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Rigid Segmental Cervical Spine Instrumentation is Safe and Efficacious in Younger Children

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Corresponding Author:	Burt Yaszay, M.D. Rady Children's Hospital, San Diego San Diego, UNITED STATES
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	Rady Children's Hospital, San Diego
Corresponding Author's Secondary Institution:	
First Author:	Ana Mitchell
First Author Secondary Information:	
Order of Authors:	Ana Mitchell
	Vidyadhar V. Upasani
	Carrie E. Bartley
	Peter O. Newton
	Burt Yaszay, M.D.
Order of Authors Secondary Information:	
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Abstract:	Background: The utilization of cervical spine instrumentation in the young pediatric patient in 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 post-operative 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 mo to 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 3.5mm cervical spine instrumentation, 3 with wiring (1 sublaminar and 2 spinous process), and 2 with cannulated screws. Postop immobilization included 16 Halo fixation, 3 collars, and 1 CTO. Overall there were 5 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 3.5mm segmental cervical spine instrumentation). One patient developed a postop 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. Level of Evidence: Therapeutic-IV

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We are submitting an original manuscript for review entitled “Rigid Segmental Cervical Spine Instrumentation is Safe and Efficacious in Younger Children”. This manuscript is not under review elsewhere and all authors meet the authorship requirements as stated in the Uniform Requirements for Manuscripts Submitted to Biomedical Journals.

Thank you for the opportunity to submit our work to the Journal of Pediatric Orthopaedics.

Best Regards,

Burt Yaszay, MD

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Ana Mitchell, BA[1]; Vidyadhar V. Upasani, MD[1,2]; Carrie E. Bartley, MA[2]; Peter O. Newton, MD[2]; Burt Yaszay, MD[2]

[1] University of California San Diego, San Diego, CA, United States
[2] Rady Children's Hospital, San Diego, CA, United States

This study was conducted at Rady Children's Hospital, San Diego

Please address all reprints and correspondence to:
Burt Yaszay, MD
3030 Children's Way
San Diego, CA 92123
Phone: (858) 966-6789
Fax: (858) 966-7494
Email: byaszay.rady@gmail.com

*IRB approval was obtained for this study.

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Abstract

Background: The utilization of cervical spine instrumentation in the young pediatric patient in 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 post-operative 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 mo to 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 3.5mm cervical spine instrumentation, 3 with wiring (1 sublaminar and 2 spinous process), and 2 with cannulated screws. Postop immobilization included 16 Halo fixation, 3 collars, and 1 CTO. Overall there were 5 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 3.5mm segmental cervical spine instrumentation). One patient developed a postop 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.

Level of Evidence: Therapeutic-IV

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 or repair injuries (4).

Cervical spinal instrumentation is now commonly used in pediatric spinal deformity correction surgery (4,5,6). Despite its widespread use, a paucity of research exists regarding the safety and efficacy of spinal implants in the pediatric population (4,5,6). 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 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 (7). In 285 occipitocervical fusions, screw instrumentation had a 99% fusion rate, whereas wiring had a 95% fusion rate ($p < 0.05$) (7). In 181 cervical fusions below the occipitocervical junction, screw instrumentation had a 99% fusion rate and wiring had an 83% fusion rate ($p < 0.05$) (7). Wiring was associated with a higher complication rate in both groups ($p < 0.05$) (7).

Mazur et al. reported on 127 occipitocervical fusions in patients with a mean age of 7.7 years (range 1.2 – 17.9 years) (8). 84.3% of the cases achieved successful fusion after one

procedure, whereas 15.7% involved surgical failure and required revision surgeries (8). Four cases involved immediate failure and required immediate reoperation within the first 48hrs postoperatively (8).

To date, no literature exists regarding the safety and efficacy of modern spine instrumentation in children under 10 years of age. The purpose of this study was 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, peri- and post-operative 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, 839.01and 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 $\leq$ 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, post-op immobilization data, and post-op follow up data was 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 to 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 mo to 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, one anterior approach, two combined anterior and posterior approaches. Fifteen cases were treated with adult 3.5mm cervical spine instrumentation, three with wiring (one sublaminar and two spinous process), and two with cannulated screws. There were a total of 107 vertebrae fused (fusion level ranged from occiput to L2). The average number of levels fused per surgery was 4.84 (range 2 – 16). Seventeen cases included a decompression. Ten cases included a laminectomy.

Postop immobilization included 16 Halo fixations, three collars, and one 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 one CTO was worn for six weeks.

Complications Data

In total, there were 5 complications related to the surgery. Two patients (10%) required a revision surgery, both of which had wiring (one sublaminar and one spinous process) and developed a non-union. One patient developed a postop 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 duratomy. A lumbar drain was placed to manage the CSF leak, CSF cultures were monitored, and the drain was discontinued after five days. Another deformity patient who underwent a C7 to 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 results from the cervical spine instrumentation. At six month follow up, the patient was undergoing occupational therapy and wearing a metacarpal phalangeal joint blocking splint for some improvement in left hand function.

Discussion

Apart from this study, no other literature has been published on the safety and efficacy of modern spinal instrumentation in children under 10 years of age. The most common indications for surgery were deformity, trauma, instability, stenosis, rotary subluxation, and infection, respectively. This was consistent with previous studies that also reported congenital anomalies as the most common surgical indication (4,7). 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. Similarly, Mazur et al. reported congenital spinal anomaly as the most common indication (29.1%) in a study population of 127 occipitocervical fusions (8). 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%) (8). 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 (8). The diversity of diagnoses was also similar to previous studies on pediatric cervical spine instrumentation surgeries (7, 8, 9, 10).

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, 7, 8, 9). 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) (5). 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 (9). The other complication was a superficial wound site infection that resolved with antibiotic treatment (9). Hwang et al. reported postsurgical complications in 26% of the 914 patients included in the literature they reviewed (7). Five percent of the 914 patients had multiple complications (7).

Hwang et al. also reported surgeries involving wiring were associated with a significantly higher complication rate (50%) than surgeries involving screws (14%). 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 thirteen months and four 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.

This analysis of twenty 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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