Occipitocervical instrumentation in the pediatric population using a custom loop construct: initial results and long-term follow-up experience

Clinical article

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*Object.* Rigid occipitocervical instrumentation for craniovertebral instability is gaining widespread acceptance for use in pediatric patients; however, most of the instrumentation has been modified from adult-sized hardware. The Wasatch loop system (formerly the Avery-Brockmeyer-Thiokol loop system) is a rigid occipitocervical fixation device designed specifically for use in children. It affixes to the occiput and incorporates either C1–2 transarticular screws or C-2 pars screws. It is preformed and is available in a variety of sizes. The authors describe their clinical experience and long-term follow-up experience with the first 22 patients.

*Methods.* An institutional review board–approved retrospective review of medical records and radiographs was performed for patients who underwent occipitocervical fusion with the Wasatch loop. The mean patient age was 4.9 years (1.2–13 years), and the overall mean follow-up was 4 years (1.5–6.5 years). Six patients had posttraumatic instability, and 16 patients had congenital instability.

*Results.* Twelve patients underwent placement of bilateral C1–2 transarticular screws, 6 patients had placement of a combination of C1–2 transarticular and C-2 pars screws, and 4 patients had placement of bilateral C-2 pars screws. One patient required a halo orthosis; the others were treated postoperatively with a hard cervical collar. All patients had radiographic evidence of solid occipitocervical arthrodesis on last follow-up examination.

*Conclusions.* The Wasatch loop system is a novel internal fixation device for children who have posttraumatic or congenital occipitocervical instability. Successful arthrodesis was achieved in all patients with minimal use of halo orthoses. (*DOI:* 10.3171/2009.10.PEDS09158)

**KEY WORDS** • instrumentation • occipitocervical instability • pediatric neurosurgery

PEDiatric occipitocervical instability can be caused by a wide variety of traumatic, congenital, and developmental problems. Not infrequently, an occipitocervical fusion is required for treatment of instability. Although the techniques used to perform occipitocervical fusions in children are well documented, there continue to be impediments associated with the use of the procedure in children. Some of these difficulties are patient related, including anatomical size constraints, considerations for future growth, and abnormal anatomy. Other difficulties lie in the fact that, previously, no occipitocervical fixation devices were specifically designed for children. Surgeons were forced to use traditional bone and wire constructs, fashion a custom-contoured occipitocervical loop, or use adult-sized hardware. Frequently, these older constructs were augmented with an external halo orthosis. Initial fusion rates using those constructs were suboptimal, ranging from 58 to 90%, depending on the author and the fixation method used.5,8,9,11,13

Supported by biomechanical studies indicating that direct screw fixation techniques are superior to bone and wire constructs,4 we previously reported the use of the Ohio Medical Instruments loop (OMI Surgical Products) and C1–2 transarticular screws for fusion in children with occipitocervical instability.2 In that report, we illustrated that rigid screw fixation for occipitocervical fusion was safe and effective, and we obtained excellent results; however, the OMI fixation system was designed for use in adults and was considered too bulky for patients younger than approximately 8 years of age. Furthermore, this system is no longer available. Other occipitocervical fixation systems suffered from the same problems.12 Current occipitocervical implants are available but are designed for adult patients. Most of these implants have a high-profile
occipital plate that is not well accommodated to the occiput in children. The high profile of the occipital plates may cause skin breakdown or even difficulty in muscle or skin closure during surgery. One pediatric-specific craniovertebral fixation system is the “inside-out” technique using lateral occipitocervical plates, but it uses a T-shaped coupler set into the occiput rather than direct screw fixation.10

Recognizing the insufficiencies in other options of occipitocervical fusion in young children and faced with a 22-month-old patient with atlantooccipital dislocation, we decided to create our own plate. We reasoned that the ideal occipitocervical plating system for children must be specifically designed with patient size in mind. It should come in a variety of sizes; be low profile, easy to use, and biomechanically sound; and avoid the use of a halo device. It should couple to either C1–2 transarticular screws or C-2 pars screws at its base and affix to the occiput at the midline bony keel. We approached ATK Thiokol in Tremonton, Utah, to manufacture the initial plate. After a successful clinical outcome in the first case, we turned to Medtronic Sofamor-Danek to continue the manufacturing process. In this report, we describe our experience and long-term follow-up results using this custom device.

Methods

Patient Population

We retrospectively reviewed the records and radiographs of patients who underwent occipitocervical fusion using the Wasatch plate system (formerly known as the Avery-Brockmeyer-Thiokol loop system) between May 2001 and March 2007. The characteristics of the patient population including age, sex, and length of follow-up were recorded. Each patient underwent careful preoperative neurological assessment and thin-cut CT scanning with multiplanar reconstruction before surgery to determine the anatomical suitability for C-2 pars or C1–2 transarticular screw placement. Postoperative imaging obtained immediately after surgery in all patients included cervical spine CT scans and radiographs. Follow-up imaging included plain cervical spine radiographs obtained at 1 and 2 months after surgery and thin-cut multiplanar CT reconstructions obtained at 3–4 months after surgery. Osseous fusion was defined by radiological evidence of a solid bony bridge from the occiput to the posterior elements of C-2. All radiographs were reviewed independently by a pediatric neuroradiologist. An independent neurosurgeon not involved in the study and with no financial interest in this device or the company that manufactures it reviewed the raw data and has verified the accuracy of the findings.

Surgical Technique

General methods of occipitocervical fusion and transarticular screw placement have been well characterized in the past and will not be described in detail here.1,2,6,7 Briefly, after induction of anesthesia the patient is placed in a pin headholder and turned prone. A posterior occipitocervical incision is made in the midline, and the occiput and upper cervical region are exposed. Preparations are made for placing either C1–2 transarticular screws or C-2 pars screws per our previous report.3

The surgical instrumentation used in this study includes the Wasatch plate and C-2 fixation screws, manufactured first by ATK Thiokol Corp. and now by Medtronic Sofamor-Danek. The Wasatch plate is a preformed 3-mm-thick titanium U-shaped loop that is contoured to lie against the occiput and the posterior aspect of C-2. The occipital portion is held in place with three 4.0-mm outer diameter screws that are passed through predrilled holes (Fig. 1). Each arm of the plate is held against C-2 by either C1–2 transarticular or C-2 pars screws with an outer diameter of 3.5 mm.

The plate comes in a variety of sizes, and the horizontal distance between the 2 arms of the plate defines the plate size (Fig. 1). For preoperative planning purposes, the distance between the C-2 pars interarticularis is measured on a preoperative coronal CT reconstruction to provide a general idea of the correct plate size (Fig. 2). During surgery, the final plate size is determined by measuring the distance between the C-2 fixation screws. To further account for anatomical variation, different plate widths are available in either short, standard, or long lengths to accommodate varying cephalad-caudal distances between the occiput and C-2. A minor amount of flexion-extension

![Fig. 1. Aerial drawing of the Wasatch plate showing configuration of screw holes into the occiput and C-2 pars. The arrowed line represents the distance between the screw holes and C-2, and corresponds to the plate size in millimeters.](image-url)
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manipulation of the patient’s craniocervical junction is usually necessary under direct fluoroscopic vision to arrive at the final, neutral head position for the patient and ensure correct positioning of the plate.

The C1–2 transarticular or C-2 pars screws traverse the holes at the bottom of the plate arms. The holes are countersunk to accommodate the screw head. The occipital screws, placed through the holes at the closed end of the plate, are fully threaded with an outer diameter of 4.0 mm and vary in length from 6 to 10 mm, with a longer screw typically placed in the midline bony keel of the occiput. Posterior iliac crest or rib autograft is the preferred substrate for bone graft material. The graft material is held in place with a multistranded titanium cable on the lower part and a small fragment screw through the upper part of the graft into the occiput (Fig. 3).

Results

Patient Demographics

A total of 22 patients underwent occipitocervical fusion using the Wasatch plate system during the defined study period (Table 1). There were 15 boys and 7 girls with a mean age of 4.9 years (1.2–13 years) and a mean time to last clinical follow-up of 20.2 months (range 3–74 months) (Tables 1 and 2). The mean overall time to follow-up was 48.2 months (range 17–79 months).

Indications for Surgery

Traumatic atlantooccipital dislocation was the indication for surgery in 6 patients. Sixteen patients had a congenital disorder resulting in significant atlantooccipital instability. Eight of these patients had Down syndrome, and 1 each had Jeune, Kniest, and DiGeorge syndromes. Three other patients had nonsyndromic congenital abnormalities. The remaining 2 patients had undergone previous fusion attempts at outside institutions that failed.

Instrumentation and Arthrodesis

Plates of a variety of sizes were implanted based on patient size (Table 1). In 12 patients, bilateral C1–2 transarticular screws were placed. Six patients underwent unilateral C1–2 transarticular screw placement with a C-2 pars screw on the contralateral side, and 4 patients underwent placement of bilateral C-2 pars screws. Fifteen of the patients had placement of iliac crest autograft bone,
and 7 patients received rib autograft. Demineralized bone matrix was used in an onlay fashion in all patients. Recombinant bone morphogenetic protein was not used in any patient.

Only one patient required the use of a halo orthosis device. All other patients were placed in a hard collar postoperatively for 2–3 months. All 22 patients underwent successful arthrodesis, with a mean time to fusion of 4.3 months (range 4–6 months) (Table 2). There were no cases of postoperative kyphotic or swan-neck deformity, no asymmetrical (vertical or lateral) growth, and no juxtafusion pathological conditions.

**Surgical Complications**

Three patients in our series had complications that required additional surgery. The first patient (Case 2) was a 3-year-old child with spondyloepiphysial dysplasia. A prototype Wasatch plate that used open ends on the arms of the loop rather than holes was implanted. The procedure was without incident, but at 1-month follow-up the screw heads had pulled out of the open ends of the loop. The patient underwent reoperation. A new Wasatch loop with closed holes at the end was implanted, the pars screws were removed, and bilateral C1–2 transarticular screws were placed. The patient was placed in a halo orthosis device. Postoperative radiographs revealed a solid fusion at 3 months.

The second case (Case 17) involved an 18-month-old girl who had a congenital abnormality with occipitocervical subluxation. On the postoperative CT scan, the C-2 translaminar screw was noted to be impinging into the canal. The patient was taken back to the operating room the next day, and the screw was removed and replaced with a trans-
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and effective device for managing occipitocervical instability in the pediatric population. In this initial group of patients with follow-up, a 100% successful arthrodesis rate was achieved with minimal use of halo orthoses. The Wasatch plating system has the following advantages over previous devices: 1) The device is preformed to fit in a low-profile manner between the inferior occiput and posterior aspect of C-2 and requires little, if any, bending before placement. 2) The device is available in a variety of sizes, accommodating patients from approximately 18 months of age to adulthood. 3) It can be anchored to C-2 with C-2 pars, C-2 translaminar, or C1–2 transarticular screws. 4) It uses the thick bone of the occipital keel for direct occipital screw fixation, thereby providing excellent stability and pullout strength.

In the past, pediatric spine surgeons treating patients with occipitocervical instability have had to use either bone and wire fusion constructs (augmented by a halo orthosis) or adult-sized spinal hardware. The Wasatch plate is the first occipitocervical instrumentation device specifically designed and sized for pediatric patients. In fact, the device evolved from the effort to provide internal stabilization in a 22-month-old boy who required fusion for occipitocervical instability due to traumatic atlantoaxial dislocation. From there, various technical modifications, such as placing the occipital screw holes in a horizontal array and lengthening the plate arms, have expanded its usefulness to patients with variations in size or bone anatomy.

The graft material used in pediatric occipitocervical fusions can make a big difference in determining the success of the arthrodesis. Posterior iliac crest autograft is the preferred substrate for bone graft material. It is readily available and can be harvested with minimal morbidity, and its size is well suited to the fusion site. In extremely young children, or in patients in whom multiple fusion attempts have been made, rib graft may be used. It is also easily harvested with minimal morbidity and gives excellent structural support. Several of the patients had demineralized bone matrix placed as part of their fusion construct; however, we cannot make a recommendation as to its benefit.

Postoperative follow-up monitoring is extremely important in this patient population. Plain lateral cervical spine radiographs should be obtained at regular postoperative intervals to evaluate the hardware. At 3–4 months after surgery, a thin-cut CT scan should be obtained to evaluate the fusion. If the fusion has not taken yet but the instrumentation is in good position, it is likely that the fusion eventually will succeed with more time. Additional CT scans obtained at 2- to 3-month intervals will usually document successful fusion (Fig. 4). Patients should be monitored yearly with plain lateral cervical spine radiographs to assess alignment and monitor for juxtafusion pathological conditions. Concern has been raised regarding the long-term effects of posterior fusion in the skeletally immature spine, both for asymmetrical growth and for internalization of the hardware. There was no evidence of vertical growth retardation across the fusion construct, likely because vertebral remodeling appears to occur within and around the fusion mass. In addition,
there has been no evidence of intracranial migration of the occipital screws.

Occipitocervical fusion does necessitate a significant restriction of mobility of the cervical spine, with a loss of 20–40° of flexion-extension and up to 60° of rotation, and this restriction should be taken into account in the risk-benefit assessment of the procedure. No additional restriction of mobility is caused by this technique compared with other techniques, and the additional strength obtained from incorporating transarticular screw placement may prevent the need to incorporate lower fixation points and restrict mobility even further. The risk-benefit assessment should take into consideration the finding of a 14% reoperation rate/first-procedure failure rate using this device. Although new technology and technique allow this operation to be more successful than ever, it is still undertaken in a very challenging patient population.

Conclusions

The Wasatch plate system is a novel internal fixation device for use in pediatric patients with occipitocervical instability. It is designed for patients with normal anatomy and posttraumatic or congenital occipitocervical instability. We have demonstrated that it is a safe and effective device for managing occipitocervical instability in the pediatric population. Initial experience is encouraging, with a 100% successful arthrodesis rate and minimal use of halo orthoses.

Disclosure

Drs. Avery and Brockmeyer are patent holders of the device described in the paper but receive no financial benefit from the patent. Dr. Avery is a common stockholder in Medtronic.

Acknowledgment

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