

Basilar Invagination

A patient guide

In brief: Basilar invagination is a condition of the craniovertebral junction — the join between the skull and the top of the spine — in which the upper cervical spine, and in particular the odontoid peg of the second neck bone, sits higher than normal and projects upwards into the opening at the base of the skull. This narrows the space available for the lower brainstem and the upper spinal cord. Modern specialist thinking, led largely by the work of Atul Goel in Mumbai, increasingly regards many cases not as a fixed bony malformation but as the end-result of chronic instability at the joint between the first and second neck bones.

What basilar invagination is

The craniovertebral junction is the meeting point of the base of the skull, the first cervical vertebra (the atlas, or C1) and the second cervical vertebra (the axis, or C2). The axis carries an upward bony projection called the odontoid process, or dens — often described as the "peg" — around which the atlas and the head rotate. In a normally formed junction the peg sits comfortably below the rim of the foramen magnum, the large opening through which the brainstem becomes the spinal cord.

In basilar invagination this geometry is disturbed. The odontoid peg and the upper cervical spine prolapse upwards, projecting into the foramen magnum and reducing the volume of the bony funnel that protects the cervicomedullary junction — the transition between the lowest part of the brainstem and the highest part of the spinal cord. The consequence is potential compression of these delicate neural structures.

It is important to distinguish basilar invagination from the term basilar impression. The two share the same end-geometry — the upper spine sitting too high in relation to the skull base — but they differ in cause. Basilar invagination is typically used for the developmental or congenital form, present from early life because of how the bones formed. Basilar impression refers to the acquired form, in which previously normal bone softens later in life and the skull base gradually settles down onto the spine. The threat to the nervous system is similar; the underlying mechanism is not.

The spinal-surgery relevance is straightforward: this is not merely an unusual shape seen on a skull radiograph. Because the peg encroaches on the space meant for the brainstem and cord, the clinical concern is myelopathy — dysfunction of the spinal cord — together with brainstem and lower-cranial-nerve effects, and, in severe or sudden presentations, the risk of serious neurological deterioration.

How it is measured (Chamberlain's, McGregor's and McRae's lines)

Because the abnormality is essentially one of position — how high the peg sits in relation to the skull base — it is judged using craniometric reference lines drawn on imaging. Three lines form the classical foundation.

****Chamberlain's line**** is drawn from the back of the hard palate to the opisthion, the posterior margin of the foramen magnum. It was described in 1939. Traditionally, a peg tip projecting more than approximately 5 mm above this line is considered abnormal. This was the criterion used in Goel's early large surgical series.

****McGregor's line**** runs from the back of the hard palate to the most caudal point of the occipital bone. It was introduced because the opisthion can be difficult to identify reliably on plain radiographs, whereas the lowest point of the occiput is easier to locate. A peg projecting more than roughly 4.5 mm — a figure sometimes quoted as around 7 mm — above this line is regarded as abnormal.

McRae's line is drawn across the foramen magnum itself, from the basion at the front to the opisthion at the back. Conceptually it is the cleanest of the three because it marks the actual margin of the neural canal: any projection of the peg above McRae's line is abnormal. For that reason McRae's line is often considered to correlate most closely with symptoms, since it represents the real space available to the brainstem and cord.

Additional measurements supplement these lines. Wackenheim's clivus line, the clivo-axial angle and the cervicomedullary angle describe the angular relationship between the skull base and the upper spine; the cervicomedullary angle in particular has been studied as a predictor of neurological outcome after surgery in one pattern of the condition. The atlanto-dental interval and clivo-dental interval are used to assess the instability component.

An important caveat applies. These lines were originally defined on plain lateral radiographs. When re-examined using computed tomography (CT) and magnetic resonance imaging (MRI), the measurements show drift and variation between observers, which has prompted calls for cross-sectional and more universal craniometric indices. The lines remain the shared language of the field, but they are best interpreted on reformatted CT and MRI rather than on plain film alone.

Group A and Group B (Goel classification)

A central organising idea in the modern literature is Atul Goel's division of basilar invagination into two groups, based on the behaviour of the joint between the first and second cervical vertebrae.

Group A is the instability-evident form. Here the atlantoaxial joint — the C1–C2 articulation — is overtly unstable, with an abnormal atlanto-dental or clivo-dental interval, and the peg has migrated into the foramen magnum, breaching the craniometric parameters. This is the pattern most readily recognised as "reducible," meaning the alignment can potentially be improved by realigning and stabilising the joint, so that decompression is generally not required.

Group B is the instability-occult form. In this pattern the atlanto-dental interval is normal or within range, so the C1–C2 joint appears stable on the usual translational measurements, and the junction may even look fixed or assimilated. Historically, Group B cases were treated by removing bone to decompress the neural structures. Goel's contention is that the underlying mechanism is still atlantoaxial instability — present but subtle, expressed through the facet joints and in the vertical plane rather than as obvious forward-and-backward slippage — and that fixation of the atlantoaxial joint, rather than decompression, remains the appropriate focus even here.

A complementary refinement re-bases the classification on facet alignment: the relative front-to-back position of the C1 and C2 facet joints. On this view, malalignment of the facet joints, rather than the dens-line measurement alone, is the true underlying substrate of the condition.

The reason this distinction matters is that it is not merely academic taxonomy. The A and B split functions, in specialist hands, as a way of framing whether the situation calls for decompression or for realignment and fixation. The contemporary Goel position narrows much of the gap between the two by holding that instability is the cause across the spectrum and that stabilisation is therefore the central treatment principle.

Why it happens (congenital and acquired)

The causes of basilar invagination divide broadly into developmental and acquired.

The **developmental, or congenital, form** is the more common. It arises from how the bones of the craniovertebral junction formed and may involve assimilation of the atlas to the occiput (the first vertebra fusing to the skull base), underdevelopment of the basi-occiput or of the atlas, an incomplete posterior arch of the atlas, anomalies of the odontoid peg such as os odontoideum, and Klippel–Feil syndrome, in which neck vertebrae are congenitally fused. There is a strong overlap with Chiari I malformation and with syringomyelia, a fluid-filled cavity within the spinal cord. Anomalies of the course of the vertebral artery are also frequently present.

The **acquired form** — basilar impression — results from softening of previously normal bone. Conditions implicated include rheumatoid arthritis, where the process is sometimes described as cranial settling; Paget's disease of bone; osteogenesis imperfecta; osteomalacia; hyperparathyroidism; and fibrous dysplasia. In these situations the skull base gradually descends onto the upper spine as the bone loses its structural integrity.

The point about the vertebral artery carries particular operative significance. In congenital basilar invagination, and especially where there is assimilation of the atlas, the artery may take an anomalous course at the C1–C2 level. This raises the risk of injuring the vessel during placement of screws into the second vertebra and influences how the surgical anatomy is planned.

Its relationship with atlantoaxial instability, Chiari and syringomyelia

Basilar invagination rarely sits in isolation. It is best understood as part of a wider complex of craniovertebral-junction disorders that share a common thread.

Atlantoaxial instability — abnormal movement or subluxation at the C1–C2 joint — is, on the modern view, the mechanism that drives the deformity. The contemporary Goel concept holds that in a large majority of cases the C1–C2 facet joints are the true site of pathology: they subluxate and telescope, allowing the peg to migrate upwards over time. Group A represents this instability in overt form; Group B represents it in occult form. The logical consequence is that the deformity can often be addressed from below — by distracting, realigning and fixing the atlantoaxial joint — restoring the height of the junction and drawing the peg back down, rather than by removing bone from the front or back.

The same instability-centred argument extends to Chiari malformation and to syringomyelia. Goel has proposed that much of the tonsillar descent labelled as Chiari I malformation in patients with craniovertebral-junction pathology is a secondary, even protective, response to underlying atlantoaxial instability, rather than a primary problem in its own right. On this model, basilar invagination, Chiari malformation and syringomyelia can form a single instability-driven complex, in which addressing the instability is held to address the whole picture. This is an influential framework, although, as discussed below, it remains debated.

How it tends to present

Basilar invagination commonly presents with the features of progressive cord and brainstem compression, often developing gradually over time. Reported features include progressive myelopathy — disturbance of gait, clumsiness of the hands, and weakness — together with neck pain and restricted or abnormal neck posture such as torticollis. Suboccipital headache, felt at the back of the head, is frequently described.

Where the lower brainstem and the lower cranial nerves are involved, features can include difficulty swallowing (dysphagia), slurred speech (dysarthria) and sleep-disordered breathing. When a syrinx co-exists within the cord, a dissociated pattern of sensory loss may be present. Examination tends to reveal long-tract signs reflecting cord involvement, signs referable to the lower cranial nerves, and external clues such as a short neck or low hairline where assimilation or Klippel–Feil syndrome is part of the picture.

A particular concern, especially in the congenital form, is that acute neurological decompensation can follow what seems a relatively minor injury, because the margin of space around the brainstem and cord is already reduced.

How it is assessed (imaging)

Assessment rests on cross-sectional imaging, used in a complementary fashion.

MRI is central for visualising the soft tissues: the degree of compression of the cord and brainstem, the presence of a syrinx, the position of the cerebellar tonsils and the cervicomedullary angle. CT, with high-quality reconstructions, defines the bony anatomy in detail — the shape of the facet joints, the presence of assimilation of the atlas, and the course of the vertebral artery, all of which bear on the surgical anatomy. Dynamic imaging in flexion and extension is used to address the crucial question of whether the joint moves, and therefore whether the deformity is reducible. The craniometric reference lines are then applied to these cross-sectional reformats rather than to plain films.

How it is distinguished from related conditions

Basilar invagination is frequently confused with several related terms, and the distinctions matter.

Platybasia is an anthropometric description only — a flattening of the basal angle of the skull, the angle formed at the clivus. It describes the shape of the skull base and is usually harmless in isolation. Importantly, most people with basilar invagination have a normal basal angle and no platybasia. The two terms are often conflated, but they are not the same thing: one is a shape, the other a displacement of the spine into the skull's opening.

Chiari malformation (type I) involves the cerebellar tonsils descending below the foramen magnum. Here the structure that is out of place is neural — the tonsils — and it descends downwards. In basilar invagination, by contrast, the structure that is out of place is bony and vertebral — the upper spine — and it ascends upwards. As noted, the modern instability-centred view holds that these two can be linked, but the primary direction and the structure involved differ.

Isolated atlantoaxial instability is abnormal mobility at the C1–C2 joint without the vertical telescoping that produces invagination. On the modern view, instability is the mechanism and basilar invagination is frequently its vertical manifestation; the difference is whether the joint has merely become loose or has also allowed the peg to migrate cranially into the foramen magnum.

The defining feature of basilar invagination, then, is the upward movement of the odontoid peg and upper cervical spine into the brainstem's space, with the attendant risk of myelopathy and cervicomedullary compression — distinct from a mere skull-base shape, from a downward neural descent, and from looseness that has not yet produced vertical settling.

What the evidence shows about management (decompression versus realignment and fixation) — impersonal

The management of basilar invagination has undergone a notable conceptual shift, and the evidence is best described impersonally, without implying a settled hierarchy.

Historically, the dominant approach for irreducible anterior compression was a ventral, decompressive paradigm: transoral odontoidectomy — removal of the peg through the mouth — often combined with occipitocervical fusion. This is effective at debulking the peg but involves deep, narrow access, a risk of nasopharyngeal contamination and infection, difficulty managing cerebrospinal-fluid leakage, and the frequent need for a separate posterior stabilising procedure.

From 2004 onwards, Goel introduced a posterior realignment paradigm: opening the atlantoaxial joint, distracting it with spacers or cages placed between the facets, reducing the invagination and fixing C1 and C2 directly with lateral-mass or pedicle screws. The aim is to restore the height of the craniovertebral junction, the length of the neck and the cervical curvature, while avoiding decompression in most cases. Subsequent techniques — including distraction-compression-extension-reduction (DCER) approaches, intra-articular distraction with anterior cages, and quantitative posterior reduction — report durable correction and improvement in myelopathy through a

single-stage posterior operation.

In comparative terms, posterior reduction and fixation has progressively displaced transoral decompression for reducible, instability-driven cases, with transoral or anterior surgery increasingly reserved for genuinely irreducible ventral compression or for situations where posterior reduction has not succeeded. Reported outcomes for both posterior reduction and for transoral release combined with posterior fixation describe high rates of fusion and improvement in functional scores.

A clear caveat governs all of this. The evidence base is dominated by retrospective, single-centre and often single-surgeon series and by classification and technique papers, most prominently Goel's. There are no large randomised trials comparing decompression with realignment and fixation, and the influential "instability is the cause" framework, while internally coherent and increasingly adopted, remains debated in the literature. The choice between decompression and realignment or fixation depends on the individual anatomy and on whether the joint is found to be reducible, and is a matter for a specialist team.

Outlook

The outlook in basilar invagination depends heavily on the underlying cause, the degree and duration of neural compression, whether the joint is reducible, and the wider craniovertebral anatomy. The published surgical series, although not randomised, consistently report improvement in myelopathy and high rates of bony fusion following both posterior realignment and fixation and front-and-back combined approaches in appropriately selected cases. The shift towards understanding much of the condition as a consequence of atlantoaxial instability has, for many specialists, made a one-stage posterior operation a realistic route to relieving pressure on the brainstem and cord without removing bone from the front. As with any craniovertebral-junction condition, the picture is individual, and management sits within specialist multidisciplinary care.