

Cage Subsidence

A patient guide

In brief: Cage subsidence is the gradual sinking of an interbody fusion cage into the bone of the vertebra above or below it after spinal fusion surgery. An interbody cage is a small spacer placed in the space left after a worn disc is removed; it restores height, opens the nerve exit channels and acts as a scaffold for the bones to fuse. Subsidence occurs when the bony surface of the vertebra, the endplate, yields under the cage and allows it to settle downwards into the vertebral body. A modest degree of settling is common, frequently causes no symptoms, and may even help the bone and the implant share load more naturally. The concern lies at the other end of the scale, where severe or progressive subsidence undoes the height and alignment that the operation achieved, narrows the nerve channels again, and may accompany a failure of the fusion to solidify. The single most important idea is that this is the bone giving way under the cage, which sets it apart from the metalwork itself breaking.

What cage subsidence is (and why the bone, not the metal, is the issue)

When a worn or damaged disc is removed during a spinal fusion, the space it leaves behind is filled with an interbody cage. This cage has several jobs at once. It props the two vertebrae apart to restore the natural height of the disc, which in turn opens up the small bony tunnels, the foramina, through which the nerve roots leave the spine. It helps to restore the gentle forward curve of the lower spine, the lordosis. And, packed with bone graft, it provides a stable scaffold across which the two vertebrae can knit together into a single block of bone, the fusion.

The surfaces of the vertebrae that the cage rests against are called the endplates. Each endplate is a thin layer of dense bone covering the softer, spongy bone of the vertebral body beneath. Cage subsidence is the process by which this endplate gives way, allowing the cage to sink, or telescope, into the vertebral body. In effect, the implant presses into the bone and the bone yields.

This is the heart of what makes cage subsidence a distinct entity, and it is worth stating plainly because it is so often confused with other problems. Subsidence is a failure of the bone, not of the metal. The cage itself usually remains structurally intact; what changes is its position, because the bony platform it stands on has given way beneath it. The endplate, and the bone immediately under it, is the weak link in the construct.

That framing explains why bone quality dominates the whole subject. A cage of a given size and material will behave very differently when it rests on the strong, dense bone of a younger or healthier spine than when it rests on the thinned, weakened bone of an osteoporotic one. The same operation can produce a stable, well-seated cage in one person and a sinking cage in another, and the difference very often lies in the bone rather than in the implant.

Why a little settling is normal, and even helpful

It would be a mistake to regard all subsidence as a complication. A degree of early, minor settling is extremely common after interbody fusion, frequently causes no symptoms at all, and is widely understood as part of the way the construct beds in.

The reasoning is mechanical. Immediately after surgery, a relatively stiff cage sits on a relatively thin endplate, and the load passing through the spine is concentrated at that interface. As the cage settles a small amount into the bone, the contact area broadens and the load is shared more evenly between the implant and the surrounding bone, rather than being borne at a few sharp points. In this sense a small amount of settling can improve the way the implant and the bone work together.

The literature describes this benign settling as a process that tends to occur early, often within the first weeks, and then to stop. Once the fusion begins to mature and new bone can carry the load across the cage-to-endplate interface, the settling no longer progresses. Studies of lateral fusion have drawn a clear distinction between this late, self-limiting settling, regarded as part of normal healing, and a more troublesome pattern in which the endplate is breached at the time of surgery and the cage then continues to sink to a greater degree. It is the progressive, larger-magnitude subsidence, not the small early settle, that carries the clinical concern.

How cage subsidence differs from its neighbours

Cage subsidence is frequently confused with several other things that can go wrong after a fusion, and distinguishing them is central to understanding it.

****It is not hardware failure.**** Hardware, or implant, failure means the metal itself failing, a screw fracturing or loosening, a rod snapping, a cage cracking or backing out. Subsidence is different in kind: the metalwork is usually intact, and it is the bone that has yielded around it. One is a problem of the implant, the other a problem of the bony platform the implant rests on.

****It is not the same as pseudarthrosis, although the two are linked.**** Pseudarthrosis, or non-union, means that the two vertebrae have failed to knit together into solid bone across the disc space. Subsidence and non-union are related but separate ideas. Subsidence can contribute to non-union, because a sinking cage creates ongoing micromovement and an unstable interface across which bone struggles to bridge; and the two can occur together, since continued motion drives both. Yet a good deal of minor subsidence happens in segments that go on to fuse perfectly well, and some studies have found no clear link between subsidence and whether or not fusion is achieved. The two are best held in mind as overlapping but distinct.

****It is not adjacent segment disease.**** Adjacent segment disease is wear and degeneration at the level next to the fusion, developing over years as the neighbouring disc takes up altered loads. Subsidence happens at the operated level itself. The two can be connected, in that severe subsidence with loss of alignment may, over time, place extra strain on the neighbouring levels, but they are different problems occurring in different places.

Holding these distinctions clearly is what allows subsidence to be recognised for what it is: a settling of the implant into yielding bone at the fused level, separate from the metal breaking, from the failure to fuse, and from wear at the next level along.

When subsidence matters: loss of correction and recurrent symptoms

Most subsidence is minor and silent. The clinically important entity is severe or progressive subsidence, and it matters because it can quietly reverse the very things the operation set out to achieve.

The first consequence is loss of correction. As the cage sinks, the disc height it was holding open is lost again, and with it some of the restored lordosis. The segment can settle into a more forward-bent, kyphotic position. In operations that rely on opening the disc space to take pressure off the nerves indirectly, particularly the lateral approaches, this loss of height directly undermines the decompression that was gained.

The second consequence follows from the first. As height is lost, the nerve exit channels, the foramina, narrow once more. This recurrent foraminal narrowing can bring back the radiating nerve pain, the radiculopathy, that the surgery was intended to relieve, along with a return of back or neck pain at the operated level.

The third consequence is the link to non-union already described. Severe subsidence and the micromovement that accompanies it are associated, in some series, with higher rates of failure to fuse, which can in turn perpetuate symptoms.

It is important, though, to keep these consequences in proportion. Across the published literature, the majority of subsidence is focal and minor, and large reviews have repeatedly found that radiographic subsidence does not reliably translate into worse symptoms or pain scores. The relationship between what is seen on a scan and what a

person experiences is, at most, loose. This is a description of associations reported in groups of patients, not a prediction for any individual.

How common it is, and where it occurs

Subsidence is one of the most commonly reported radiographic findings after interbody fusion, with figures that vary widely according to the type of operation and, crucially, the threshold used to define it.

In anterior cervical fusion of the neck, a large systematic review of seventy-one studies covering more than four and a half thousand patients reported a mean incidence of around twenty-one per cent, with individual studies ranging from none at all to over eighty per cent. In lateral fusion of the lower back, reviews report subsidence in roughly a quarter to a third of levels, with stand-alone constructs at the higher end. In anterior lumbar fusion, rates of around a fifth to a quarter are described. The very wide spread reflects how differently subsidence is defined from study to study as much as any real difference between operations.

The location is also patterned. The upper, or cranial, endplate is mechanically weaker than the lower one, and subsidence and endplate injury are observed most often there. This is one reason the bone immediately beneath the upper endplate receives particular attention.

What measurement thresholds mean

There is no single agreed definition of cage subsidence, and this is a recurring frustration in the literature. Different studies measure different things, which is why reported rates are so variable.

The commonest approach is to measure the loss of disc or interbody height, comparing a scan taken immediately after surgery with a later one, and to call it subsidence once the loss crosses a set threshold. The most frequently used thresholds are a loss of two millimetres or more, with some studies using a stricter cut-off of three millimetres, a figure especially common in cervical work. A widely used refinement labels a two-millimetre loss as minor and a three-millimetre loss as major.

Other studies, particularly of lateral fusion, express subsidence as a percentage of the disc height lost, using a graded scale that runs from minimal loss through to almost complete collapse, and many take a loss of a quarter of the height as the point at which subsidence is declared. Because these methods are not interchangeable, the same spine could be counted as having subsidence under one definition and not under another. This is the main reason the published rates differ so much, and why the number alone means little without knowing how it was defined.

Why it happens: bone quality, endplates, cages and fixation

The factors that drive subsidence can be grouped into the quality of the bone, the handling of the endplate, the design and placement of the cage, and whether the cage stands alone or is supported.

****Bone quality is the dominant factor.**** Low bone mineral density, and osteoporosis in particular, are the strongest and most consistent risks, with several analyses placing the risk in osteoporotic bone at roughly double that of normal bone. Weak bone concentrates stress at the cage-endplate interface and yields more readily. A growing body of work shows that bone quality measured specifically at the endplate, rather than averaged across the whole vertebra, predicts subsidence best, whether assessed by the density of the bone on a CT scan, by signal on an MRI scan, or by formal bone density testing. The practical message running through this literature is that the state of the bone is the backdrop against which everything else plays out.

****The endplate and its preparation matter greatly.**** The dense layer of subchondral bone just beneath the cartilage is far stronger than the spongy bone below it. When the endplate is breached, or too much of this strong layer is removed during preparation, the cage is left resting on weak bone and subsides more readily. Biomechanical work shows that the stress on the endplate, and the tendency to subside, rises steeply as the endplate is thinned, and especially so in osteoporotic bone. A breach made at the moment of surgery, an intraoperative endplate injury, is particularly associated with progressive sinking afterwards. Preserving as much

of the strong subchondral bone as possible is repeatedly identified as protective.

****Cage design and position contribute.**** The cage's footprint, the area over which it contacts the bone, is important: a larger footprint that rests on the strong peripheral rim of the endplate, the apophyseal ring, spreads load and resists subsidence, while a small or poorly matched footprint concentrates it. Excessive cage height, and over-distraction of the disc space to insert an oversized cage, over-tension the endplates and raise the risk. Cage position plays a part too, with a cage placed too far forward, away from the stronger posterior bone, identified as a risk in anterior lumbar fusion. Cage material, typically a plastic called PEEK whose stiffness is close to that of bone, or titanium which is stiffer, has been studied extensively, but the evidence is mixed and subsidence is clearly multifactorial rather than explained by material alone.

****Standing alone versus being supported makes a difference.**** A cage placed by itself, without supplementary screws and rods, allows more micromovement and subsides more often than one supported by posterior fixation, which provides immediate rigid stability. This is one reason stand-alone constructs are consistently reported with higher subsidence rates.

****The approach shapes the pattern.**** Lateral and oblique fusions place a broad cage spanning the strong outer rim of the endplate, which is biomechanically favourable, but because these operations rely on maintaining height to keep the nerves decompressed indirectly, subsidence directly threatens that decompression. Posterior approaches use a smaller cage on more central, weaker bone but are usually supported by screws. Anterior lumbar fusion uses a large cage whose position and stand-alone status influence the risk. Cervical fusion, with its smaller endplates, shows a high background rate that is reduced by adding screws or integrated plates. These are tendencies described in the literature rather than rules for any case.

How it is assessed

The assessment of cage subsidence rests on serial imaging, comparing the position and height achieved immediately after surgery with later studies to judge whether, and how much, the cage has settled.

****Plain X-rays****, including views taken in bending forwards and backwards, are the standard means of measuring the loss of disc and segmental height over time and of looking for any associated instability or signs that the fusion has not taken.

****Computed tomography, the CT scan****, is the most detailed way of examining the interface between the cage and the bone. It shows whether the endplate has been breached, demonstrates the bridging bone that signals a solid fusion, and measures how far the cage has migrated into the vertebral body. The density of the bone on a CT scan, expressed in Hounsfield units, also serves as a measure of bone quality that has been shown to predict both subsidence and the likelihood of further surgery.

****Magnetic resonance imaging, the MRI scan****, is used to assess the bone marrow and endplate changes, to look at whether the nerves are being compressed again, and increasingly to grade bone quality through scoring systems based on the signal of the vertebrae.

****Bone density testing****, such as a DEXA scan, formally measures bone mineral density, which is central to understanding the backdrop against which subsidence occurs. Together these tests describe both the mechanical situation of the cage and the quality of the bone supporting it.

What the evidence shows about management (observe vs revise) — impersonal

It is important to be clear at the outset that the evidence base for managing cage subsidence is built almost entirely on retrospective series, biomechanical and cadaveric experiments, computer-based simulation studies and narrative reviews. There are no large randomised trials that define when subsidence should be treated, nor agreed numerical thresholds for intervention. The descriptions that follow report what the literature observes, not guidance for any person, and decisions in practice are individualised.

****Observation**** is the course described for the great majority of subsidence, which is minor, stable and without symptoms. Such settling is frequently understood as part of normal cage incorporation and load-sharing, and most published series report that no revision surgery was needed for subsidence alone. Where subsidence is detected but the segment is settling within the expected early window and then stabilising, the literature treats it as part of the healing process rather than as a complication to be acted upon.

****Attention to bone health**** is a recurring theme on the preventive side. Because low bone density is the dominant risk, the assessment and treatment of osteoporosis before surgery, together with endplate-sparing technique, careful cage sizing and the use of supplementary fixation where appropriate, are described as the principal levers for reducing subsidence in the first place.

****Revision surgery**** is reserved in the literature for the minority of cases where subsidence is severe or progressive and is causing problems: significant loss of correction with developing kyphosis, recurrent narrowing of the nerve channels producing radicular pain, an established and symptomatic failure to fuse, or instability. The reconstructive options described include adding or revising posterior instrumentation to provide stability, exchanging the cage for one with a larger footprint or an expandable design, restoring the lost height and alignment, and addressing the underlying bone quality. Open revision surgery carries its own recognised risks, which the series document, and so the threshold for undertaking it is weighed against the severity of the problem.

In summary, the evidence points towards observation for the common, minor and stable form of subsidence, prevention through bone-health optimisation and sound technique, and reconstructive surgery reserved for the severe, progressive and symptomatic minority, all within a framework of individualised, shared decision-making rather than fixed rules.

Outlook

The outlook in cage subsidence is, for most people, reassuring, and it tracks closely with the distinction between minor settling and severe sinking. The common, minor form tends to be self-limiting, stabilising once the fusion matures, is compatible with a solid fusion and a good result, and large reviews have repeatedly failed to find a reliable link between this kind of radiographic settling and worse symptoms.

The concern lies with the severe and progressive form, which can undo the height, alignment and indirect decompression that the operation achieved, bring back nerve and back or neck pain, and sometimes accompany a failure of the fusion to consolidate. Even here, much depends on the surrounding circumstances: the quality of the bone, the magnitude and progression of the settling, the type of operation, whether the cage was supported by additional fixation, and, above all, whether the fusion ultimately takes.

Across the whole field, the consistent themes are that bone quality is the dominant backdrop, that a small amount of early settling is normal and often beneficial, that the appearance on a scan and the symptoms a person feels are only loosely related, and that any individual outlook is a matter for assessment by the treating team rather than something that can be read from a category or a measurement alone.