

SPINAL CORD INVOLVEMENT IN HERITABLE SKELETAL DYSPLASIAS

A.B. TODOROV (1)*, S.E. KOPITS (2), G.B. UDVARHELYI (3)

(1) Division of Medical Genetics, Department of Medicine,
The Johns Hopkins University School of Medicine

(2) Department of Orthopedic Surgery and Pediatrics,
The Johns Hopkins University School of Medicine

(3) Department of Neurological Surgery, Johns Hopkins University School of Medicine,
Baltimore, Maryland, USA

The neurological complications encountered in selected heritable skeletal dysplasias are described. The neurologic deficit may be caused by static (localized spinal cord compression; small spinal canal syndrome) or dynamic (atlantoaxial dislocation) involvement of the spinal cord. The neurologic symptoms have to be recognized early, as neurosurgical management is possible and may definitely improve the neurological condition.

The site of neurological involvement in heritable disorders of connective tissue may differ and may show variable degree of severity. Neurological involvement may be expressed, for example, as mental deterioration in mucopolysaccharidosis I (Hurler's syndrome); as median nerve compression in spherophakia brachymorphia syndrome (Weill-Marchesani syndrome); or as profound muscular wasting in diaphyseal dysplasia (Camurati-Engelmann's progressive diaphyseal dysplasia).

In the past few years neurologists have become interested in the neurological evaluation of heritable skeletal dysplasias, particularly for two reasons.

1. Neurological examination of persons affected with such conditions offers special challenges to the examiner. One must understand the natural history and the resulting disability as it relates to the clinical findings: dislocation of the hips in spondyloepiphyseal dysplasia congenita may contribute to a delay in motor milestones of development. There are technical problems, such as how to elicit a patellar reflex in an achondroplastic child because of ligamentous laxity. Also previous orthopedic procedures may make it difficult to evaluate correctly the neurological status.

2. The more important reason is the possibility of surgical treatment.

We would like to discuss in particular spinal cord involvement in selected heritable skeletal dysplasias. It is possible to classify the neurological deficit as caused by a static or a dynamic compression of the spinal cord within the medullary canal. Examples of static

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types of involvement are the following: (a) localized spinal cord compression (e.g., by wedged vertebral body); and (b) the constitutionally small spinal canal (e.g., achondroplasia).

The typical example of dynamic compression of the spinal cord is given by the atlantoaxial dislocation related to an odontoid process malformation and ligamentous laxity at the atlantoaxial level (e.g., Morquio's syndrome).

The distinction between the different types of involvement is of practical importance. In the first case would become necessary to remove of the posterior portion of the wedged vertebra which is determining the ventral compression of the cord; in the second, an extensive laminectomy is indicated; while in the third a reduction of the atlantoaxial relationship and posterior occipitocervical fusion is necessary.

The discussion of the neurological symptomatology and neurosurgical management in heritable skeletal dysplasias is based on the patients we have had the opportunity to follow up at the Moore Clinic at Johns Hopkins Hospital.

LOCALIZED SPINAL CORD COMPRESSION

It is interesting to note that the scoliosis developing in osteogenesis imperfecta or Marfan's syndrome is often severe, yet it is not accompanied by neurological deficit. In other conditions, kyphosis may be associated with ventral compression of the spinal cord if there is a wedged vertebra protruding into the spinal canal. This was observed in a case of diastrophic dwarfism necessitating surgical decompression. Thoracolumbar kyphosis is normally observed in achondroplastic infants. In the vast majority of cases, it decreases spontaneously by the time they begin to walk. However, we have observed its persistence and progression in isolated cases and cord compression may occur. Since in kyphosis we are dealing with the localized (ventral) compression of the spinal cord, the logical procedure is to remove the posterior portion of the spinal vertebra which encroaches ventrally upon the cord. In the above mentioned case of diastrophic dwarfism, however, a laminectomy was performed with excellent recovery.

Spinal cord compression by bony overgrowth has been described in cases of vitamin-D-resistant rickets (Yoshikawa et al. 1968) although it was not observed in our series of 12 cases nor in an extensive survey conducted in North Carolina.

CONSTITUTIONALLY SMALL SPINAL CORD

Out of 393 achondroplasts registered at the Moore Clinic, 9 have undergone neurosurgery for a small spinal canal syndrome.

Achondroplastic dwarfs are the prototypes of individuals who develop the small spinal canal syndrome. The anatomical basis for the spinal cord involvement is the spade-shaped constriction of the canal related to a premature closure of the ossification centers of the vertebral pedicles (neurosomatic growth plate). The constriction may be demonstrated in lateral X-rays of the spine by the shortness of the pedicles and in antero-posterior view by the diminished interpedicular distance (I.P.D.). Measurement of the I.P.D. was done in symptom-free achondroplasts and in achondroplasts with neurological deficit severe enough to justify a decompressive laminectomy. The I.P.D. of the lumbar area was significantly smaller (Mann-Whitney U test) in the surgical series than in the nonsurgical cases.

Neurologically, it is possible to identify three types of deficit: (1) compression of the nerve roots, (2) lower spinal cord compression, and (3) compression at the cervical spinal canal level and the foramen magnum.

1. *Radicular symptomatology* is characterized by: (a) weakness of dorsiflexion and/or eversion of the foot; occasionally weakness of plantar flexion of the foot; in other cases the quadriceps femoris is involved with weakness of extension and "giving away" of the knee; (b) hypoactive or absent osteotendinous reflexes of the lower extremities, the cutaneous plantar reflex being in flexion; (c) complaints by the patient of painful paraesthesias. Presence of mild sensory changes, ranging from patchy loss of cutaneous sensation to clearly delineated radicular hypoesthesia was observed. Frequently there was definite proprioceptive loss. Although the radicular deficit most frequently involves the L5/S1 roots bilaterally, followed by the L3 and L4 roots, it may also involve the entire cauda equina with sphincter disturbances. Two achondroplastics had severe radicular involvement of the cervical.

2. *Lower spinal cord compression* is characterized by: (a) muscular deficit ranging from mild paraparesis to severe spastic paraplegia; (b) presence of hyperactive osteotendinous reflexes, clonus, and cutaneous plantar reflex in extension; (c) superficial sensory deficit usually below the lower costal margin (T₉-T₁₀ level), preserving often the lowest sacral dermatomes; and (d) marked deficit of posture and vibratory sensation. The sensory deficits may be explained by the anatomical observations of a lower spinal cord compression by Donath and Vogl (1925). They have described a deep indentation of the posterior columns from the periphery and slight myelin degeneration of both lateral columns at the level of the cord compression. Ascending degeneration of the posterior columns and descending degeneration of the pyramidal tracts was observed starting at the point of cord compression.

3. *Compression at the upper spinal canal level and foramen magnum* is difficult to characterize. The clinical picture is vague except in the advanced stages of the disability, and it is different from what a classical neurologist may expect. The symptomatology described below is derived from our experience of 2 cases and of the 4 cases described in the literature (Hancock and Phillips 1965, Cohen et al. 1967, Nelson 1970): (a) tetraparesis, usually spastic (sometimes flaccid), manifested by osteotendinous hyper-reflexia, spasticity, clonus, and a positive Babinski sign; (b) absence of a definite pattern of sensory changes; (c) an accident preceding the appearance of symptoms (in 2 cases); and (d) occipital headache (in 1 case) and nystagmus (in 1 case).

Symptoms due to a small foramen magnum may appear in the first years of life and one may erroneously attribute the delay in ambulation to the usual delay in motor milestones observed in achondroplasia. It is therefore necessary to be cautious in accepting any symptomatology as "developmental delay". Early surgery may provide significant improvement. Cohen et al. (1967) have described a 4-year old child who improved after surgery, and three years later this child was said to be free of any neurological deficit. The small foramen magnum syndrome may be responsible for a communicating hydrocephalus.

The anatomical lesions of compression at the upper cervical canal level and the foramen magnum have been recently observed in a homozygous form of achondroplasia (Yang 1973). Segmental malacia of the upper cervical cord was observed at the level of a hypoplastic foramen magnum. Histologically, there was diffuse gliosis and vascular proliferation of mod-

erate degree. Large swollen and vacuolated axons were present. The gray matter was poorly demarcated and only a very few, shrunken neurons were seen in the anterior horns.

The distinction between the three types of spinal cord involvement in achondroplasia has practical interest in terms of operative results. After pooling the 7 patients operated on at the Johns Hopkins Hospital (GBU) with the 29 referred to us by other neurosurgical centers or sufficiently well described in the literature, the operative results were as follows: the decompressive laminectomy gave definite improvement in 13 out of 15 cases of radicular involvement. In the group of spinal cord involvement, surgery was beneficial to over half of the patients. In the group with upper cervical canal compression 2 out of 5 patients improved postoperatively. Of the remaining 3, 1 died during surgery and there was a worsening of the clinical picture in the other 2.

Decompressive laminectomy has to be extensive, especially in the group with lower spinal cord involvement, to avoid a recurrence of the neurological symptomatology. One extreme case needed a laminectomy from C4 to the sacrum. Lateral foraminotomy may be combined with laminectomies in the treatment of the radicular type of compression.

Few achondroplasts developed symptoms of cord compression shortly after a laminectomy at a level higher than the previous one. At surgery, the neurostructures were found protruding through the previously decompressed area. The borders of the window appeared to be constricting the underlying cord in a relative sense. In one case a fibrous string was present deep to the first complete neural arch and this was obviously adding to the compression. It is possible therefore that the boundaries of the laminectomy defect may turn into compressive factors themselves. This would explain why in achondroplastic dwarfs a first laminectomy may have to be followed by others.

In deciding the extent of the laminectomy it is necessary to outline precisely the upper level of the spinal canal stenosis. Pantopaque myelography performed by lumbar puncture was in general useless. The dye accumulates against the posterior border of the scalloped vertebral bodies and does not permit correct visualization of the stenosis. Introduction of the dye through a right-ventricle puncture seems to be far less dangerous than suboccipital puncture and has given more precise information about the level of compression.

It should be noted that we have *not* observed spinal instability consequent to extensive laminectomies in achondroplasts if the facets were spared at surgery. None of the 7 achondroplasts operated on in our hospital needed orthopedic stabilization procedures. A brace was recommended in cases of extensive laminectomies when the patient became active.

ATLANTOAXIAL DISLOCATION RELATED TO ODONTOID-PROCESS MALFORMATION AND LIGAMENOUS LAXITY AT THE ATLANTOAXIAL LEVEL

The anatomical basis of this complication is found in the bony dysplasia of the odontoid process. Out of 29 patients seen in the Moore Clinic with such dysplasia, 19 were found to have aplasia of the odontoid process, 3 hypoplasia, and 7 a congenital detachment of the odontoid process (Perovic et al. 1973). A key contributing factor in the appearance of neurological symptoms was ligamentous laxity associated with the odontoid process dysplasia. Atlantoaxial dislocation may occur in several hereditary skeletal dysplasias:

- a. Mucopolysaccharidosis IV (Morquio's syndrome) and non-keratan-sulfate-excreting Morquio's syndrome (13 cases)
- b. Spondyloepiphyseal dysplasia congenita (3 cases)

- c. Pseudoachondroplastic dysplasia (4 cases)
- d. Metaphyseal chondrodysplasia, McKusick's type, formerly cartilage-hair hypoplasia (3 cases)
- e. Spondyloepiphyseal dysplasia and other conditions such as Scott's syndrome (Scott 1971), Dyggve-Melchior-Clausen syndrome (Naffah 1973), or unclassified forms of dwarfism.

Myelopathy was present in all cases of Morquio's syndrome studied by us. The first symptoms appear by the age of 5 or 6 years and are manifested by a decrease in the endurance to physical exercise. The patients walk shorter distances than before, change their pattern of activities, play more sitting games, avoid walking through the snow. They are unable to ambulate without help in the early teens and frequently use a tricycle at home. They usually are bed-ridden in their twenties and are likely to die in the late twenties due to complications of chronic progressive quadriplegia, particularly the males. Most frequently death is caused by intercurrent respiratory infection. Long tract signs referable to an atlantoaxial dislocation have been reported by Langer and Carey (1966) in 5 out of 6 adults. It was our experience, as Kopits et al. (1972) have pointed out, that the decrease in exercise tolerance is the earliest and therefore most important sign of myelopathy. This was present in all our patients with myelopathy. This sign preceded by months and even years the appearance of long tract signs, which were present in 9 out of 13 patients. Posterior column signs and sphincter disturbance were occasionally or rarely present. There was no superficial sensory loss. Lhermitte's sign has not been observed.

In spondyloepiphyseal dysplasia congenita, atlantoaxial dislocation usually occurs in early infancy. Compression of the respiratory center may cause episodes of acute respiratory arrest and syncope. Walking is usually delayed in these cases due to a flaccid quadriplegia involving the lower more than the upper extremities. Pyramidal tract signs as well as Babinski's sign usually appear later. There is no superficial sensory deficit. Gas myelography was used (Perovic et al. 1973) to diagnose the presence and outline the extent of the cervical cord compression. It proved to be a very helpful method in determining therapy, particularly in borderline cases.

Patients with congenital atlantoaxial dislocation treated by posterior cervical laminectomy in general did not improve neurologically. In fact, there was often an increased deficit following such a procedure. Similar observations have been made Wadia (1973). Therefore, the principles of reduction of the atlantoaxial dislocation and posterior occipitocervical fusion were followed in the treatment (StK) of 12 patients with myelopathy. All patients survived the treatment although cardiorespiratory arrest occurred in 2 during and after surgery. Both patients recovered without residuals from this accident. All patients improved postoperatively, including the 3 who developed nonunion of their fusion. The improvement was commensurate with the preoperative neurological status and continued steadily over the first two years following surgery, and to a lesser degree subsequently.

The high incidence of myelopathy and the good operative results are arguments for preventive occipitocervical fusion in all patients with atlantoaxial dislocation due to odontoid process malformation.

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Alexandre B. Todorov, M.D., Division of Medical Genetics, Department of Medicine, The Johns Hopkins University School of Medicine, Baltimore, Maryland, USA.