Transarticular Laser Discal Fragmentectomy. A New Minimally Invasive Surgical Approach for Challenging Disc Herniations in the Elderly

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Key words: disc herniation, percutaneous disc decompression, laser

Summary

This report describes two elderly patients with large disc fragments extruded into lumbar radicular recesses not treatable by any conventional conservative, minimally invasive or surgical approach. Direct access to the disc fragments was obtained crossing the articular zygapophyseal cavity instead of the interlaminar space and spinal canal, using a small needle through which a laser fibre was inserted to deliver energy for tissue ablation. The procedures obtained regression of both symptoms and the bulk of the fragments at early and late clinical and MR follow-ups.

Introduction

Radicular pain from lumbar root compression, usually caused by herniation of an intervertebral disc, has a high prevalence in the general population ^{1,2}. Spontaneous regression of symptoms in a period of one to two months, and also of the bulk of herniated disc material in a more variable span of time, is the most common clinical feature in up to 80 % of patients ^{3,4}. The remaining group of patients qualifies for surgical treatment. Disc displacement may occur in many forms, but most often disc herniations are reported for treatment purposes

as contained and non-contained ⁵. Patients with sequestered or extruded lumbar disc herniations usually undergo an open microdiscectomy with favourable clinical results ⁶⁻⁹, while several alternative minimally invasive techniques have been developed for contained lesions ¹⁰, and these are normally more suitable for fragile patients, such as the elderly. However, extrusion or sequestration of a disc fragment are not unusual in the elderly population, and this condition can be very invalidating. Conversely, an open approach would be burdened by an excessive risk in terms of peri-operative morbidity. We describe two cases of large extruded herniations in elderly patients, not suitable for open surgery, in which we used a totally percutaneous CT-guided approach, obtaining a complete regression of symptoms and disappearance or marked reduction of the herniation at early and delayed post-operative imaging studies.

Materials and Methods

Surgical Procedure and Instrumentation

The patient, in mild sedation, is positioned in prone decubitus in the CT unit and the lesion centred with the standard technique routinely used for spine injections. After local anaesthe-

Figure 1 Sagittal (A) and axial (B) MR images depicting a large extruded fragment originating from the L4-L5 disc space, compressing the dural sac and occupying the entire right L5 radicular recess.

Figure 2 Transarticular laser fragmentectomy. The 22 G needle traversing the synovial cavity directly enters the discal fragment. The optic fibre (not visible) is passed through it. Arrows show gas from tissue vaporization. The gas diffuses through the nucleus material, entering the disc space.

sia, a 22-gauge hollow needle is navigated through the corresponding synovial cavity, a needle of such calibre being flexible enough to adapt to the curvature of the cavity. To avoid possible penetration of the sharp tip into the inner cartilage and cortex of the articular process, preventing its progression, the bevel of the needle point is used, turning it in the proper direction or even using a screwing movement (similar to the standard technique we use to access

intracanalicular synovial cysts). Through the needle, we deploy a 360 μ m laser fibre inside the disk fragment, protruding two millimetres outside the needle. The fibre is then activated with a diode laser generator (EVOLVE® Laser System, Biolitec, Bonn, Germany) with a wavelength of 980 nm. Laser energy is activated in a pulsed manner, at 12 Watts, 0.1 second pulses, one pulse every two seconds (1.9 second interval between each pulse). During energy delivery, saline is ad-

ministered through the same needle, by means of an automated pump, at a rate of 8 drops/hour: this minimal saline perfusion through the access needle prevents the tissue temperature exceeding 100°C. Every 100 joules a CT scan is taken to check for needle/fibre position and to visualize possible gas bubbles from tissue vaporization. If any bubbles are present, the fibre is slightly repositioned inside the fragment. A total of 800 joules was delivered in each case. The “active” area where tissue is vaporized is a sphere of about two millimetres around the tip of the fibre, so attention is paid to avoid positioning the limits of the sphere outside the fragment or in close proximity to the exiting root or dura. Energy delivery is also stopped for one to two minutes to allow heat dispersion if the patient complains of radicular pain or intense paraesthesias, and then reactivated. In addition, the strength of the muscles corresponding to the root is regularly clinically checked. However, the integrity of the root is also continuously tested by means of electromyography monitoring, as discussed below. At the end of the procedure the fibre is first withdrawn, the needle being left in place for a few seconds with a mild aspiration to eliminate gases from vaporization, then withdrawn with injection of steroids and local anaesthetics into the synovial cavity.

Intraoperative Electromyography Monitoring

An expert neurophysiologist was present in all the procedures performing electromyography (EMG) monitoring of the “at risk” neuromuscular structures. Neurophysiological monitoring was obtained by an “Eclipse-Axon” instrument opportunely set up for continuous free run EMG activity and electrically elicited triggered EMG response. At least three EMG channels from the target muscles were simultaneously recorded, choosing the muscles innervated by the compressed root and the superior and inferior radicular districts, i.e. adductor major (roots L2-L3), medial vastus (L3-L4) and anterior tibialis (L4-L5) for the L3-L4 disk herniation (case 2), anterior tibialis and triceps surae (L5-S1) for the L4-L5 disk herniation (case 1).

Case 1

An 82-year old man presented with an eight-month history of invalidating sciatica in the right leg, due to root compression in the L5 radicular recess by an extruded fragment from the L4-L5 disc. Comorbidities were represented by heart

and lung diseases. Pain proved resistant to prolonged physical therapy, epidural injections, and pulsed radiofrequency (PRF) of the affected root. Alleviation of pain with opioids was moderate and inconstant. At surgical evaluation, the case was discarded by anaesthesiologists and neurosurgeons because of age and comorbidities. MR (Figure 1) showed the large fragment in the L5 radicular recess. Transarticular laser fragmentectomy was performed (Figure 2).

Case 2

A 79-year-old woman presented with a six-month history of invalidating sciatica in the left leg, due to root compression in the L4 radicular recess by a sequestered fragment from L3-L4 disc, as shown by CT and MR studies (Figure 4). Comorbidities were represented by cardiac ischaemic disease and diabetes. Pain proved resistant to physical therapy, epidural injections, PRF of the affected root and a percutaneous L3-L4 decompression performed by means of an aspiration probe (SpineJet® – HydroCision, MA, USA) (Figure 5). Alleviation of pain with opioids was moderate and inconstant. At surgical evaluation, the case was discarded by anaesthesiologists and neurosurgeons because of age and co-morbidities. Transarticular laser fragmentectomy was performed (Figure 6).

Both patients gave a fully informed consent to this relatively new approach to their pathological condition. The description of this case series was authorized by our local ethical committee.

Results

Both patients experienced an immediate relief of pain from the same day of the procedure, in case 1 almost complete (pain from 8/10 VAS to 1/10), in case two VAS from 8/10 to 4/10. These results, the first day possibly related to local anaesthesia and mild sedation, lasted the following days and progressively improved to complete disappearance in two weeks in case 1 and in six weeks in case 2.

We performed an MR follow-up study at two months in both cases, showing a marked reduction of the fragment, of at least 90 % in case one (Figure 3) and more than 60 % in case two (Figure 7). No complications occurred during or after the procedures. Clinical results remained stable at late follow-ups (more than two years in both cases).

Figure 3 MR follow-up at 2 months shows complete regression of the herniation.

Figure 4 MR (A) and CT (B) axial images showing a large sequestered disc fragment occupying the left radicular recess and markedly compressing the dural sac.

Discussion

Percutaneous laser disc decompression (PLDD) was introduced in human practice by Choy et al.¹¹⁻¹³ in 1986. By 2002, more than 35,000 PLDDs had been performed¹³. Laser (the acronym standing for Light Amplification by the Stimulated Emission of Radiation) is a

high-energy beam of light formed by energizing an active lasing medium. The radiant energy of the laser beam can be transformed into heat energy that produces medical and surgical effects in tissue, such as coagulation, vaporization, or cutting. In PLDD, the aim is to obtain a vaporization of the water bound to hydrophilic groupings of proteoglycans of the

Figure 5 L3-L4 intradiscal decompression by means of an aspiration probe.

Figure 6 Transarticular laser fragmentectomy. Note repositioning of needle and fibre during the procedure in both cranial-caudal and lateral-medial directions. Note also the different distribution of gas from tissue vaporization in the two situations, and its progressive diffusion and accumulation in the centre of the disc (where it was not present pre-operatively).

nucleus pulposus (water composes approximately 90% of the young nucleus). Intradiscal decompression is obtained by shrinkage of the water-rich nucleus pulposus by vaporization. The evaporation of water and the increase in temperature causes protein denaturation and subsequent renaturation, leading a structural change in the nucleus pulposus, limiting its ca-

pability to attract water ¹¹⁻¹³. Thus, PLDD is based on the concept of the intervertebral disc being a closed hydraulic system consisting of the highly hydrated nucleus pulposus surrounded by the inelastic annulus fibrosus. Application of laser energy evaporates water in the nucleus pulposus, thus leading to reduction of intradiscal pressure and nerve root com-

Figure 7 MR follow-up at 2 months shows marked regression of the herniation with re-expansion of the dural sac.

Figure 8 Trans-canal PLDD in a young patient. A) Disc herniation occupying the radicular recess (arrow). B) Trans-canal access to the disc space for laser intradiscal decompression. C) Bubbles from nucleus vaporization in both disc space and radicular recess. The arrow shows reopening of the radicular recess thanks to immediate reduction of disc volume due to nucleus shrinkage.

pression¹⁴. Consequently, only contained herniations can be expected to respond to reduction of intradiscal pressure by this mechanism, and disc extrusions or sequestered herniations are considered to be exclusion criteria for PLDD.

Based on our extensive and long-lasting experience with this technique, we applied the same physical principles and devices to two challenging cases. Our patients both harboured large disc extrusions in the radicular recess and complained of intense and invalidating radicular pain. Both patients underwent a prolonged period of conservative therapies, including

physical therapy, epidural injections, and PRF. Open surgery was deemed at too high risk, while at the same time an intradiscal decompressive discectomy as previously described (either PLDD or with a different kind of device) would have been ineffective in the presence of extruded-sequestered disc fragments. Patient 2 underwent a percutaneous discectomy by aspiration with no effect. Pain control with opioids was poor. In the long term, this painful and invalidating condition, through loss of mobility and psychological demotivation related to a reduced quality of life, can even become life-threatening in such patients.

Our alternative approach entailed direct deployment of a laser fibre inside the extruded disc fragments under CT guidance, crossing the synovial articular space to access the radicular recesses where the fragments had migrated, compressing the exiting root. To accomplish this goal, we used the same technique and pathway routinely used for treatment of lumbar synovial cysts^{15,16}. In both cases we obtained a reduction of pain to a non-disabling level and reduction of the extruded disc fragment (in one case complete disappearance, in the other a marked reduction) at post-operative imaging studies.

We chose a transarticular approach instead of a more classical trans-canalicular one (Figure 8) for the following reasons. In our cases, the synovial cavity was easily accessible and its direction gave the needle and probe direct access to the radicular recess and the disc fragment displaced in it. This is a relatively unusual situation in the elderly population, in which the posterior zygapophyseal articular processes are frequently involved by spondylotic deformation, with hypertrophy, a curved and distorted synovial cavity, and large osteophytes occluding the entrance to it. Thanks to the absence of spondylotic deformation, the cavity was also easily crossed by the needle.

Using the synovial cavity prevents possible punctures of the dura. Although a transdural route can be, and has been for a long time, safely used to access the disc space (for discography or percutaneous discectomy), in our cases we preferred to avoid a dural breach to gain better control of energy delivery, because an inadvertent cerebrospinal fluid leak could have reduced the effectiveness of action of the laser energy. Moreover, dural breaches could open the subarachnoid space to possible debris. Eliminating dural breaches also prevents the occurrence of post-operative headache.

The anterior, convex-shaped surface of the facet joint covers almost all the radicular recess. This condition allows needle and fibre to be repositioned in a cranial-caudal direction during the procedure, without the risk of multiple dural punctures.

The functional integrity of the root is checked during the intervention, as previously described, both clinically (no reduction of muscles strength, absence of pain and/or paraesthesias in the root territory) and by EMG. A sudden, involuntary s-EMG signal coming from the muscles innervated by the com-

pressed root and from the two roots adjacent to it was always reported and interpreted as a warning signal. In these cases we immediately stopped the procedure and then stimulated the region, looking for a t-EMG response. We considered a potential risk for the nerve root the activation of a muscular response in the appropriate region at an electrical stimulation below 5 mA. Between 5 to 10 mA we carried on the surgical procedure very carefully, paying special attention to s-EMG activity.

Although we routinely use different energies and devices (radiofrequencies, coblation, mechanical etc.) more often than PLDD to perform percutaneous herniectomies/discectomies, we chose laser in these cases because of the extremely reduced size of the laser fibre used to deliver energy to the target tissue. The optic fibre has a diameter of 360 µm, it can be passed through needles of any size, and it is also very flexible and hence can follow any curved trajectory inside the zygapophyseal joint. The small size of the fibre also fits the reduced size of the radicular recess (other probes used for intradiscal nucleus ablation, such as mechanical, radio frequency (RF) or coblation devices, are much bulkier). The area of tissue ablation is limited to a small volume just around the tip of the fibre, it is spherically shaped and of well-defined size, depending on the amount of energy delivered. Unlike RF or coblation probes, gas bubbles from laser nucleus vaporization are visualized on CT scans during the procedure, thereby allowing discontinuation of energy delivery and repositioning of the fibre.

We used a diode laser, which has some advantages over other types of lasers. Lasers are generally classified according to the medium they use to produce the laser light, and every medium determines a specific and typical wavelength of laser light. Many types of lasers have been reported in the literature for spine applications¹⁰⁻¹⁷. The way in which light interacts with a tissue largely depends on its wavelength. Penetration depth at a certain wavelength is mostly affected by absorption by specific molecules, such as water (the principal component of the nucleus pulposus), haemoproteins, pigments, nucleic acids, and so on. As a laser is absorbed by the tissue, several surgical effects take place: at 60°C protein denaturation and coagulation of blood vessels, near 100°C evaporation of intracellular water causing shrinkage and tissue loss, beyond this point

carbonization will progressively occur. In diode lasers the active medium is a semiconductor diode similar to light-emitting diodes; they have a typical wavelength at 810-890-940-980 nm (980 in our equipment). Diode lasers differ from conventional lasers for their small size and weight, and for their low current, voltage and power requirements, making them ideal for use in portable (and inexpensive) electronic equipment. Therefore, they can operate using small battery power supplies: hence the advantage of a much less expensive and less cumbersome power unit. Advantages of the 980 wavelength (peak absorption of water) of the diode laser are maximum absorption by well-hydrated soft tissues like the nucleus pulposus^{10,18,19}. For the diode laser the size of the optic fibre can be as small as 220 µm, although the best compromise is obtained with the 360 µm probe (too high concentration of the delivered energy for the 220 µm fibre). Such small fibre size fits coaxially in 21 gauge needles.

A minimal saline perfusion through the access cannula is maintained during activation of the fibre and energy delivery. As long as water is present around the tip of the probe, the tissue temperature never exceeds 100°C, the sphere of ablation remains constant in volume and carbonization does not occur. Carbonization is a major drawback of tissue ablation obtained by means of energy delivery (laser or

RF) in tissues, since the carbonized debris is toxic and may act as a foreign body, activating an inflammatory cascade that can be worse in its effects than the pathologic tissue itself.

The number of cases is limited, because, to be observed, they require several, infrequent conditions to be satisfied: i) a huge extruded fragment, rarely observed in elderly patients, whose discs are more frequently degenerated with a dehydrated nucleus pulposus; ii) the fragments do not spontaneously resorb over a long period of time; iii) symptoms are unresponsive to common conservative pain treatments, such as physical therapy or ganglion PRF and spinal-epidural injections; iv) medical treatments (mainly NSAIDs and/or opioids) not sufficient to an acceptable quality of life; v) herniations are not surgically accessible to open surgery because of local or general conditions, and are unresponsive to other minimally invasive approaches.

Conclusion

Our approach is unusual but proved safe and effective, although the extremely small number of cases is a clear limitation. Transarticular laser discal fragmentectomy can be taken into consideration when dealing with relatively infrequent but very difficult cases.

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