OCCIPITO-ATLANTO-AXIAL FUSION IN MORQUIO-BRAILSFORD SYNDROME

A TEN-YEAR EXPERIENCE

ANDREW O. RANSFORD, H. ALAN CROCKARD, JOHN M. STEVENS, SAEED MODAGHEGH

From University College Hospital, the Royal National Orthopaedic Hospital and the National Hospital for Neurology and Neurosurgery, London, England

In 17 patients (eleven males, six females) with Morquio-Brailsford syndrome (mucopolysaccharidosis IV) we have used onlay femoral and tibial autografts placed posteriorly and secured to the laminae of C1 and C2 to obtain satisfactory occipito-C1/C2 posterior fusion. They were immobilised postoperatively in a halo-plaster body jacket for four months. The age at operation varied between three and 28 years. Those with myelopathic symptoms of recent onset made some recovery, but severely myelopathic patients showed little or no recovery.

We advise prophylactic occipitocervical fusion in these patients since the cartilaginous dens is not strong enough to ensure atlanto-axial mechanical stability.

J Bone Joint Surg [Br] 1996;78-B:307-13.

Received 4 July 1995; Accepted 17 August 1995

In 1929 Morquio of Uruguay and Brailsford of England independently described what is now known as Morquio-Brailsford syndrome; this is a mucopolysaccharidosis type IV (MPS IV). It is inherited recessively (McKusick 1972) and is caused by the absence or reduction in activity of one of two lysosomal hydrolase enzymes, N-acetyl galactosamine-6-sulphate sulphotase (MPS IV type A) and β -galactosidase (MPS IV type B).

In the UK, four infants are born each year with this syndrome. They seem normal at birth and the syndrome becomes apparent at the age of 18 to 20 months. The diagnosis is made on the physical and radiological features, blood enzymes, and a skin biopsy. Excessive urinary levels of keratin sulphate are confirmatory. The children have a normal puberty and intelligence. The classical 'beaked' appearance of T11, T12 or L1 on a lateral spinal radiograph (Fig. 1) (Langer and Carey 1966) is produced by incomplete ossification of the cartilaginous vertebral body; this

Fig. 1

The so-called 'beaked' appearance of the thoracolumbar vertebrae in MPS IV. The cartilaginous body is only partially ossified. The bulging fleshy discs and compressible vertebral body allow the occurrence of a small angular kyphosis.

A. O. Ransford, FRCS, Consultant Orthopaedic Surgeon
Royal National Orthopaedic Hospital NHS Trust, Brockley Hill, Stan-
more, Middlesex HA7 4LP, UK.

H. A. Crockard, FRCS, Consultant Neurosurgeon
J. M. Stevens, DRACR, FRCR, Consultant Neuroradiologist
National Hospital for Neurology and Neurosurgery, Queen Square, Lon-
don WC1N 3BG, UK.

S. Modagheh, MD, Assistant Professor of Orthopaedics
Firouzgar Medical Centre, Tehran, Iran.

Correspondence should be sent to Mr A. O. Ransford.

©1996 British Editorial Society of Bone and Joint Surgery
0301-620X/96/21129 \$2.00

Fig. 2

Fig. 3

Figure 2 – Twins with MPS IV aged 17 years in 1994 (eight years after neck fusion). Case 3, on the left, presented with neurological symptoms. She improved postoperatively but seven years after operation became short of breath and confined to a wheelchair. Her twin (case 4) on the right, remains active after prophylactic fusion. Figure 3 – Case 16 in 1994. She became wheelchair-bound in 1992, but has shown improvement one year after cervical fusion.

compresses easily under gravity, producing a minor gibbus (Hesinger 1977).

An 'os odontoideum' is invariably present, as in many other skeletal dysplasias. This is due to a partially cartilaginous dens, fracture of which may not be visible on radiographs. In addition, the ring of C1 is potentially unstable because of failure of ossification anteriorly or posteriorly or both. In theory, this can create laxity of the transverse ligament. The combination results in a complex C1/C2 instability which readily produces a myelopathy in a neuraxis already compromised by a tight spinal canal.

PATIENTS AND METHODS

Kopits et al (1972) and Kopits (1976) were the first to introduce the technique of onlay femoral and tibial autografting to the laminae of C1 and C2, with protection in a halo-plaster body jacket.

From 1984 to 1994, we performed occipito-atlanto-axial fusion in 17 patients with MPS IV (Figs 2 and 3). Two patients have since died. The mean age at fusion was ten years (3 to 22 for type-A patients). Details are given in Table I.

The importance of prophylactic occipitocervical stabilisation became apparent to us when we treated twins with

the syndrome (cases 3 and 4). Case 3 was myelopathic at presentation but both she and her unaffected sister (case 4) had stabilisation at the same time. The latter remains ambulant while her sister requires the use of a wheelchair (Fig. 2).

Preoperative imaging. We performed preoperative CT/myelography in 13 patients under general anaesthesia. Four recent patients have also had MRI which, although non-invasive, is not as satisfactory as CT/myelography. We find that six-year-old children will usually co-operate with MRI and this helped to determine the age at which operation was advised. A combination of CT without myelography and MRI will probably be satisfactory in the future (Fig. 4). The CT/myelographic studies of 11 of our patients have previously been reported (Stevens et al 1991).

Operative technique

Halo body jacket. We fitted a four-pin halo under general anaesthesia (often at the same time as the radiological investigation), and found it preferable to fit the plaster jacket later. Patients with obvious C1/C2 subluxation required immobilisation in the reduced position. Attempted reduction under general anaesthesia with an image intensifier is a painstaking exercise. The head should be posterior to the body and looking up. The child, if awake, co-operative and seated to allow the fitting of halo bars, will

Table I. Details of 17 patients with MPS IV who had occipito-atlanto-axial fusion

Case	Sex	Year of operation	Age at operation (yr)	MPS type	Preoperative neurology	Postoperative neurology	Comments
1	F	1984 1985	7 8	A	-	-	Failed Gallie fusion Thoracolumbar fusion at 13 years/wheelchair
2	F	1986	4	A	+++	++	Occasional use wheelchair
3	F	1986	9	A	++	++	1994 wheelchair
4	F	1986	9	A	-	-	1994 ambulant
5	M	1986	28	B	-	-	Hip problems. THR 1994
6	M	1987	21	A	+	-	
7	M	1988	3	A	+++	+	Hemiplegic. Transoral surgery
8	M	1988	6	A	+++	++	Further C5/C6 problems Wheelchair
9	M	1989	6	A	++	+	Died, cor pulmonale 1993
10	M	1989	3	A	-		Avoidable ITU death
11	M	1990	11	A	+	+	
12	M	1990	7	A	-	-	
13	F	1991	7	A	-	-	
14	M	1992	7	A	++	+	Ambulant. Ankle clonus
15	M	1992	18	A	++	+	
16	F	1993	22	A	+++	-	
17	M	1994	7	A	-	-	

on request hold the head in the most comfortable position, which is usually reduced and safe from the neurological point of view.

Anaesthesia. Having determined the optimum position of reduction, the halo is detached from the bars to allow intubation under anaesthesia. The halo body jacket is then reassembled exactly as before. Kopits advised postoperative ventilation and we used this in nine patients. The endotracheal tube slipped out of one patient (case 10), aged three years, during ventilation, with a fatal result. We now insist that plaster shears and halo disconnecting Allen keys be on hand at the bedside. Patients are discharged with an Allen key strapped to an upright on the halo frame in case of choking or vomiting. We no longer ventilate post-operatively unless it is specifically indicated.

Bone graft. In 16 patients we took donor bone from both distal femora and one proximal tibia. For the femur we used a lateral approach just above the patella and removed pieces of bone 3 cm long and 1 cm wide of one-third circumference. In very young children the marrow is abundant but in adolescents it contains only fat. If the epiphysis was encountered it was ignored as vertical growth had ceased.

A small reciprocating saw was the best tool. One piece of proximal tibia was removed in a similar fashion. The wounds were closed over suction drains and protected by temporary plaster-of-Paris splints. After recovery these were replaced by removable orthoses which were worn for six weeks.

Fig. 4

Case 17. Preoperative MRI. The bone detail is poor. Some narrowing of the neuraxis at C1 and C2 probably reflects repetitive damage.

Neck operation. The patients were placed face downwards in the halo body jacket with the back of the head shaved. The posterior upper neck was approached via a longitudinal incision. The extension of the neck required to achieve C1/C2 reduction makes the approach rather difficult, and the

stripping of soft tissues from the posterior lamina of the atlas is complicated by the midline failure of ossification of C1. Sublaminar wires were passed under the lamina of C1 and C2, leaving the unossified cartilage intact to prevent dislodging of the C1 sublaminar wires. The holes for the wires were usually drilled before the femoral and tibial grafts were obtained. The grafts were placed longitudinally and wired into position to abut hard against the occiput.

One hemiplegic patient had a transoral decompression before posterior fusion (Ashraf et al 1991). Histological examination of the os odontoideum showed that it consisted of reactive tissue and partially ossified bone.

Late postoperative course. Removable splints were used to protect the legs for six weeks and the halo body jacket was worn for four months. During this period the patients were recumbent, sitting or reclining at no more than 45°. When out of doors they rode in a canvas buggy. Physiotherapy was given to restore leg and arm muscle strength. After removal of the halo body jacket the neck was supported by a custom-made two-shell plastic collar for a further two months. This strict regime has prevented any serious halo pin complications.

RESULTS

In all 16 surviving patients there was solid fusion from the occiput to C2 within six months.

Neurological results. Evaluation of neurological recovery was difficult, since these patients have hip and knee problems which cause difficulty in walking after long recumbency (Fig. 3). In the 12 children with obvious neurological signs there was a variable degree of improvement. Eight were markedly myelopathic and showed poor recovery and one has since died from respiratory complications. We agree with Kopits et al (1972) that fusion stabilises the cervical myelopathy with neurological and respiratory

improvement but this may last for only two or three years. The best results were obtained in the patients who had prophylactic fusions (cases 4, 12, 13 and 17) and they remain the most mobile. Two of these were siblings (one a twin) of patients who developed a neurological deficit (Fig. 2).

Early in the series we were unsure that we were correct in advocating early prophylactic fusion, since it was difficult to demonstrate C1/C2 instability on flexion/extension radiographs (Fig. 5). We now realise that demonstrable instability is a late feature and if present is associated with myelopathic symptoms.

DISCUSSION

Atlanto-axial instability. Survival beyond teenage years mainly depends on the extent of the occipito-atlanto-axial pathology. Some MPS IV patients survive into adult life without problems, possibly because they have developed ossification of the odontoid peg and the C1 ring to a variable extent. Other features, especially cardiac abnormalities, are important (Blaw and Langer 1969; Melzak 1969; Beighton and Craig 1973; Lipson 1977).

We have shown (Stevens et al 1991) that the widely held view that C1/C2 instability is secondary to ligamentous laxity (Svensson and Aaro 1988) is an oversimplification of the pathology. We believe that the presence of an os odontoideum is evidence of instability and have shown in four patients studied by pre- and postfusion CT/myelography that the odontoid will ossify when the instability has been eliminated (Figs 6 and 8). A cartilaginous dens is probably more 'deformable' and perhaps allows extra atlanto-axial transitory movements. Fracture of the dens may not be seen on radiographs but the consequences are obvious. We feel that repeated trauma to the cartilaginous dens may retard ossification.

Fig. 5

Preoperative flexion/extension radiographs. The arch of C1 is marked by an arrow-head, the cartilaginous dens by an arrow. Reduction is in extension with posterior translation, as in the extension radiograph.

Fig. 6a

Fig. 6b

Case 1. CT myelography. Figure 6a – The spinal cord is thinned at C1 and C2 and the contrast column is compressed. In the axial images the anterior arch of C1 is incompletely ossified. Figure 6b – After fusion. The dens is ossified and the contrast column is more evenly distributed. In other images the ring of C1 has ossified anteriorly.

Fig. 7a

Fig. 7b

Case 3. CT myelographic findings (a) sagittally and (b) axially.

There is a second site of instability. We have confirmed by CT/myelography (Stevens et al 1991) the findings of Edwards et al (1982) that there is stenosis of the foramen magnum and the spinal canal of C1 which is often seen in other skeletal dysplasias (Lipson 1977; Ryken and Menezes 1994). Often the ring of C1 is incompletely ossified ante-

riorly (Figs 6a and 7b) or posteriorly or both, producing a distortable bone. At surgery, failure of ossification of the posterior arch of C1 is obvious. If the two halves of the ring of C1 approximate to each other the transverse ligament may become lax; if they separate, the ligament will tighten. After successful fusion ossification proceeds both anteriorly

Fig. 8

Postoperative radiograph showing posterior occipitocervical fusion and an ossified odontoid peg.

and posteriorly. Posteriorly, of course, the defect is included in the fusion.

Attempts to show instability at C1/C2 by lateral flexion/extension radiographs of the occipitocervical area in these patients is an oversimplification of the problem: if present the patient is almost certainly myelopathic (Blaw and Langer 1969; Kopits et al 1972; Beighton and Craig 1973; Goldberg 1976; Lipson 1977). When C1/C2 instability is present in association with stenosis of the foramen magnum and C1 the brain stem is vulnerable.

Operative technique. We no longer routinely use postoperative ventilation. The source of donor bone is important; the iliac crest is cartilaginous and cannot be used. Removal of the femoral and tibial strut grafts is not without complications: we have seen a fractured femur in a non-MPS patient and one patient in the present series developed problems with tracking of the patella. Damage to the growth plates is of no consequence since no further growth can be expected, even after a successful marrow transplant.

We now favour rib for use as donor bone (Fig. 9), having had success with this in patients with Goldenhar's syndrome, Down's syndrome and spondyloepiphyseal dysplasia. The holding jacket should be hinged to allow access and we have used this technique in our latest patient (case 17). It is easy to remove 5 cm of each of three adjacent ribs, usually the eighth, ninth and tenth, through a longitudinal incision just lateral to the sacrospinalis muscle, and without entering the pleural cavity. The technique may produce scoliosis and we use it with caution in children with a normal growth potential. Another possible source of bone is full-thickness parieto-occipital skull cortex, which has been used in a non-MPS IV patient by one of us (HAC). We do not agree with the use of any bone substitute.

Os odontoideum. We prefer the term cartilaginous dens, even although some ossification may be present. The dens may deform or fracture, and we believe that only when

fracture has occurred can anteroposterior subluxation be demonstrated on plain flexion/extension radiographs. We have shown that the intact but cartilaginous odontoid deforms on flexion/extension CT. The dens seems to ossify normally after a craniocervical fusion, and it is uncertain why this does not occur in the unfused neck.

Atlas ring. The C1 ring may be affected by incomplete ossification anteriorly or posteriorly or both, but if it is completely ossified it may be hypertrophic. The influence on the transverse ligament has already been discussed. This may contribute to further instability which itself threatens the brain stem, particularly when associated with stenosis of the canal.

Sublaminar wires. We now consider that passing wires around the foramen magnum or C1 is not safe. Grafts can be stabilised to the occiput by passing polydioxanone or polyglactin sutures extradurally through paired small occipital burr holes just posterior to the foramen magnum. A sublaminar suture under C2 will then secure the graft caudally. A laminoplasty of C1 may be considered.

The thoracolumbar kyphus. One of our patients (case 1) has required anterior decompression at the thoracolumbar junction (Holte et al 1994). The cartilaginous vertebral body looked normal and was identified by the intersegmental vessels. The discs bulged between the vertebral bodies. The partial ossification of a normal cartilaginous vertebra produces a 'beaked' appearance on the lateral spinal radiographs and allows vertical compression of the vertebra

Fig. 9

Bone graft may be obtained from posterior ribs (arrowed scar). The thoracolumbar kyphus can be seen.

anteriorly, producing a small gibbus and this may show gross hypermobility when examined by lateral flexion/extension radiography.

Bracing of the gibbus to prevent progressive kyphosis is unrewarding as the patients do not grow but the bulging disc and spinal stenosis may be responsible for additional cord or conus damage. Survivors of neck surgery with good results may also be susceptible to conus compression at the thoracolumbar junction. In three patients measurement of somatosensory evoked potentials from the arms and legs has shown that there is a neurological conduction failure at the thoracolumbar junction. This aspect of the syndrome requires further research and evaluation.

Prophylactic fusion. In common with other skeletal dysplasias which show failure of ossification of the dens prophylactic fusion is indicated. The correct age for this has still to be determined, but we consider that four years may be appropriate unless myelopathic signs begin to develop before this.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

REFERENCES

- Ashraf J, Crockard HA, Ransford AO, Stevens JM. Transoral decompression and posterior stabilisation in Morquio's disease. *Arch Dis Child* 1991;66:1318-21.
- Beighton P, Craig J. Atlanto-axial subluxation in the Morquio syndrome: report of a case. *J Bone Joint Surg [Br]* 1973;55-B:478-81.
- Blaw ME, Langer LO. Spinal cord compression in Morquio-Brailsford's disease. *J Pediatr* 1969;74:593-600.
- Brailsford JF. Chondro-osteo-dystrophy, roentgenographic and clinical features of a child with dislocation of vertebrae. *Am J Surg* 1929;7:404-10.
- Edwards MK, Harwood-Nash DC, Fitz CR, Chuang SH. CT metrizamide myelography of the cervical spine in Morquio syndrome. *AJNR* 1982;3:666-9.
- Goldberg MJ. Orthopedic aspects of bone dysplasias. *Orthop Clin North Am* 1976;7:445-56.
- Hesinger RN. Kyphosis secondary to skeletal dysplasias and metabolic disease. *Clin Orthop* 1977;128:113-28.
- Holte DC, Rogers MA, Ransford AO, Crockard HA. Thoracic spinal cord compression in Morquio-Brailsford's disease: report of a case and review of the literature. *Neuro-Orthopedics* 1994;12:1-17.
- Kopits SE. Orthopaedic complications of dwarfism. *Clin Orthop* 1976;114:153-79.
- Kopits SE, Perovic MN, McKusick V, Robinson RA, Bailey JA. Congenital atlantoaxial dislocations in various forms of dwarfism. *J Bone Joint Surg [Am]* 1972;54-A:1349-50.
- Langer LO Jr, Carey LS. The roentgenographic features of the K S mucopolysaccharidosis of Morquio (Morquio-Brailsford's disease). *Am J Roentgen* 1966;97:1-20.
- Lipson SJL. Dysplasia of the odontoid process in Morquio's syndrome causing quadriplegia. *J Bone Joint Surg [Am]* 1977;59-A:340-4.
- McKusick VA. *Heritable disorders of connective tissue*. 4th ed. St Louis: CV Mosby, 1972;293-371.
- Melzak J. Spinal deformities with paraplegia in two sisters with Morquio-Brailsford Syndrome. *Paraplegia* 1969;6:246-58.
- Morquio L. Sur une forme de dystrophie osseuse familiale. *Arch Med Enfants* 1929;32:129-40.
- Ryken TC, Menezes AH. Cervico-medullary compression in achondroplasia. *J NeuroSurg* 1994;81:43-8.
- Stevens JM, Kendall BE, Crockard HA, Ransford AO. The odontoid process in Morquio-Brailsford's disease: the effects of occipitocervical fusion. *J Bone Joint Surg [Br]* 1991;73-B:851-8.
- Svensson O, Aaro S. Cervical instability on skeletal dysplasia: report of 6 surgically fused cases. *Acta Orthop Scand* 1988;59:66-70.