

Jefferson Fracture

A patient guide

In brief: A Jefferson fracture is a burst fracture of the atlas, the ring-shaped first vertebra of the neck (C1), in which the bony ring breaks in two or more places at once and the side pillars are forced outwards. What sets it apart from other atlas injuries, and from atlantoaxial instability, is a single underlying question: did the burst also tear the transverse ligament that anchors the top two neck bones to one another? The answer to that question, rather than the appearance of the broken bone alone, is what shapes how the injury is understood and managed.

What a Jefferson fracture is

The atlas, or C1, is the topmost vertebra of the spine. It is unusual among the vertebrae in that it has no solid body and no spinous process; instead it is a closed ring of bone made up of two side pillars, called the lateral masses, joined by a shorter anterior arch at the front and a longer posterior arch at the back. The ring sits directly beneath the skull and carries the entire weight of the head, transmitting that load down onto the second vertebra, the axis or C2.

A Jefferson fracture is the specific pattern in which this ring is broken at multiple points rather than at a single point. The injury was first described in detail by the British neurosurgeon Sir Geoffrey Jefferson in 1920, who reported four cases and reviewed those previously recorded in the literature. His name has been attached to the pattern ever since. In the classical, fully developed form there are four breaks, with the anterior arch fractured on both sides and the posterior arch fractured on both sides, so that the ring separates into several fragments and the two lateral masses are free to splay outward. In practice, two-part and three-part variants, where the ring is broken asymmetrically at fewer points, are encountered more frequently than the full four-part injury.

The crucial structural feature is that the closed ring loses its integrity in more than one place. A ring that is broken at only a single point can still hold its shape reasonably well, because the rest of the loop continues to brace it. Once the ring is broken at two or more points, it can open up, and the lateral masses are pushed apart in a centrifugal, or outward, direction. This outward spreading of the side pillars is the hallmark that distinguishes a Jefferson burst from the simpler, isolated fractures of the atlas, and it is also what places the transverse ligament under tension.

The atlas ring and the axial-load mechanism

The mechanism behind a Jefferson fracture is consistent and helps explain why the ring breaks the way it does. The injury is produced by an axial load: a force that travels straight down through the long axis of the spine, entering at the top of the head. Common circumstances include a fall in which a person lands on the crown of the head, a dive into shallow water, a heavy object striking the vertex, or a road-traffic collision in which the head is loaded downward against a fixed surface.

When such a force is applied, it passes from the skull through the occipital condyles, the two rounded prominences at the base of the skull that rest in the cupped superior surfaces of the atlas lateral masses. The articular surfaces between the skull and the atlas are not flat but obliquely angled, so the downward push does not simply compress the atlas straight down. Instead, the wedge shape of the joint converts part of the vertical force into a sideways, splaying force. The occipital condyles drive down and outward into the lateral masses, which are forced apart from one another. The bony ring, unable to spread without breaking, fractures at its weakest points, typically where the arches meet the lateral masses.

As the lateral masses separate, the transverse ligament, which runs across the inside of the ring, is stretched. Whether that ligament survives the stretch or fails under it is the pivotal event of the whole injury. A modest degree of splay leaves the ligament intact; a greater degree of splay can rupture it within its substance or pull its bony anchorage off the lateral mass.

A second and somewhat counter-intuitive consequence of the outward splay is that, at the moment of injury, it tends to enlarge the space available for the spinal cord rather than narrow it. The spinal canal at the level of the atlas is relatively capacious. The American surgeon Steel described this as the "rule of thirds": at C1, the spinal cord occupies roughly one-third of the canal, the dens of C2 occupies roughly another third, and the remaining third is free space. When the ring bursts outward, the canal momentarily becomes wider, not tighter. This is one reason why many people with an isolated Jefferson fracture have no injury to the spinal cord despite a dramatic appearance on imaging. The danger they carry is less about the cord at the moment of impact and more about the possibility of later instability if the transverse ligament has failed.

The transverse ligament and why it is the key

The transverse atlantal ligament, often abbreviated to TAL, is a thick, strong horizontal band of tissue that spans the inside of the atlas ring, passing behind the dens, the upward-projecting peg of bone that rises from the body of C2. The ligament inserts onto small tubercles on the inner surface of each lateral mass. Its job is to hold the dens snugly against the back of the anterior arch of the atlas, and in doing so it is the primary restraint preventing the atlas from sliding forward on the axis. Together with the smaller vertical bands that run up to the skull and down to the axis, it forms a cross-shaped structure known as the cruciate ligament. It works alongside the alar ligaments, which are the main restraints against excessive rotation.

The reason the transverse ligament dominates discussion of Jefferson fractures is that the joint between the atlas and the axis has almost no bony interlock to keep the atlas from sliding forward. There is no disc and no deep socket at this level; the surfaces are broad and relatively flat, designed to permit the wide rotation that allows the head to turn. The stability of that joint depends overwhelmingly on its ligaments, and on the transverse ligament above all. If the transverse ligament is competent, the atlas stays anchored to the dens and the injury behaves as a stable, contained bony problem. If the transverse ligament is incompetent, the atlas can translate forward on the axis, and the injury behaves as a potentially unstable problem at the atlantoaxial junction, regardless of how the bone itself looks.

This is why the bony fracture pattern, taken on its own, is an incomplete description of a Jefferson fracture. Two injuries can look very similar on a plain image of the bone yet behave completely differently, simply because in one the ligament held and in the other it did not. The competence of the transverse ligament is therefore the organising principle around which the entire assessment is built.

The Rule of Spence and the Dickman types

Because the transverse ligament cannot be seen directly on an X-ray or a plain CT image of the bone, a long-standing approach has been to infer its condition from how far the lateral masses have spread. This is the basis of the Rule of Spence. In a cadaveric study published in 1970, Spence and colleagues observed that when the combined overhang of the atlas lateral masses beyond the margins of the axis lateral masses, measured on an open-mouth view and adding together the left and right sides, exceeded roughly 6.9 millimetres, the transverse ligament had usually ruptured. The reasoning is mechanical: the ligament can only stretch so far, so a large amount of splay implies that it must have given way.

The Rule of Spence has proved durable but also imperfect, and the literature has refined it considerably. Heller and colleagues pointed out in 1993 that the standard open-mouth X-ray magnifies the anatomy by roughly eighteen to twenty per cent, so the measured overhang overstates the true displacement; correcting for this raised the practical threshold to around 8.1 millimetres on plain films. Measuring on CT, which does not magnify in the same way, avoids that particular error. More fundamentally, a biomechanical study by Woods and colleagues in 2018 found

that the ligament can begin to fail at far smaller displacements than the classical figure suggests, in the region of 3.8 millimetres. As a result, contemporary writers, including a 2022 reappraisal pointedly titled around the rule's retirement, regard lateral-mass displacement as a useful screening signal that something may be wrong, rather than as a reliable measure of whether the ligament has actually torn.

The second framework, and the one that captures the most important conceptual distinction, is Dickman's classification, published in 1996 and based on a series of thirty-nine transverse-ligament injuries. Dickman divided injuries of the transverse ligament into two types according to where the failure occurred. A Type I injury is an intrasubstance rupture: the ligament tears across its own middle, within the soft tissue itself. A Type II injury is a bony avulsion: the ligament itself stays intact, but the small piece of bone to which it is attached on the lateral mass is pulled away.

This distinction matters because the two types heal in fundamentally different ways. A Type II bony avulsion is, in effect, a fracture, and bone has a dependable capacity to knit back together when held still. The ligament's anchorage can therefore be restored by immobilisation, without an operation. A Type I intrasubstance tear is a torn ligament, and a torn ligament held under the constant tension of a load-bearing joint does not reliably heal back to its former strength. Immobilisation alone tends to fail in this situation, which is why the literature describes surgical stabilisation for Type I injuries. The bony-versus-ligamentous distinction, in short, is the reason two transverse-ligament injuries that may appear similar at first glance can have entirely different natural histories.

How it differs from other C1 injuries and from atlantoaxial instability

The atlas ring can break in several patterns, and the various classification systems, including those of Landells and Van Peteghem, of Levine and Edwards, and the more recent Gehweiler scheme, exist to separate them. An isolated fracture of the posterior arch is the commonest single fracture of the atlas; because it breaks the ring at only one region and does not allow the lateral masses to spread, it is generally a stable injury. There are also isolated fractures of the anterior arch, isolated fractures of a single lateral mass, and isolated fractures of a transverse process. What distinguishes the Jefferson pattern from all of these is that it disrupts the ring at multiple points and allows the lateral masses to splay. In the Gehweiler scheme, the combined anterior-and-posterior-arch burst is the Jefferson type, and it is further subdivided according to whether the transverse ligament is intact or disrupted, which underlines once again that the ligament, not just the bone, defines the injury's character.

The distinction from atlantoaxial instability is a different kind of difference. A Jefferson fracture is, by definition, a bony injury: a burst of the C1 ring caused by axial compression. Atlantoaxial instability is not a fracture at all but a condition in which the atlas can translate abnormally on the axis. That instability can arise from many causes, including rheumatoid disease, a congenital separation of the dens known as os odontoideum, or trauma. The two ideas meet at the transverse ligament. A Jefferson fracture can cause atlantoaxial instability if, and only if, the burst also tore the transverse ligament. So the two are not competing diagnoses but linked ones: the fracture is the bony event, and the instability is the possible ligamentous consequence. The unifying clinical question, the one that runs through every part of the assessment, is simply whether the burst that broke the bone also broke the ligament.

This linkage also explains why the splaying that can decompress the canal at the moment of injury is not reassuring on its own. The immediate widening of the canal protects the cord during impact, but if the ligament has failed, the atlas may later be able to drift forward on the axis, and it is this delayed atlantoaxial instability, rather than the original burst, that represents the longer-term hazard.

How it tends to present

A Jefferson fracture typically follows a clearly remembered episode of force applied to the top of the head, such as a fall onto the crown, a shallow dive, or a road-traffic collision. The most consistent feature afterwards is pain and stiffness high in the neck, often felt at the very top, beneath the skull, and sometimes radiating towards the back of the head. People frequently hold the head rigidly and are reluctant to turn or nod, because movement at the upper neck aggravates the discomfort.

A striking feature of the isolated injury is that, despite the alarming appearance on imaging, the spinal cord is often uninjured, for the reasons described above concerning the outward splay and the generous reserve space at this level. Many people are therefore neurologically intact, with normal power, sensation and reflexes in the limbs. When there are neurological features, or symptoms arising from nearby structures, these are recognised as warranting careful evaluation. Because the upper neck is anatomically close to the lower cranial nerves and the vertebral arteries, occipital and suboccipital symptoms are sometimes described. It is also relevant that the atlas is frequently injured together with the axis below it: a substantial proportion of atlas fractures, reported in the region of four in ten, are accompanied by a fracture of C2, and the presence of such a combined injury independently influences how the whole problem is regarded.

How it is assessed (CT, open-mouth view, MRI for the ligament)

Assessment of a Jefferson fracture proceeds in layers, each answering a different question. The first question is what the bone is doing, and computed tomography is the standard tool for that. A CT scan shows the fracture pattern in fine detail: how many fragments there are, where the breaks lie, how far the lateral masses have displaced, whether the fragments remain congruent, and whether there is an associated fracture of the axis. CT has largely superseded plain radiography for defining the bony anatomy, because it resolves overlapping structures that an X-ray cannot.

The second question is what the displacement implies about the transverse ligament. Historically this was estimated from the open-mouth, or odontoid, radiograph, on which the combined overhang of the lateral masses is measured for the Rule of Spence. The equivalent measurement can now be taken from a coronal reconstruction of the CT, which avoids the magnification that affects plain films. This measurement is treated as a screening signal rather than a verdict, for the reasons set out earlier.

The third question, and increasingly the decisive one where the displacement is borderline, is the actual condition of the transverse ligament. Magnetic resonance imaging is regarded as the reference standard for looking directly at the ligament. On suitable sequences, gradient-echo imaging in particular, the normal ligament appears as a dark, low-signal band; a torn ligament may show discontinuity, swelling or a bright signal indicating fluid and bruising, and a bony avulsion may also be apparent. High-resolution MRI is therefore increasingly considered the definitive arbiter of whether the ligament has remained competent, and it is what allows a Dickman Type I tear to be distinguished from a Type II avulsion, and both from an intact ligament.

What the evidence shows about management (collar/halo vs fusion vs ring osteosynthesis)

The published literature organises management of the Jefferson fracture around the same axis that organises its assessment: the integrity of the transverse ligament, together with the degree of bony displacement and the presence or absence of an associated axis fracture.

Where the transverse ligament is competent and the injury is consequently regarded as stable, the literature describes non-operative management with external immobilisation. For minimally displaced injuries this commonly means a rigid cervical collar; for injuries that are more displaced but in which the ligament is intact, a halo vest has historically been used to hold the upper neck still while the bone heals. Long-term outcomes from the older series, including the work of Hadley and colleagues in 1988, of Levine and Edwards in 1991, and of

Landells and Van Peteghem in 1988, are reported as generally good, although residual neck pain and stiffness are not uncommon afterwards.

Where the transverse ligament is incompetent, and particularly where the failure is a Dickman Type I intrasubstance tear, the injury is regarded as unstable at the atlantoaxial joint, and the historical approach has been surgical fusion of the atlas to the axis. Such a C1–C2 fusion restores stability but does so at the cost of roughly half of the neck's rotation, because most rotation of the head occurs at precisely this joint. A Dickman Type II bony avulsion occupies an intermediate position: because it is a bony injury, it can often be managed with halo immobilisation, with the avulsed fragment healing and stability being restored without fusion.

The contemporary literature also describes a surgical evolution intended to spare neck movement. Motion-preserving C1-ring osteosynthesis aims to reduce and fix the broken ring itself, typically with screws placed into the lateral masses and a connecting rod across the back, rather than fusing the atlas to the axis. A multicentre, prospective, randomised controlled trial reported by Chen and colleagues in 2022, with five years of follow-up, found C1-ring osteosynthesis superior to C1–C2 fixation and fusion for long-term neck pain and for preservation of physiological cervical motion, with no difference observed in healing or in complication rates. Guideline documents, including the AANS/CNS guideline published by Ryken and colleagues in 2013 and the consensus recommendations of the German DGOU spine section, anchor their algorithms on ligament integrity and on whether the atlas fracture is isolated or combined with an axis fracture. Several authors, including the 2019 reappraisal by the Radcliff group and the 2022 critique of the Rule of Spence, caution that neither the Rule of Spence nor Dickman's classification predicts instability perfectly, which is part of why direct imaging of the ligament has assumed such importance. The selection among collar, halo, fusion and ring osteosynthesis is an individual matter that depends on the full picture and is determined by appropriately qualified specialists.

Outlook

The outlook for a Jefferson fracture depends heavily on the very distinction that defines the injury. Where the transverse ligament has remained intact, the injury is a contained bony problem with a generally favourable course; the bone tends to heal with immobilisation, the spinal cord is usually unharmed, and the principal residue is often some long-term neck stiffness or aching rather than any threat to function. Where the ligament has failed, the picture is more complex, because the lasting concern is the stability of the joint between the atlas and the axis rather than the healing of the bone, and restoring that stability may involve surgery. Even then, the modern shift towards motion-preserving techniques means that the historical trade-off, in which stability was bought at the price of half the neck's rotation, is no longer the only path described in the literature. Because the atlas is so often injured alongside the axis, the broader outlook is also shaped by any accompanying C2 fracture. Across the spectrum, the recurring theme is that the bone usually heals; it is the condition of the ligament that determines how straightforward, or how involved, recovery proves to be.