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Approaches in injections for radicular pain: The transforaminal, epidural and transfacet approaches

P. Brunner\textsuperscript{a,∗}, N. Amoretti\textsuperscript{b}, F. Soares\textsuperscript{a}, E. Brunner\textsuperscript{a}, É. Cazaux\textsuperscript{a}, O. Brocq\textsuperscript{a}, S. Chanalet\textsuperscript{a}, M. Liberatore\textsuperscript{a}, J.-M. Cucchi\textsuperscript{a}, M.-Y. Mourou\textsuperscript{a}, G. Michelozzi\textsuperscript{a}, C. Robino\textsuperscript{a}

\textsuperscript{a} Princesse Grace Hospital, 1, avenue Pasteur, BP 489, 98012 Monaco Cedex, Principality of Monaco
\textsuperscript{b} L’Archet Hospital, Nice University Hospital, 151, route Saint-Antoine-de-Ginestière, 06202 Nice cedex 3, France

KEYWORDS
Spine; Pain; Injection; Transfacet injection

Abstract Spinal injections must be carried out adhering to very strict conditions. However, these procedures have almost come to be seen as everyday and may be practised under quite questionable conditions. The recent reports of new and extremely serious neurological complications have changed the attitudes of those making referrals as well as the attitudes of the interventional radiologists carrying out these procedures. The range of indications for transforaminal injections has shrunk in favour of epidural injections. Where the transforaminal approach is still used, the needle must be positioned extremely accurately. A prior radioopaque contrast medium injection is essential from a safety perspective. The transforaminal epidural injection via the transfacet approach looks to be a promising alternative that is strictly avascular.

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Spinal injections are gaining an increasingly important role in the management of lumbar radicular pain, cervicobrachial neuralgia, and degenerative spinal diseases. These techniques may be offered when conventional treatments have proved to be ineffective or not effective enough, and they allow patients to continue through a ‘‘peak’’ and to give themselves time to recover; in these cases symptoms usually spontaneously progress favourably.

In radicular syndrome, the pain is caused by both mechanical and inflammatory phenomena. The mechanical causes are of two types: direct pressure from the structure responsible (herniated disc, foraminal stenosis, central canal stenosis, facet joint synovial cysts), or secondary problems related to local microvascularisation changes

∗ Corresponding author.
E-mail address: pbrunner@chpg.mc (P. Brunner).

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http://dx.doi.org/10.1016/j.diii.2012.07.005
(mainly epidural venous plexus congestion). The inflammatory phenomena result from a cascade of biochemical and enzymatic events that are involved in releasing inflammatory mediators, in particular phospholipases released from the nucleus into the epidural space, as well as numerous other inflammatory mediators (prostaglandins, leucotrienes, TNF-alpha). A fall in nociceptive C-fibre conduction is also a factor that can generate pain. This inflammatory response, which causes chemical radiculitis, is clearly demonstrated on MRI by contrast uptake at the point of contact causing the disc-nerve root irritation. It is currently accepted that according to statistics mechanical irritation is responsible for approximately 40% of cases and inflammation for 60% of cases [1].

The principle behind these image-guided spinal injections is to deliver an active substance (cortisone derivative, local anaesthetic, etc.) by placing it as close as possible to the intended target, presumed to be the source of the pain, in order to inhibit the cascade of inflammatory response. In current practice, these techniques are mainly used to treat the mid and lower lumbar spine and the cervical spine, as these are the most common sites of disc pathologies and/or osteoarthritis and it is here that symptoms are most pronounced. Over the past few years, the practice of these injections has grown considerably. Medicare statements have shown a significant increase in these interventions in the United States [1]: between 1994 and 2001 the number of epidural injections increased by 271%, and posterior articular injections by 231%; between 2002 and 2006, the number of epidural injections increased by 59% and posterior articular injections by 178%. The management of radicular pain accounted for 40% of these injections, while 36% were for simple lower back pain and 24% for spinal canal stenosis [2]. At the same time, the incidence of sciatica grew by between 0.5 and 1% a year. The considerable increase in these procedures is based on a broad consensus among clinicians who witness the exceptional benefit that these techniques offer on a daily basis in their practice. To date, there have only been a few essentially open studies that have provided analytical and scientific support for this broad medical consensus.

It therefore seemed that things were getting better in the "everyday" procedures of interventional osteoarticular radiology until the first new, often irreversible, and very serious neurological complications were described [3,4]. These complications were not the usual and almost reassuring ones (those which are usually treatable) such as infections (epidural abscess), allergies, dural puncture, etc., but they were of a new type that very little was known about or clear and they were difficult to predict. Since then more than 30 cases of complications of paraplegia and tetraplegia related to ischaemia of the spinal cord have been described in the literature. At first, various reasonably rational explanations were put forward, all involving the radicular arteries, such as an injury (dissection) by the injection needle or a spasm caused by the local anaesthetic. It is now accepted that the most important feature in the pathophysiology of these accidents is usually connected to the accidental catheterisation of one of the radicular arteries [5] that is then injected with a non-hydrolysable cortisone derivative, and this coalesces to lead to embolisation of these arterioles as well as the anterior spinal artery lower down. The drastic outcome of this is spinal cord ischaemia [6–9]. Less frequently, other arterioles can be involved depending on the injection target and the part of the spine involved: vertebral arteries, deep or ascending cervical arteries, the arteries of the conus medullaris, new arterioles linked to angiogenesis.

A second explanation that has recently been offered is that some cortisone derivatives have a modulatory effect on erythrocyte morphology that could trigger red blood cell deformities and thus encourage their propensity to aggregate. Panic spread through the field of interventional radiology, with Afssaps (the French health products safety agency) issuing warnings in collaboration with the French Rheumatology and Radiology Societies, to officially alert the profession to the risks of these procedures. The recommendations in the latest warning from Afssaps (March 2011) were: "patients undergoing cervical spine injections must be informed of the inherent risks of these extremely serious neurological complications, and spinal injections should only be used to treat pathologies that are resistant to the standard non-invasive treatments. Catheterisation of the foramina should be avoided in order to keep away from any arteries that perfuse the spinal cord and finally injections should be avoided in patients who have had spinal surgery".

The major problem for those in the imaging profession is that the vessels that are the source of these potential risks (the radicular arteries) cannot be identified on the image guidance techniques currently in use and their probable locations remain uncertain due to anatomical variations.

Therefore, it has been and continues to be necessary to find technical methods for reducing these risks of extremely serious complications as far as possible. We will discuss the various techniques of spinal injections that we practise on a regular basis, from a perspective of a practice that always looks to avoid arteries that have the potential to cause complications.

**Transforaminal nerve root injections**

Transforaminal injections have for a long time been considered to be the gold standard of these types of injections. Indeed, the rationale for transforaminal injections is to inject the active product or products targeting only the point of contact where a nerve root passes through its foramen while trying to avoid "contaminating" the over-and underlying roots [10]. The idea is certainly tempting, fitting in with the principle: "only treat what is causing pain". These injections have been carried out for over 20 years using different techniques that involve inserting needle relatively deeply into foramen. This has two objectives: to treat pain and to diagnose, as specific nerve root involvement can be confirmed using nerve blocks carried out with local anaesthetic when imaging has not shown what the source of the problem is or if it has highlighted other potential areas of irritation that could have produced the patient’s symptoms. CT-guidance is the best modality to use when targeting the nerve roots in the intervertebral foramina.
Approaches bypassed yield the positioning in the needle. A pre-curved needle can be steered towards the target by a gentle pressure on its bevel. It can also be used like a key to bypass obstacles, while a straight needle offers less ballistic flexibility because it can really only be moved forwards and backwards and there is much less opportunity to change the rectilinear trajectory by applying pressure to the bevel. The needle is advanced gently with local anaesthetic being injected at the same time. The target is the posterior articular process. Once contact with the bone has been established, the articular process should be bypassed as far as edge of the foramen (Fig. 1). An injection of 1 ml of non-ionic contrast medium allows an image of the radicular arteries to be obtained and very often also an epidurogram and foraminogram, although this depends on the calibre of the foramen as well as on whether or not there is an occupying process (herniated disc) that would form an obstruction to the contrast medium diffusing within the space. Next, it is best to inject 1 ml of local anaesthetic and wait for one minute. If the patient does not report any unusual sensations, the active product is then gently injected.

What are the classic errors in positioning needles for lumbar transforaminal injections?

Dorsal root ganglion puncture. It is essential to avoid this very painful puncture by carefully controlling needle progression. This inappropriate puncture does not yield any information in terms of diagnosing the nerve root involved and it does not improve the efficacy of the procedure. Use of a pre-curved needle allows for a more medial positioning in relation to the dorsal root ganglion and it is the best way to avoid accidentally puncturing it.

A contrast injection must always be used to check for this inappropriate puncture, and the image demonstrated would be an annulogram, or even a discogram. Withdrawing the pre-curved needle by a few millimetres and possibly slightly rotating it will allow it to be correctly repositioned in the lateral part of the foramen.

Vascular puncture. This is a potentially dangerous type of puncture that must always be checked for by firstly carrying out an aspiration test and most importantly by use of a contrast medium. If there is no contrast seen on the control views, a punctured arteriole should be suspected; if contrast is visible in the neighbouring soft tissue then venous passage is likely. The needles must of course be repositioned each time. Carrying out this test is not a guarantee that there is no accidental puncture: this is because punctures of the small arterioles may not lead to a blood positive aspiration “test”, as although it has almost 100% specificity, it has below 50% sensitivity. A local anaesthetic test is also always very useful and is recommended.

Cervical spine

Cervical transforaminal injections have been practised for more than 20 years. Several open studies report good and very good results in over 60% of patients treated [1]. Approaching a foramen in the cervical spine is a procedure that is even more likely to cause problems and it must be seriously discussed beforehand with all involved parties (referring doctor, radiologist carrying out the procedure, patient). It is carried out under very strict conditions. It should preferably by CT-guided and carried out by an experienced operator who will be able to achieve optimal positioning of the needle tip. It is essential to use a contrast medium. In situ local anaesthetic injection is strongly recommended. There are two possible approaches to the foramen:

- anterolateral approach: this approach is slightly more uncomfortable (for the patient) than the posterolateral approach; it is also less satisfactory from a technical viewpoint. After bypassing the neurovascular bundle of the neck, the needle, which is usually straight, is steered following the axis of the foramen as far as its posterior and lateral part. As with lumbar injections the contrast

![Figure 1](image-url)  
Figure 1. Transforaminal injection L4-L5: a: pre-curved needle in contact with the lateral part of the foramen; b: injection of 1 ml of contrast medium, radiculogram L4.
medium is then injected followed by the local anaesthetic and finally the active product (Fig. 2);

- posterolateral approach: this is the approach that we use most often. Anaesthetising the soft tissue is much less uncomfortable for the patient. A pre-curved needle is advanced until it comes into contact with the lateral part of the articular process. Once contact has been made with the most lateral part of the posterior wall of the foramen, the contrast medium is injected, followed by the local anaesthetic (Figs. 3 and 4).

    Whichever approach is used, it is absolutely essential for the needle tip to remain in the lateral and posterior part of the foramen, and if possible in its superior part, further away from the nerve root. This is because the radicular arteries originate from the vertebral artery and pass around the spine to usually, but not always, enter the anterior part of the foramen, alongside the nerve root. Nonetheless, there are other arterioles passing through the posterior part of the foramen, namely the branches of the ascending and deep cervical arteries. With increasing regularity, we now also carry out an initial intravascular contrast-enhanced CT scan in order to study the vascular anatomy of the foramina, and to locate the radicular arteries and the foraminal veins.

**What are the classic errors in positioning needles for transforaminal cervical injections?**

To be sure, we can think about these errors in the same way as with lumbar transforaminal injections: anecdotally reported positioning errors can become dangerous positioning errors that must, be avoided in order to minimise as far as possible the risk of iatrogenicity.

    Joint capsule puncture: Although this puncture is unintended it does not have any detrimental impact aside from being ineffective, and it is a classic error in cervical transforaminal injections. When the needle tip makes contact with the posterior articular process, the bevel can puncture the posterior joint capsule. Often the contrast medium can be falsely reassuring; the contrast does seem to diffuse into the foramén and then behind into the epidural space homolaterally. But when the CT views are analysed more closely, the contrast is seen to diffuse into the capsule of the inferior articular process. This capsule often stretches quite far back, up to the spinous process and sometimes meets the controlateral joint capsule. It is sensible to check for this positioning error as it is a common pitfall and, of course, to reposition the injection needle.

**Figure 2.** Transforaminal injection C6-C7: a: anterolateral approach, straight needle in contact with the lateral part of the articular process; b: injection of 1 ml of contrast medium, radiculogram C7.

**Figure 3.** Transforaminal injection C5-C6: a: posterolateral approach, straight needle in contact with the lateral part of the articular process; b: injection of 1 ml of contrast medium, radiculogram C6.
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An epidural injection and, more particularly, a paramedian epidural injection is a standard procedure that has been carried out for many years, the first ones being described in 1953. Since then, there have probably been several hundred thousand patients who have benefitted from these types of injections for the treatment of spinal pain.

Who is a candidate for this injection?

These injections are indicated to treat radicular pain, especially when it is discogenic, lumbar disc pain, central canal stenosis or foraminal stenosis, etc. The epidural space extends from the foramen magnum to the sacrococcygeal ligament; it contains fatty tissue, lymphatic vessels, arterioles and a large venous plexus. This space is enclosed, partitioned off by the dura mater, the ligamentum flavum and the posterior longitudinal ligament. The posterior epidural space varies in size: in the lumbar spine it measures on average 5–6 mm, in the cervical spine on average 2 mm, and a little more around C7. All these anatomical features point to potential problems: the immediate proximity of the dura mater along the length of the spine (risk of puncture) and of the spinal cord at the cervical spine, the presence of arterioles that perfuse the spinal cord or the conus medullaris (risk of arteriole embolisation by the microparticles of the active product and due to the erythrocyte aggregation caused by the active products), and the enclosed nature of the epidural space (risk of non-homogenous or unintended distribution of the active products).

Vascular puncture: This is potentially a more serious puncture that could lead to neurological complications and it is absolutely crucial to identify it (see other chapters).

Paramedian epidural nerve root injections

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Technical points

Lumbar spine

The epidural space is approached through the interlaminar route on the symptomatic side. This space is very often open on one or several CT scan views and access can be achieved using these anatomic windows. In patients with significant lordosis and/or osteoarthritis, interlaminar access may be more complex but it will usually be possible if the injection needle is angled caudocranially. The use of pre-curved needles often allows the bone surrounding the spinal canal to be bypassed, usually passing through the opening of the vertebral arch at the junction between the lamina and the spinous process. The needle is advanced while also gently releasing the local anaesthetic; when the ligamentum flavum is breached the operator will feel this due to the classic sign of a loss of resistance on the plunger.

Once in the epidural space, 1 ml of non-ionic contrast medium is injected. The way in which it diffuses predicts how the active product that is to be injected next will be distributed (Fig. 5). If the epidural space is filled with a mass of tissue (herniated disc, fibrosis, etc.), the contrast medium will diffuse principally towards the free contralateral epidural space. It may be appropriate to inject on the damaged side at the uperlying level, based on the theory that the active product will diffuse downwards and homolaterally.

While it is possible to use injections in radicular pain linked to postoperative fibrosis, it is essential to stay away from the areas of fibrous change. This is because paraplegia-type neurological complications due to ischaemia have been described in the literature following these types of nerve root injections. These complications have been connected to angiogenesis and adhesions leading to accidental catheterisation of these new and hypertrophied arterioles. It is always possible to inject these cases following the tried and tested sacral hiatus approach but this procedure is still quite painful for the patient and results are very mixed, as the active product distributes throughout the sacral and lumbar spine before reaching the site of the fibrosis. The
alternative is a paramedian epidural injection at the vertebrae superior to the fibrosis in a clear fatty space, free from any fibrous changes, or better still a periepidural transfacet approach could be used (see description in the following section).

What are the classic errors in positioning needles for epidural injections?

**Subdural puncture**
This is a classic error that is often misread, in which the tip of the needle is positioned between the dura mater and the arachnoid mater. This constitutes a breach of the dura mater, which means that only *prednisolone acetate* can be injected, after the needle has been repositioned in the epidural space.

**Intrathecal puncture**
This event poses the same problem as a breach of the dura mater. However, this kind of puncture can also be intentional, in particular as a second line option when there has been resistance to a first epidural injection or as a first line treatment to manage severe spinal canal stenosis.

**Puncture of a nerve root sheath**
This situation is clinically identical to that of an intrathecal puncture.

**Vascular puncture**
There is no doubt that this situation is underestimated. Blood reflux after aspiration is a very unreliable test that can be falsely reassuring. It is therefore essential to inject a contrast medium before the active products are injected. If a vein is punctured, this would have no detrimental consequences aside from being therapeutically ineffective; in this case the contrast would be seen in the epidural and foraminal venous plexuses and often in the adjacent perispinal muscular venous network. An arterial puncture, on the contrary, can have drastic consequences involving the previously described risk of embolism. The contrast medium would not be visualised because it would have passed into the arterial system. Therefore, if no contrast medium is visible it is crucial not to inject the active product.

**Posterior articular process puncture**
This situation is a serious pitfall, and a classic error that can be made with paramedian epidural injections. This is because when the facet joint is punctured, the operator will once again feel a loss of resistance in the plunger of the syringe for injection, just as when the ligamentum flavum is passed and the epidural space entered.

**Cervical spine**
Radiologists carrying out injections are often wary of the paramedian epidural approach in the cervical spine; this area may be the source of looming fears and so there are not many teams who carry out this kind of procedure. Those who do practise cervical injections often only do so using the transfacial approach because the needle remains away from the spinal cord. The real problem is not the spinal cord but the radicular arteries that are involved in its vascularisation. Epidural or transfacial epidural injections therefore have a clear place in the management of cervicobrachial neuralgia that is resistant to conventional treatments.

The interlaminar approach can also be used; the feeling of a loss of resistance in the plunger is very much less marked in the cervical spine because the ligamentum flavum is much thinner and there is less negative pressure in the epidural space. It is essential for the needle to always remain tangential to the spinal cord, with the opening of the bevel oriented towards the centre of the spinal canal [11,12]. One millilitre of contrast medium is injected before the active product (Figs. 6 and 7). It is relatively easy to achieve diffusion of the active product towards the pre-foraminal to foraminal space by rotating the needle and consequently the bevel opening. The risk of puncture and catheterisation of an arteriole within the spinal canal that perfuses the spinal cord is much lower due to the needle being perpendicular to the courses of these arterioles, meaning that it is rarer for one of these arterioles to be accidentally catheterised.

**Transfacet approach nerve root injections**
This type of injection is in the process of radically changing our daily practice of injections. The idea was originally
Approaches

avascular: where taking antiplatelet aggregant agents, because it was difficult to find a window in their treatment or to alternate their antiplatelet aggregant agents with low molecular weight heparin. What was therefore required was a nearby avascular area through which active products could be administered. There were only two sites considered to be avascular: the intervertebral disc and the facet joints.

The facet joint has for a long time been the ideal target in patients with lower back pain, and on arthrograms of the facet joints prior to injections it is quite common to see the contrast medium passing into the epidural space or where the foramina meet the epidural space. In this way, the concept of epidural infiltration via the transfacet approach was developed, no longer only to benefit these patients taking antiplatelet aggregant agents but also to stay further away from the foramina, which are spaces that carry such high risks.

Technical points

The whole issue of these injections revolves around how it is possible to obtain passage into the epidural space. How can passage into the epidural space be forced? Furthermore, after carrying out injections to the lumbar spine on a daily basis, we also began to apply this concept to the cervical spine.

Of course, the standard approach via the inferior joint recess under radiological guidance is not wholly suited to this technique; in fact the position needs to be above where it would be for the usual approaches, and then the joint space is catheterised to a varying depth in order to inject the contrast medium with a pressure that is also variable, in the hope of achieving a breach of the capsule on the side of the joint within the spinal canal. This means that the aim of our work is to understand how to achieve a breach of the capsule. In which facet joints do the capsules tear and which tear with greatest ease? There is still no clear answer to this question; it is possible to provide some aspects of an answer based on day-to-day practice. Indeed, when we carry out any of these injections targeting the epidural space or foramen and epidural space we first carry out an intrarticular injection on the same side as and at the level of the nerve root to be injected in an effort to cause a breach to the capsule and achieve passage to the epidural space or foramen and epidural space. The underlying aim is to avoid an epidural or transforaminal injection, which would then no longer be necessary (Figs. 8–10). Based on the almost 2000 injections that we carry out in this way every year at our Spine Centre, it appears that highly osteoarthritic joints “tear” more easily. Younger subjects, on the other hand, have joints that have suffered less degeneration and so they facilitate easier and deeper catheterisation, meaning that it is possible to fill them completely before obtaining reflux along the length of the needle and therefore to achieve a breach on the side within the spinal canal. If there is resistance to the tear, there are a range of technical options that can be tried: continue attempting to catheterise the joint space, create a mechanical breach by cutting the capsule with the bevel of the needle, pressurise and depressurise the joint compartment by aspirating and injecting a radioopaque contrast medium, or inject air as well as contrast, as injecting this double state (solid-gas) weakens the joint capsule. In the cervical spine, the configuration is identical and this procedure is without doubt even more valuable than it is in the lumbar spine (Figs. 11–14). This is because

Figure 6. Epidural injection C6-C7: a: needle in the lateral epidural space via the translaminar approach; b: injection of 1 ml of contrast medium, lateral epidurogram.

Figure 7. Epidural injection C5-C6. Needle in the lateral epidural space, injection of 1 ml of contrast medium, epidurogram foraminogram C5-C6.
there is no longer a needle in the foramen which means there is no longer a risk of injuring or embolising a radicular artery; equally, there is no longer any need to worry about making the error of placing the needle in the spinal canal close to the spinal cord. This approach is also routinely attempted as a first line treatment for any lumbar spine injection that is carried out for postoperative fibrosis, as this is a situation with a high risk of neurological complications.

**Discussion**

Spinal injections carry a risk, although it is certainly very low, of extremely serious neurological consequences. The first complications of this type were described in 1998. Since then, over thirty cases have been described. The complications involve spinal cord ischaemia or cerebellar infarct or even ischaemia of the conus medullaris. This risk, although low, nonetheless remains very real. The teams who have seen these types of complications have often been very experienced in this kind of procedure; the frequency of these complications is somewhere between one accident in every several thousand injections and one in every several tens of thousands of injections and here lies the problem: we are no longer talking about the exceptional, but the extremely rare yet still possible! The riskier situations now appear to have been identified and so it is important to attempt to avoid them, and to bypass them by using safer approaches; in summary, to change practices. This means that transforaminal injections should be carried out less and less often, and instead be replaced by transforaminal epidural injections in which the therapeutic benefit is not inferior, but more importantly the risk-benefit ratio is more favourable [13,14]. If, in spite of this, the indication for a transforaminal injection is retained, it is essential to carry it out under specific technical conditions that it is crucial to be aware of: never catheterise the foramen, and position the needle tip at the posterior and lateral part of the foramen; CT-guidance is therefore indispensable,
and even more so for injections to the cervical spine. A prior contrast medium injection is also crucial so that the operator can check for errors of needle positioning that can have drastic results, and a second injection of local anaesthetic provides an additional level of safety. The transfacet approach to the epidural space and foramen is the most ingenious and certainly the safest route because it is done by puncturing an avascular site, thus sidestepping the risks of the vascular complications described in other approaches.

The issue of needle calibre is also currently debated. The majority of teams use a 22G calibre needle (all the accidents reported were described with 22G needles or finer), which equates to an external diameter of 700 microns, and this
means that accidental catheterisation of a radicular artery (200–1000 microns in diameter) is possible. Needles with a greater calibre (20G) are thought to be safer because they could not accidentally catheterise these arterioles. Coaxial needles with a soft atraumatic catheter are currently being developed and these should also help to avoid these accidental catheterisations.

Finally, another solution to the neurological complications, and perhaps the essential solution, could be to use other cortisone derivatives or other active products (anti-TNF, etc.) with comparable therapeutic effects that do not come in suspension form, meaning that they would not be likely to embolise arterioles that perfuse the spinal cord [15]. In France, only prednisolone acetate and Cortivazol are authorised for epidural injections; it is worth noting that nearly half of the cases reported of neurological complications involving ischaemia of the spinal cord occurred in France.
KEY POINTS

- Spinal injections are a second line treatment procedure for the management of pain of spinal origin.
- These procedures are not free of risks.
- Extremely serious neurological complications involving spinal cord or cerebellar ischaemia have been seen in recent years.
- These are normally caused when the injection needle accidentally catheterises a radicular artery and when this is followed by an injection of particulate steroids that can coalesce into aggregates leading to obstruction of the affected artery as well as the anterior spinal artery; the conformational changes to red blood cells triggered by some injected active substances are another likely cause.
- Transforaminal injections carry a greater risk of these kinds of neurological events than epidural injections.
- Injection needle positioning must comply with very strict criteria.
- A prior in situ contrast medium injection is essential in order to detect potentially dangerous errors.
- An in situ local anaesthetic injection when transforaminal injections are being carried out adds an additional level of safety.
- Transforaminal epidural injections using the transfacet approach are without doubt the safest type because the joint cavity is an avascular site distant from the arterioles that are potentially a source of dangerous complications.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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