BASILAR IMPRESSION IN OSTEOGENESIS IMPERFECTA
A REPORT OF THREE CASES IN ONE FAMILY

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Basilar impression is a well-recognised though rare complication of osteogenesis imperfecta. Three patients, all members of the same family, with advanced basilar impression complicating osteogenesis imperfecta tarda, are described. The clinical features in these cases illustrate the natural history of this condition: from asymptomatic ventricular dilatation, through the foramen magnum compression syndrome, to death from brain-stem compression. The radiological criteria on which the diagnosis is based, are defined. Review of the literature reveals only seven previously documented cases, all in patients with mild forms of osteogenesis imperfecta. The unusually low incidence of basilar impression in osteogenesis imperfecta and its apparent restriction to patients with mild forms of the disease is discussed. The examination of close relatives of patients with basilar impression and osteogenesis imperfecta is emphasised in order to anticipate the onset of severe neurological complications.

The term “basilar impression” describes the invagination of the foramen magnum into the posterior cranial fossa, and the concomitant translocation of the upper cervical vertebrae into this cranial depression. Primary basilar impression is generally considered to be due to a congenital developmental anomaly with a familial tendency (Bull, Nixon and Pratt 1955; Hurwitz and Shepherd 1966; Paradis and Sax 1972). Secondary basilar impression occurs as the result of generalised skeletal disease: in Paget’s disease (Poppel et al. 1953; Epstein and Epstein 1969), in hyperparathyroidism and osteomalacia (Bull et al. 1955) and in osteogenesis imperfecta. However, despite frequent reference to basilar impression as a complication of osteogenesis imperfecta (McGregor 1948; Caniggia, Stuart and Guideri 1958; Murray and Jacobson 1977), there appear to be only seven cases previously documented in the literature. Three further cases, all members of the same family, with features consistent with osteogenesis imperfecta tarda levis, are reported here.

Family pedigree
The family pedigree is shown in Figure 1. The parents were not related to one another. The three affected members of the family, the mother and her two sons, all exhibited features of osteogenesis imperfecta and basilar impression. The daughter (III, 2) had no stigmata of osteogenesis imperfecta and neurological examination was normal. Radiographs of her skull and cervical spine showed a normal shaped skull without wormian bones and a normal anatomical relationship at the craniovertebral junction. The other unaffected members of the family,

![Diagram of family pedigree](image)

though not available for examination, had no history of neurological or orthopaedic problems. The pattern of inheritance appears to be autosomal dominant.

CASE REPORTS
The clinical and radiological data relevant to osteogenesis imperfecta in the affected members of the family are detailed in Table I.

Case I (III, 1). This man, aged 26 years, is a computer
programmer. In 1978, at the age of 21 years, he began to suffer occipital headaches which gradually became so severe that any form of exertion would provoke an attack of vomiting. He could only find relief by lying down for several hours. By 1980, he had developed facial paraesthesia, intermittent dysphagia and poor balance and gait.

Clinical examination revealed the features of a typical foramen magnum compression syndrome with bilateral decreased corneal reflexes; diminished appreciation of light touch and pin-prick over the maxillae and mandible; right facial weakness; central and tympanosclerotic deafness in the right ear; decreased gag reflex; fasciculation on both sides of the tongue; and coarse horizontal nystagmus. No neurological abnormality was detected in the upper limbs. His gait was grossly ataxic, heel–shin co-ordination was poor and his reflexes were uniformly brisk with downgoing plantar responses.

Lateral radiographs showed a typical tam-o’-shanter skull with occipital wormian bones and gross basilar impression at the craniocervical junction (Fig. 2). The atlas and the axis had migrated above McGregor’s line and the dens was markedly displaced above Chamberlain’s line (Fig. 3). Bull’s angle measured 45 degrees. Computerised tomography confirmed these findings, showing the anterior arch of the atlas and the odontoid peg in juxtaposition to the petrous part of the temporal bone (Fig. 4). There was also gross dilatation of the third and lateral ventricles (Fig. 5).

In 1981, he underwent a foramen magnum decompression with laminectomy of C1 and C2. The dura was left widely open. His postoperative course was complicated by prolonged respiratory depression and persistence of ventricular dilatation. Both, however, resolved satisfactorily with the insertion of a ventriculoperitoneal shunt. Over the subsequent months his cranial nerve signs abated but he was left with a mildly ataxic gait.

One year later he suffered a partial relapse with the appearance of new symptoms. He noted that his head had continued to sink towards his shoulders and his gait had again become grossly ataxic. He also developed weakness of the intrinsic muscles of the right hand with loss of fine control of finger movements. His writing became almost illegible. A fine tremor of the right hand

Table 1. Clinical features related to osteogenesis imperfecta

<table>
<thead>
<tr>
<th>Case 1 (III, 1)</th>
<th>Case 2 (III, 3)</th>
<th>Case 3 (II, 3)</th>
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<tbody>
<tr>
<td>Light blue sclera</td>
<td>Light blue sclera</td>
<td>Light blue sclera</td>
</tr>
<tr>
<td>Tam-o’-shanter skull</td>
<td>Tam-o’-shanter skull</td>
<td>Tam-o’-shanter skull</td>
</tr>
<tr>
<td>Dentinogenesis imperfecta</td>
<td>Dentinogenesis imperfecta</td>
<td>Dentinogenesis imperfecta</td>
</tr>
<tr>
<td>Thoracolumbar scoliosis</td>
<td>None</td>
<td>Unknown</td>
</tr>
<tr>
<td>Otosclerosis</td>
<td>Untested</td>
<td>Unknown</td>
</tr>
<tr>
<td>5 ft 2 in (157.5 cm)</td>
<td>5 ft 4 in (162.5 cm)</td>
<td>4 ft 11 in (150 cm)</td>
</tr>
</tbody>
</table>

Fractures:
- L femur x 3
- R femur x 1
- R pubis ramus

Other bony anomalies:
- L protrusio acetabuli
- R protrusio acetabuli
- R dislocated radial head
was obvious and co-ordination was moderately impaired. There was diminished tactile sensation over the dorsum of the hand. Coarse nystagmus, with both vertical and horizontal components, was apparent. Radiologically there was evidence of further migration of the odontoid peg into the posterior cranial fossa.

Since the laminae of C1 and C2, together with part of the occipital bone, had been removed at the previous operation, a modified occipitocervical fusion was undertaken. The dissection was carried down to the occiput, where a new membrane had developed at the site of the dural decompression. An extensive bone graft, in the form of corticocancellous sticks taken from both iliac crests, was then used to span the gap from C3/C4 to the occiput. The patient was maintained on skull traction during the operation and for two weeks after operation. A Minerva type of plaster jacket was then applied.

At the end of three months the jacket was removed and radiographs revealed a column of bone supporting the occiput from C3 and C4 (Fig. 6). Radiologically there was no evidence of any movement between the upper cervical vertebrae. Flexion and extension was only detectable at C5/C6 and C6/C7. The neurological signs and symptoms in the right arm had resolved. The long tract signs in the lower limbs were no longer detectable, although his gait remained mildly ataxic and the horizontal nystagmus persisted.

Case 2 (III, 3). This man, aged 23 years, was a university student. The clinical features of osteogenesis imperfecta which he exhibited were almost identical to those of his brother, although his fracture profile was more extensive. He walked with a mild limp, the left leg being 2 cm shorter than the right. Both tibiae were bowed. He was asymptomatic except for very intermittent headaches, and neurological examination failed to reveal any significant abnormalities.

Lateral radiographs showed a typical tam-o'-shanter skull with occipital wormian bones. Both the atlas and axis were situated above McGregor's line and the dens
after this she was noted to have an ataxic gait and to suffer frequent falls. Weakness and poor co-ordination of her right hand had resulted in her handwriting becoming illegible. She was investigated and told she was suffering from a terminal illness in which “her backbone was growing into her brain”. The following year she suffered a heavy fall, sustaining direct trauma to the skull and died soon after. The post-mortem confirmed gross basilar impression and medullary compression. The opening of the foramen magnum was reduced to a slit 15 by 3 mm in depth.

DISCUSSION

Basilar impression is defined radiologically by reference to a number of parameters.

1. McGregor’s line (McGregor 1948). This line, drawn from the posterior edge of the hard palate to the most caudal part of the occiput, normally passes just above the tip of the odontoid peg, the mean position of the tip relative to this line being 0.39 mm ± 3.02 mm (Bull et al. 1955). Measurements of 27 mm and 29 mm above McGregor’s line were recorded for the propositus and his brother respectively (Fig. 10).

2. Chamberlain’s line (Chamberlain 1939). This line, from the posterior edge of the hard palate to the dorsal lip of the foramen magnum, also lies in close relationship to the tip of the dens (mean position 0.06 mm ± 3.3 mm below this line). The dorsal lip, however, can be difficult to define radiologically and furthermore, can itself become invaginated. Nevertheless, in both brothers these measurements were markedly abnormal; the distance from the tip of the dens to Chamberlain’s line being 20 mm in Case 1 and 22 mm in Case 2 (Fig. 10).

3. Bull’s angle (Bull et al. 1955). This angle, at the
intersection of the plane of the hard palate and the plane of
the atlas, was 45 degrees in both Cases 1 and 2 (Fig.
10). Thirteen degrees is the usually accepted upper limit of
normal.

4. Fischgold's line (Fischgold and Metzger 1952). This
line, joining the lower margins of the mastoid processes
on a transoral anteroposterior tomogram of the base of
the skull, normally passes through the atlanto-occipital
articulation. In Case 2, both the atlas and the axis have
come to lie above this line, which now passes through the
C2/C3 disc space (Figs 8 and 9).

5. Computerised tomography provides clear definition of
the abnormal anatomical configuration at the cranio-
cervical junction (Fig. 4) and of the degree of ventricular
dilatation (Fig. 5).

Table II. Summary of clinical data in previously reported patients

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Age (years)</td>
<td>12</td>
<td>23</td>
<td>36</td>
<td>32</td>
<td>30</td>
<td>51</td>
</tr>
<tr>
<td>Sex</td>
<td>F</td>
<td>F</td>
<td>M</td>
<td>F</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Sclerae</td>
<td>Blue</td>
<td>--</td>
<td>White</td>
<td>White</td>
<td>Blue</td>
<td>White</td>
</tr>
<tr>
<td>Scoliosis</td>
<td>--</td>
<td>Severe</td>
<td>Marked</td>
<td>Marked</td>
<td>None</td>
<td>--</td>
</tr>
<tr>
<td>Stature</td>
<td>Average</td>
<td>Short</td>
<td>5 ft 4 in (162.6 cm)</td>
<td>4 ft 8 in (141.8 cm)</td>
<td>5 ft (152.4 cm)</td>
<td>Short</td>
</tr>
<tr>
<td>Family history</td>
<td>--</td>
<td>+ve</td>
<td>+ve</td>
<td>None</td>
<td>--</td>
<td>+ve</td>
</tr>
<tr>
<td>Fractures</td>
<td>× 20 by age 4 years</td>
<td>Leg</td>
<td>Skull</td>
<td>Pelvis</td>
<td>R femur</td>
<td>No data</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ilium</td>
<td>Pelvis</td>
<td>Both legs</td>
<td>L femur × 2 T7 vertebra</td>
<td></td>
</tr>
<tr>
<td>Clinical presentation</td>
<td>FMCS</td>
<td>FMCS</td>
<td>FMCS</td>
<td>Tetraplegia after a fall</td>
<td>Neuro-psychiatric</td>
<td>Asymptomatic</td>
</tr>
</tbody>
</table>

FMCS = Foramen magnum compression syndrome

The invagination of the foramen magnum is accom-
panied by a medialisation of the occipital condyles, and
this in turn, produces stenosis at the foraminal outlet.
The resulting foramen magnum compression syndrome
is manifested clinically as a disturbance of a number of
neurological functions: interference with the normal
cerebrospinal fluid pathways, producing internal hydro-
cephalus and ventricular dilatation; direct pressure on
the cerebellum causing bilateral cerebellar disturbance;
compression of the brain-stem resulting in interference
with lower cranial nerve function and a disturbance of the
respiratory centres; and spinal cord compression at the
level of the foramen magnum producing long tract
signs.

Abnormal fragility of the bones is generally regarded as
the cause of the invagination of the foramen magnum.
In osteogenesis imperfecta, it is possible that repeated
microfractures in this area, which then heal in an
abnormal position, gradually allow the rim of the foramen
magnum to become infolded. However, if this were the
only factor, the incidence of basilar impression in
osteogenesis imperfecta might be expected to be higher
than observed, specially within the group with the more
severe form of the disease.

Review of the seven patients with basilar impression
and osteogenesis imperfecta reported in the literature
suggests that all had the mild form, defined as osteogenesis
imperfecta tarda levis (Looser 1960) or Types 1 and 4
(Sillence, Senn and Danks 1979). The clinical data related
to these patients are summarised in Table II. Only one
patient had numerous fractures, but the author described
her deformity as insignificant (Ray 1942). The patient
reported by Frank, Berger and Tew (1982) had a family
history of osteogenesis imperfecta tarda and no skeletal
deformity was described. The remaining patients exhib-
ited features consistent with Types 1 or 4 of the disease.

The two patients described by Hurwitz and McSwiney
(1960) were siblings. One other sister was thought to have
early basilar impression but the evidence for osteogenesis
imperfecta was inconclusive.

It is not clear why basilar impression appears to be
a complication only in patients with mild forms of
osteogenesis imperfecta. Recent work, however, has
shown differences in the collagen make-up of patients
with different forms of the disease. In most patients with
Type 1, the amount of total skin collagen and the
extracted polymeric collagen fraction is abnormally low,
whereas in many patients with the severe form of the
disease, these measurements are within normal limits.
Furthermore, the solubility properties of the polymeric
collagen, measured by its resistance to cold alkali or
proteolytic enzymes, followed by gelatinisation, appear
normal in patients with mild disease but abnormal in
severely affected patients (Francis, Smith and Bauze
1974). In patients with mild disease, the pro α-1(I) chain of
Type I collagen seems to be produced in reduced
amounts (Francis et al. 1981). A non-functional allele of
the collagen DNA appears to be responsible for the decreased production of this collagen chain (Barsh, David and Byers 1982). It is possible that the different clinical manifestations exhibited by different families with osteogenesis imperfecta may be a reflection of different aberrations in the collagen DNA sequence.

The three patients in this family illustrate the natural history of basilar impression: from asymptomatic early ventricular dilatation (Case 2), through the asymptomatic early ventricular dilatation (Case 1), to death from acute brain-stem compression (Case 3). In Case 1 progressive invagination following decompression of the foramen magnum was observed, a problem not previously described. Whether this was secondary to the operative procedure or to the underlying bone pathology, or both, is uncertain.

Although foramen magnum decompression often results in resolution of the cranial nerve signs, evidence of cerebellar and long tract disturbance commonly persists. It is likely that the outcome of surgery depends in part on the duration of the compression syndrome, since irreversible neurological damage due to pressure atrophy may have occurred in long-standing cases by the time decompressive procedures are undertaken. Central respiratory depression as a presenting complication (Frank et al. 1982) or following surgery, as in Case 1 and one of the patients reported by Hurwitz and McSwiney (1960), may require prolonged respiratory assistance and ventriculo-peritoneal shunting.

Basilar impression appears to be an uncommon but serious complication of osteogenesis imperfecta. When it occurs, the evidence suggests that it affects patients with mild forms of the disease. The reason for this remains uncertain. Two families with basilar impression and osteogenesis imperfecta have now been described. This emphasises the importance of screening the relatives of these patients in order to anticipate severe neurological complications, since early foramen magnum decompression may result in full recovery. Where progressive invagination is encountered, an extensive occipitocervical fusion is recommended.

The authors wish to thank Dr Martin Francis and Dr Roger Smith for their helpful comments in the preparation of this paper.

REFERENCES


