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CASE REPORT

Extreme proximal junctional kyphosis—a complication of delayed lambdoid suture closure in Hajdu–Cheney syndrome: a case report and literature review

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Abstract
Purpose To describe the manifestations, surgical treatment, and potential complications of Hajdu–Cheney syndrome (HCS), and the management of these complications.
Methods The clinical presentation, management and outcome of HCS with severe osteoporosis and open skull sutures is presented, together with a literature review.
Results A 20-year-old female with HCS underwent posterior occipitocervical fusion for symptoms of progressive basilar invagination. Because of delayed lambdoid suture closure, the stiff fusion construct lead to increased suture distraction, most notably in the upright (suture-open) position, with relief in the supine (suture-closed) position. This was successfully remedied with extension of the fusion construct anteriorly over the skull vertex to the frontal bones.
Conclusions In patients with HCS and other conditions with delayed suture closure, the surgeon must be cognizant of the presence of mobility at the suture lines, and consider extending the fusion construct anteriorly over the skull vertex up to the frontal bones. Because of significant osteoporosis in these syndromes, multiple fixation points and augmentation with bone graft are important principles.

Keywords Hajdu–Cheney syndrome · Platybasia · Calvarial sutures · Wormian bones · Cranial nerves

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Introduction

Hajdu–Cheney syndrome (HCS) is a rare autosomal-dominant disorder with less than 100 cases reported in the literature [1–3]. Sporadic cases are more common than inherited mutations [4–6]. It is also known as essential osteolysis, cryptogenic osteolysis, acro-osteolysis, acrodystrophia universalis hereditaria and familial osseous atrophy [7].

It is characterized by acro-osteolysis of the distal phalanges (present in 84% of cases) and severe osteoporosis (present in 60%) [8]. As a result of severe osteoporosis and fractures, there is increased morbidity and mortality [1]. Other key features include any three of the following seven characteristics: wormian bones (67%) or open skull sutures (54%), platybasia/basilar invagination (53%), premature loss of teeth (65%, resulting in resorption of alveolar bone), micrognathia, coarse hair, midfacial flattening, and short stature (51%) [8–10]. There may be urinary anomalies, cardiac malformations and hearing loss as well [5].

In this report, we describe the initial treatment of HCS and the unique complications that followed, as well as the subsequent novel surgical intervention to address these complications.

Case report

A female patient was diagnosed with HCS after presenting with bilateral hip dislocation at the age of 1 year, and later multiple cervical compression fractures and cranial nerve palsies. At age 20 years, she presented with severe osteoporosis with multiple compression fractures, basilar invagination with brainstem compression, hydrocephalus, and mid-cervical kyphosis and thoracic lordoscoliosis (Fig. 1). She had become increasingly symptomatic over

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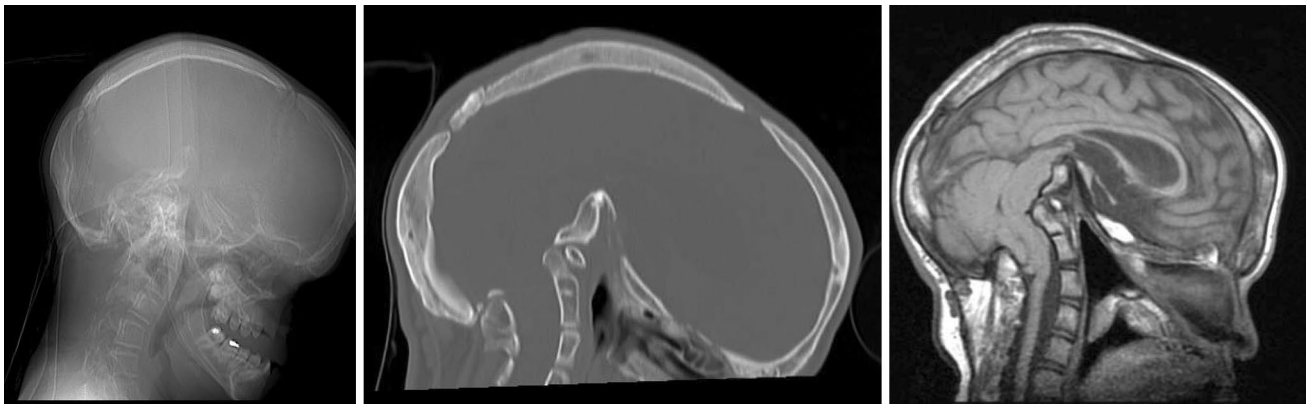

Fig. 1 Lateral CT scout view (left), sagittal CT scan (center) and sagittal FSE T1 MRI image showing basilar invagination. The lambdoid suture remains closed. Wormian bones are visible within the suture

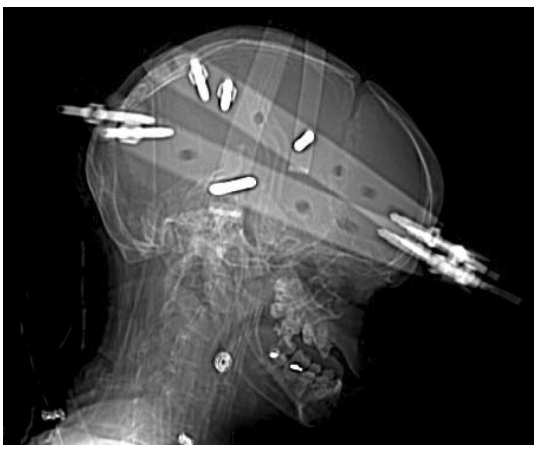

Fig. 2 Lateral CT scout view showing mild lambdoid suture diastasis following halo vest placement

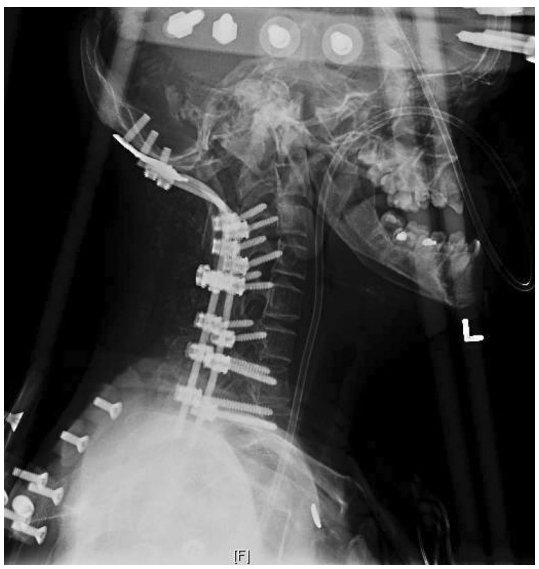

Fig. 3 Increased lambdoid suture diastasis is seen following instrumented posterior occipitocervical fusion

the last 4 years, with loss of hearing (worse on the left), obstructive sleep apnoea (OSA) treated with continuous positive airway pressure (CPAP), and posterior cervical pain with coughing. Past medical history includes pulmonary hypertension and allergic rhinitis. She was a college student at the time of presentation.

She was initially placed in halo traction but this had to be discontinued because she developed transient motor weakness (Fig. 2). She then underwent suboccipital craniectomy and posterior cervical laminectomy of C1–C4 with decompression of the spinal cord and brainstem, posterior osteotomies of C3–T1, and occiput to T2 instrumented fusion with a posterior plate (Harm's technique), lateral mass and pedicle screws (Mountaineer OCT, Synthes, Paoli, PA, USA) augmented with structural allograft rib struts and demineralized bone matrix putty, bone morphogeneic protein (BMP), and re-application of the halo vest (Fig. 3).

Postoperatively, she had improvement in swallowing and hearing, but developed left lower motor neuron facial palsy for which she was treated with tapered steroids for a diagnosis of Bell's palsy.

She returned 2 months later for removal of the halo vest and transition to a cervico-thoracic orthosis. Following halo removal, she complained of worsening hearing bilaterally, right ear pain, and posterior headache. She underwent emergent computed tomography (CT) and magnetic resonance imaging (MRI) which revealed no acute intracranial abnormalities, and no significant changes compared to previous exams except for post-operative changes and visible instrumentation. Imaging further demonstrated un-kinking of the brainstem, and release of cerebellar compression.

Three days after halo removal her mother noted increased speech effort and increasingly "wet", garbled speech. There was also increased snoring during sleep, and regurgitation of food. After sitting upright for 3–4 min, she would experience sharp pain at the angle of her right mandible and marked nausea. Eating was more difficult with the halo off. The mother also noted a change in the patient's facial features.

Radiographs of her skull were obtained in the supine and sitting upright position (Fig. 4). These radiographs demonstrated lambdoid suture diastasis, with increased diastasis in the upright position, and decreased diastasis when supine. This was consistent with anterior-caudad translation of the parietal bones away from the occipital bone when upright, and reduction when supine. There was also downward frontoparietal sag in the upright position, accounting for a change in facial features.

Three-dimensional models of her skull were created from CT scans. She was then placed in halo cervical traction and later taken back to the operating room for revision surgery. The posterior hardware was exposed and the decompression was explored and found to be satisfactory. A burr was then used to create long troughs in the parietal bones on either side. Titanium rods were contoured to fit into these troughs, affixed to connectors, and connected to the main construct. Titanium mesh (Synthes, Paoli, PA, USA) was then placed over the rods and used to connect the frontal and parietal bones. Narrower strips of mesh were used to connect the temporal and parietal bones. The mesh was fixed with multiple small titanium screws. The construct was augmented by onlay strips of allograft rib and demineralized bone matrix.

At 18 months after the revision surgery, she continues to do well with resolution of cranial nerve symptoms. Radiographs demonstrate intact hardware (Fig. 5).

Discussion

The etiology of HCS is thought to be mutations in exon 34, the terminal exon of the NOTCH2 gene [1, 2]. However, the exact mechanism of increased localized bone resorption and generalized osteoporosis remains unknown [2]. Focal acro-osteolysis is associated with neovascularization, inflammation and fibrosis, suggesting a focal inflammatory process [1, 11]. At other sites, the mechanism is less clear. Tissue biopsies have shown increased osteoclasts with normal/increased osteoblasts, suggesting increased bone turnover [1, 11, 12]. Mast cell infiltration has also been observed [11, 12]. But it is not known if bone loss is a result of increased bone resorption, decreased formation, or both.

Our patient demonstrated some of the distinctive features of HCS: marked platybasia, open skull sutures, micrognathia, midfacial flattening, short stature, kyphoscoliosis decreased bone density and compression fractures.

Surgery was indicated because of the progression of cranial nerve symptoms arising from cranial nerve stretching, a consequence of platybasia [13]. Left untreated, platybasia in HCS generally occurs after 10 years of age, and is known to become more serious with age. Platybasia is responsible for basilar invagination with ascending luxation of the odontoid process [5, 8]. Hydrocephalus is the most common complication [5]. Other complications include central respiratory arrest, syringomyelia and sudden death [1, 2, 6, 8].

Our patient's symptoms remained stable following instrumented occiput-to-T2 fusion while in the halo vest, but rapidly escalated following halo vest removal. This is because the occiput-to-T2 construct united the cervical spine and occipital bone as one unit, while the halo vest kept the other calvarial bones reduced to the surgical construct at the lambdoid suture. Following halo removal, the skull was able to float freely and translate forward, away from the stiff

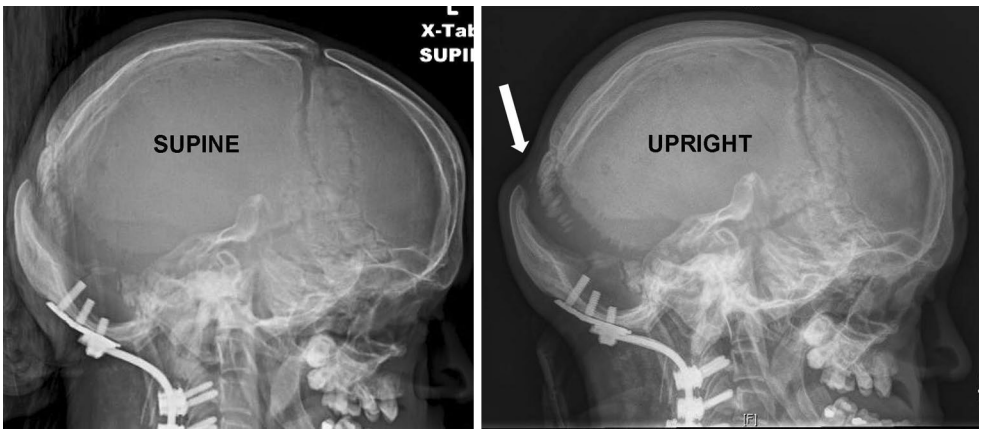

Fig. 4 Following halo vest removal, dynamic instability is seen. Supine (left) and upright (right) radiographs demonstrate increased lambdoid suture diastasis in the upright position compared with the supine position

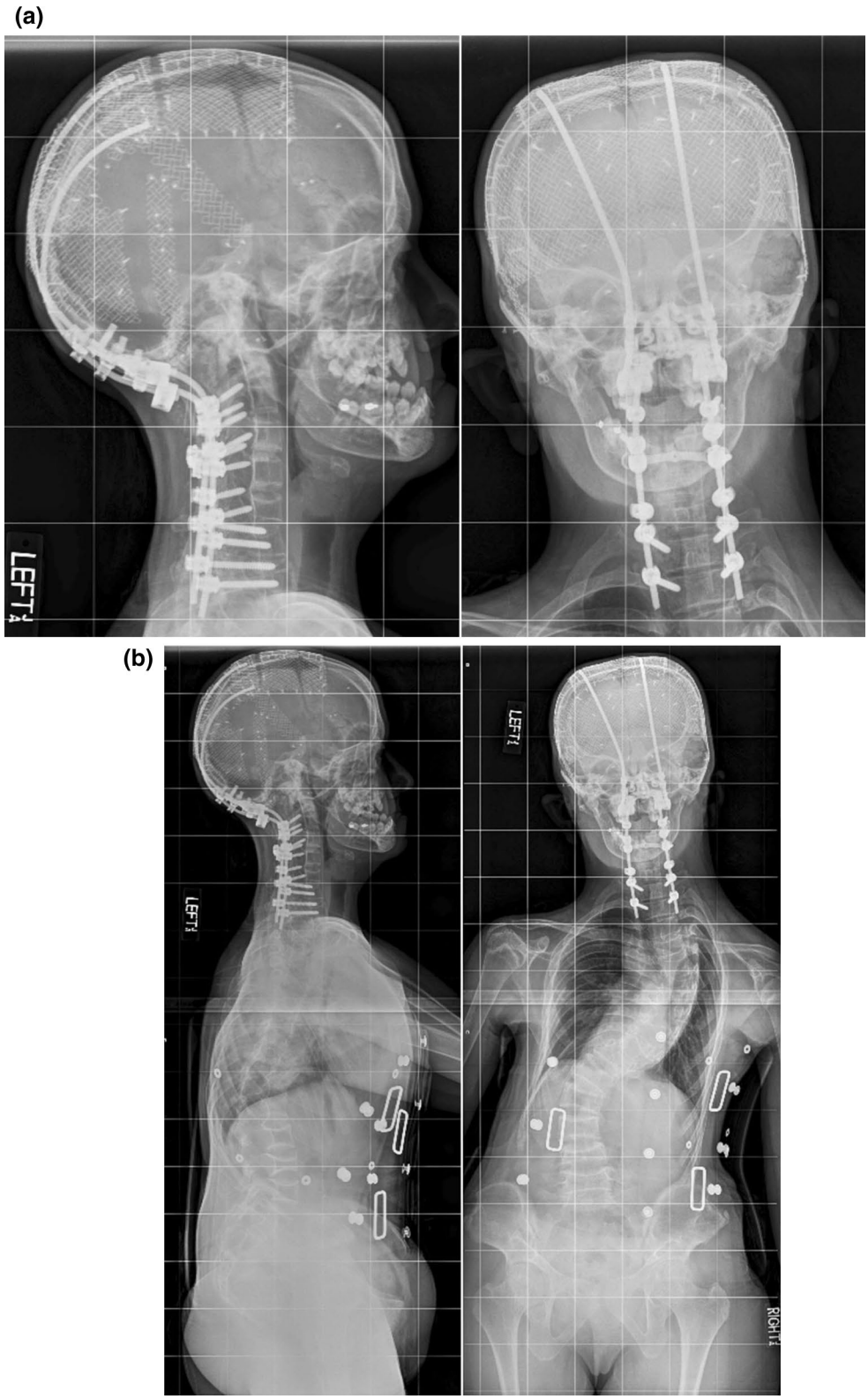

Fig. 5 Standing AP and lateral radiographs of the cervical spine and skull (**a**) and entire spine (**b**) at 18 months from the revision surgery show intact hardware and satisfactory alignment of the instrumented region

occipital-cervical construct, especially in the upright position, because of the unfused lambdoid suture. This aggravated traction neuropraxia of the cranial nerves arising from the pons and medulla, and increased brainstem kinking from foramen magnum impression, and basilar invagination [2, 3]. The symptoms and central involvement are as follows: Periaural pain (CN VII, pons), hearing loss (CN VIII, pons), snoring (CN IX, medulla), hoarse, low-pitched voice (vocal cords, superior laryngeal nerve from CN X, medulla), choking (CN X, medulla), nausea and dyspepsia (CN X, medulla), vomiting (vomiting center, medulla) [2].

Management must include addressing the open calvarial sutures. While replacing the halo vest is an obvious option, it is but a temporary solution. Definitive measures must include closure of the lambdoid gap and instrumented fusion. In addition, because frontoparietal distraction across the coronal suture and forward nutation of the frontal bone was also noted radiographically, there was concern that a stiff fusion construct stopping at the parietal bones might aggravate distraction at the coronal suture. The fusion construct was thus extended anteriorly to involve the both frontal bones, with a mesh plate spanning the anterior fontanelle, coronal, metopic and sagittal sutures, anchored to both frontal and parietal bones.

Some authors warn against occipitocervical fusion because of the possibility of posterior fusion creating a "hinge", allowing for forward inflection of the anterior skull base, and potentially worsening anterior compression of the encephalic trunk [5, 14]. Our patient is a living example of how this occipitocervical fusion "hinge" can lead to distraction and creation of a proximal junctional kyphosis-like phenomenon across the unfused sutures and aggravation of neurological complaints. These same authors advise Milwaukee bracing, over posterior fusion, as the only means of slowing basilar invagination while the ossification centers ossify [5, 14, 15]. Our 20-year-old patient demonstrated symptom progression even in early adulthood in spite of halo immobilization, making surgical intervention inevitable.

Because of severe osteoporosis associated with HCS, we employed multiple fixation points (at least 3 fixation points superior and inferior to the apex of deformity) and long instrumentation constructs to reduce the risk of implant pullout and loosening [16, 17]. This was also heavily augmented with structural and morcelized bone graft.

Resolution of cranial nerve symptoms in our patient is testament to the success of this novel but highly complex technique. In general, there is no specific treatment for HCS because of the rarity of this condition. However, other authors have described treatment of HCS with neurological complaints related to basilar invagination. The spectrum of surgical intervention includes foramen magnum decompression with occipital craniectomy, C-1 laminectomy, posterior cervical fusion and ventriculoperitoneal shunt placement [5, 18]. For large basilar invaginations, anterior transoral decompression with occipitocervical internal fixation has been described. However, the oral anomalies of HCS, especially mandibular hypoplasia and midfacial flattening can considerably limit the utility of this approach [3, 5].

In HCS, adjunct measures have been attempted to increase bone mineral density and reduce the risk of fractures. Anecdotal cases treated with bisphosphonates and/or teriparatide have been reported, but there is no convincing evidence that either is beneficial [19, 20]. While animal models suggest that teriparatide might increase post-operative fusions rates, there is insufficient literature to support their use in humans for this purpose [16]. Similarly, vitamin D therapy is also recommended, although the benefit remains unproven [2, 21].

Conclusions

In conclusion, this case illustrates the highly complex surgical problems arising from occipitocervical fusion in a patient with HCS. The clinical course of HCS is determined by the development of neurological complications related to basilar invagination [3, 12]. While a cursory examination may suggest that occipitocervical fusion can provide an easy solution to increased cervical and occipitocervical mobility, the surgeon must be cognizant that in HCS, mobility does not stop at the craniocervical junction, but extends cephalad to involve the calvarial sutures. Comprehensive surgery must then involve a multi-disciplinary team and a continuous fusion construct arcing over the vertex to reach the frontal bones bilaterally. In addition, because of significant osteoporosis, multiple points of fixation are necessary to minimize the risk of screw pullout and loosening.

Compliance with ethical standards

Conflict of interest None of the authors has any potential conflict of interest.

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