not return for follow-up at our institution. Two patients died of causes unrelated to their surgery at 13 months and 4 months after surgery. We expect some may have followed up in their home locations, as our institution serves a vacationing population. The small number of patients and the retrospective nature of this study also limited our analyses.

Table 1 Details regarding the indications for surgery, procedures, and outcomes

Study ID	Diagnosis	Surgical indication	Procedure	Complications	Length of follow-up (month)
1	Trauma (MVA)	Occipital-cervical dissociation	1. PSF & Inst. occiput–C2 2. Halo	None	3
2	Osteogenesis imperfecta congenital kyphosis	Severe kyphosis of the cervical thoracic junction	1. PSF & Inst. occiput–T5 2. VCR C7–T2 3. Halo	None	9
3	Klippel Feil syndrome	Congenital cervicothoracic dislocation	1. PSF & Inst. C3–T3 2. VCR C7 & T1 3. Halo	None	24
4	Trauma (ped vs. auto)	C6–C7 fracture dislocation	1. PSF & Inst. C6–C7	None	9
5	Charge syndrome, trauma (fall)	C1/C2 instability	1. PSF & Inst. C1–C2 2. Iliac crest bone graft	1. Superficial infection at halo pin site; Resolved	3
6	Trauma (MVA)	Occipital-cervical dissociation	1. PSF & Inst. occiput–C3 2. Iliac crest bone graft	1. CSF leak; Resolved	6
7	Congenital anomaly of spine	Congenital cervicothoracic dislocation	1. PSF & Inst. C4–T4 2. VCR C6 & C7 3. Iliac crest bone graft 4. Halo	1. Superficial infection at halo pin site; Resolved 2. Neurologic—left arm weakness; Chronic condition, not resolved at latest follow-up	6
8	Chronic C1–C2 rotary subluxation	C1–C2 rotary subluxation	1. PSF & Inst. C1–C2 2. Iliac crest bone graft	None	12
9	Down syndrome	C1–C2 rotary subluxation	1. PSF & Inst. C1–C2 2. Iliac crest bone graft	None	6
10	Trauma (MVA)	C7 burst fracture	1. PSF & Inst. C5–T2 2. Laminectomy C6–T1	None	6
11	Congenital scoliosis, Klippel Feil syndrome	Severe cervicothoracic scoliosis	1. PSF & Inst. C7–T6 2. VCR T4 3. Halo	None	3
12	Congenital scoliosis, Klippel Feil syndrome, VATER syndrome, tethered cord, status post release	Congenital scoliosis	1. PSF & Inst. C7–T5 2. VCR T2 & T3 3. Halo	None	12
13	Trauma (ped vs. auto)	Cervical 6–7 flexion distraction injury	1. Wire cerclage C6–C7	1. Broken wire and non-union treated with revision procedure; Resolved	3
14	Hurler's syndrome	Cervical stenosis with progressive myelopathy	1. PSF & Inst. occiput–C4 2. Iliac crest bone graft 3. Halo	1. Superficial infection at halo pin site; Resolved	24
15	Hurler's syndrome		1. PSF & Inst. occiput–C5 2. Halo	None	24
16	Klippel Feil syndrome	Cervicothoracic scoliosis	1. PSF & Inst. C5–T5	None	12

Table 1 (continued)

Study ID	Diagnosis	Surgical indication	Procedure	Complications	Length of follow-up (month)
			2. Osteotomies (C6–C7, T2–T3, T4–T5)		
			3. Halo		
17	Trauma (MVA)	C2 apophyseal fracture	1. C2–C3 spinous process wiring 2. Iliac crest bone graft	None	3
18	Disseminated coccidiodomycosis, fungal osteomyelitis	C2 coccidiodomycosis infection	1. PSF & Inst. occiput–C2 2. Iliac crest bone graft	None	6
			3. Halo		
19	Trauma (stroller vs. auto)	Occipital-cervical dissociation & C7–T2 intradural hematoma	1. Halo cast 2. Laminectomy C7–T2	None	NA
			3. PSF & Inst. occipital–C2		
20	Down syndrome	C1–C2 instability	1. Removal of instrumentation from C1–C2 2. PSF & Inst. C1–C2 with transarticular screws	1. Superficial infection at halo pin site; Resolved	6
			3. Iliac crest bone graft		
			4. Halo		
21	Trauma (fall)	C1–C2 instability	1. C1–C2 arthrodesis w/ sublaminar wires	1. Incomplete fusion and continued instability, treated with revision procedure; Resolved.	3
22	Escobar syndrome	Severe kyphoscoliosis resulting in respiratory distress	1. PSF & Inst. C7–L2	1. Motor and sensory deficit in lower extremities treated with revision procedure; Resolved.	24
			2. VCR T6	2. Wound infection treated with suppressive abx	

PSF & Inst. posterior spinal fusion and instrumentation

ASF anterior spinal fusion

VCR vertebral column resection

Conclusion

This analysis of 20 cervical spine fusion patients found that the use of rigid segmental instrumentation was both safe and efficacious when used in the pediatric population. Whether used with halo or orthosis, patients experience minimal to no complications from the instrumentation and achieve successful fusion. Cervical spine wiring on the other hand had a high risk of non-union requiring revision surgery.

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Compliance with ethical standards IRB approval was obtained for this study.

Conflict of interest The authors declare that they have no conflict of interest.

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