Editorial

The strategies behind "inside-out" and "outside-in" endoscopy of the lumbar spine: treating the pain generator

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The concepts

Two conceptually different transforaminal endoscopic methods of accessing and decompressing the lumbar intervertebral discs have emerged over the years: the "inside-out," and the "outside-in" technique. While the distinction between these two methods driven by the initial placement of the endoscopic working cannula either inside the intervertebral disc (inside-out) or into the neuroforamen (outside-in) seems somewhat trivial on the surface, it is far from it when one looks beyond the access issue. The differences go much deeper than the initial starting point, considering which of the common pain generators can be directly visualized and treated.

The "inside-out" technique historically evolved based on the technology of contemporary spinal endoscopes available at the time. First generation endoscopes had a small working channel which typically did not allow utilization of instruments larger than 2.5 mm in diameter. The array of decompression procedures that could be done was restricted to soft tissue removal. Yeung *et al.* popularized the "inside-out" technique in 1998 in the United States and developed an entire platform of instruments around the Yeung Endoscopic Spine System YESS™ (1). The desire to perform foraminal decompression procedures with removal of bone let to larger diameter trephines and rongeurs including Kerrison rongeurs, which in turn called for spinal endoscopes with larger working channels and integration of advanced optical systems that were capable of delivering enough light, and irrigation fluid to handle bleeding, and removal of debris. It seemed only natural to place these large devices and instruments into the neuroforamen rather than into the intervertebral disc space for ease of use, avoid injury to the nerve roots, and perhaps to see what more can be done inside the spinal canal. The "outside-in" technique was born in the late 1990ies as a result of Thomas Hoogland's (2) curiosity and his advancement of the work predicated by Leu and Hauser (3), and the need to work inside the spinal canal and neuroforamen and not just in the confines of the intervertebral disc space. At the time, "outside-in" was perceived as a significant breakthrough and arguments over its superiority were vehemently exchanged by their respective advocates with the "inside-out" proponents, because "outside-in" was seemingly able to deal with both bony and soft tissue stenosis and, thus, was useful for a broader range of clinical indications. The "inside-out" technique was thought to be reserved for patients with a herniated disc. As it turned out, this is an oversimplification of the distinction between these two procedures which deserves further discussion.

What's it all about?

The fundamental difference between the "inside-out" and "outside-in" technique is often not immediately evident to the novice surgeon who is deciding on entering the field of spinal endoscopy and seemingly has to choose between the two techniques. The most critical difference is the initial location of the tip of the working cannula. With the "inside-out" technique, the tip of the working cannula

rests anterior and directly underneath the dural sac. The only structure separating the two is the posterior annulus whose degenerative pathologies are often painful. With the "outside-in" technique, the tip of the working cannula sits directly posterolateral to the dural sac in the neuroforamen. This is of course after serial dilation has occurred which in some cases even requires a foraminoplasty with drills and trephines to accomplish this. The latter is often not required with the "inside-out" technique unless the patient has concomitant severe degeneration of the facet joint complex with lateral overhang, which may obliterate the access to the intervertebral disc through the transforaminal approach.

Where the working cannula is initially placed with either of the two techniques determines what the surgeon can see, evaluate, and treat endoscopically. It may even drive intraoperative surgical decision making in the awake yet sedated patient where provocative testing of suspected painful conditions of the lumbar motion segment with disco- and epidurography and diagnostic anesthetic injections may aid in correctly identifying and treating the primary pain plural generator. These can vary quite a bit and contributing endoscopic visualized painful conditions may range from (I) inflamed disc; (II) inflamed nerve; (III) hypervascular scar; (IV) hypertrophied superior articular process (SAP) and ligamentum flavum; (V) tender capsule; (VI) impacting facet margin; (VII) superior foraminal facet osteophyte; (VIII) superior foraminal ligament impingement; to (IX) a hidden shoulder osteophyte. While these confirmed problems are easily identified with the "outside-in" method, additional intradiscal painful conditions, such as medial annular tears and unstable disc fragments may be better visualized with the "inside-out" technique because of the position of the endoscopic working cannula underneath the dural sac. Other painful patho-anatomy visualized through the endoscope may include autonomic, and furcal nerves, conjoined nerves, and synovial cysts (4).

Is one technique superior to the other?

When answering this question, one has to move away from the issue of where the endoscopic working cannula is initially positioned. Yes, the intradiscal medial and anterior versus the neuroforaminal posterolateral position of the tip of the working cannula at the beginning of the surgery is a drastic and easily discernable difference between the two techniques. Beyond that there may not be that many differences between the two techniques as their contemporary versions have the ability to remove both bony and soft tissue pathology (5). Perhaps one of the most understated facts about the "inside-out" technique is the ability to turn the opening of the working cannular towards the posterior annulus and to enter the epidural space through an annular window once the discectomy including an annular resection is completed (5). The latter serves two purposes: (I) to decompress the neural elements; (II) to remove pain generators residing within the annulus itself or bony osteophytes. Direct visualization of the anterior dural sac from the approach side to the lateral recess of the opposite side becomes feasible. Any painful conditions in the epidural space may now be evaluated and, if needed treated, in spite of the fact that the surgery commenced inside the disc. This expanded view of the anterior lumbar epidural space is unique to the "inside-out" technique. Most skilled surgeon may never have a complete view of it with the "outside-in" method. Their decompression may routinely take them to the lateral recess where they visualize the traversing nerve root. Obviously, one could at this stage push the working cannula forward into the intervertebral disc space and employ the steps unique to the "inside-out" technique to directly visualize the entire dural sac from one lateral recess to the other. This hybrid of "outside-in" and "inside-out" may offer the surgeon the ability to perform a complete evaluation of the pain generators within the symptomatic lumbar motion segment and is a more obvious choice in patients with advanced degenerative disc disease where there often is a collapsed vacuum disc without any structural integrity. In younger patients, propagation of progressive vertical disc collapse is of concern with the "inside-out" technique.

The question if one technique is superior over the other is not exactly fair. Both the "inside-out" and the "outside-in" are capable of adequately decompressing the neural elements and directly visualize the majority of painful patho-anatomy that plagues the lion's share of patients. The key to favorable clinical outcome though is in getting the pain generator. Whether the endoscopic lumbar decompression surgery commenced within the intervertebral disc or in the neuroforamen seems secondary as long as the surgeon correctly identifies and adequately treats the pain generator. When that is accomplished clinical outcomes with either of the two decompression techniques discussed herein will be quite similar at least in the short-term as corroborated

by the myriad of two-year follow-up studies. Reoperation rates recently analyzed in the long-term in patients with a minimum of five-year follow-up suggest that additional corrective procedures within the same motion segment are more common with the "outside-in" technique than with the "inside-out" method (5). Presumably, this is because of more complete evaluation and treatment of the diseased spinal motion segment with the "inside-out" technique where both the lateral recess and the central area underneath the dural sac is routinely accessed. In other words, omission of the routine direct visualization of potentially painful patho-anatomy underneath the dural sac with the "outside-in" technique may be the root cause for higher long-term reoperation rates within the same motion segment.

Strategies for treating the pain generator

Arriving at the proper plan of care is perhaps the most challenging aspect of endoscopic spine surgery as it involves identifying the pain generator. This may be straightforward in patients with an advanced single level disease and severe spinal stenosis. In patients with unilateral leg symptoms due to severe foraminal and lateral recess stenosis at one level, the decision on the surgical plan is even easier—a transforaminal endoscopic foraminoplasty and discectomy. However, the situation may not be as straightforward in younger patients with less advanced disease without central but bony and soft tissue lateral recess or foraminal stenosis. Those patients often have a long history of insidious onset of sciatica-type back- and leg pain with dysesthesias and decreased walking endurance. Severe motor weakness is uncommon. Many acute on chronic episodes often cycle for years with unsuccessful repetitive rounds of physical therapy, pain management, and interventional injections. Surgical treatment is frequently delayed because the patients' advanced imaging studies may not support surgical intervention by conventional standards for open translaminar surgery and their practitioners are telling many of them that they are not "bad enough" for surgery.

On the other of the spectrum are older patients with multilevel stenosis where the art of providing appropriate care lies in reducing the endoscopic decompression surgery to the most symptomatic level while deliberately ignoring others. The intent behind this approach is to provide pain relief with a meaningful improvement of the patients' function within the context of each patient's demand without excessive surgical risk exposure. Most patients report excellent and good self-reported outcomes if they can double their walking endurance until they reach their pain limit. Following traditional open lumbar spine surgery, poor perioperative management of medical comorbidities, such as diabetes mellitus, heart-, and lung disease, is often the reason for unintended postoperative aftercare and hospital readmission rather than surgical site complications (6). Surgeons are concerned with their patients doing poorly after a translaminar lumbar stenosis operation and may recommend against traditional surgery by telling their patient's that they are either "too old", or "too bad" to tolerate surgery, or that their surgery would be "too risky". In other words, the "misfits" and the "rejects" of traditional open or other forms of minimally invasive translaminar spine surgery are often the types of patients who seek out help from an endoscopically trained spine surgeon.

Prognosticators of favorable clinical outcomes

Traditional radiology reporting of advanced lumbar imaging studies, including MRI and CT, often lacks detail in the description of the neuroforaminal dimensions and frequently underestimates the extent of stenosis in the lateral recess. Extraforaminal disc herniations lateral and anterior to the spinal canal underneath the dorsal root ganglion (DRG) causing its chronic inflammation are located in another notoriously poorly imaged area in routine MRI scanning. The latter type of patients often goes on undiagnosed when their practitioners only rely on the MRI report. The prognostic value of routine lumbar MRI reporting for a successful clinical outcome with the endoscopic transforaminal decompression surgery is relatively weak. A recent study calculated a sensitivity of 68.34%, a specificity of 68.29%, and an accuracy of 68.24% when correlating findings reported by the radiologist with the directly intraoperatively endoscopically visualized compressive pathology (7). The prognostic value of the same MRI scan when graded by the treating surgeon improved considerably with a calculated sensitivity of 87.2%, a specificity of 73.03%, and improved accuracy of 86.51% (7). Given the relatively high false negative rate (30%) with routine MRI reporting in patients who are considered for the endoscopic decompression procedure (7), additional prognosticators of successful outcome including diagnostic selective nerve root blocks, and transforaminal epidural steroid injections (TESI) should be used. A diagnostic response to a lidocaine

containing TESI with greater than 50% pain relief being reported by the patient predicts successful outcome with the endoscopic decompression procedure at the suspected symptomatic level with a sensitivity of 90.17%, a specificity 70.79%, and a positive predictive value of 98.38% (8).

Is transforaminal outdated?

Both the "inside-out" and the "outside-in" techniques were developed over 20 years ago. Nowadays, these transforaminal techniques are successfully employed for an increasing number of clinical indications ranging from herniated disc to spinal stenosis. However, other techniques including the interlaminar, full-endoscopic method, which combines the transforaminal and interlaminar approach, the over-the-top technique, and the unilateral biportal endoscopic (UBE) technique—to name a few—have gotten some traction particularly in Asian countries as alternatives to the traditional transforaminal approach. When assessing the relevancy of these additional technologies one has to take into consideration the regional variations in culture, surgeon-training, preferences, cost of equipment and disposables, reimbursement as well as the other motivators—financial or not—set forth by the local health care systems in each country. In the United States, the emphasis is on transitioning more spine surgeries into an outpatient surgery center setting by performing simplified versions of spinal decompression and reconstructive procedures in conjunction with advanced anesthesia using Enhanced Recovery After Surgery (ERAS) protocols. The transforaminal approach is highly suitable for this type of surgical setting as it is not as painful as translaminar approaches that require some degree of muscle dissection to create and maintain an access the posterior elements. One could also argue that there is a lower rate of dural tears with the transforaminal approach and a lower overall complication rate with it than with other types of interlaminar or translaminar decompression procedures. Therefore, the transforaminal technique more likely than not will remain the workhorse platform for outpatient endoscopic decompression procedures performed in the United States.

Conclusions

The "inside-out" technique enables the surgeon to visualize the anterior aspect of the dural sac better than the "outside-in" approach which is typically limited by the traversing nerve root unless the surgeon decides to advance the working cannula into the disc and converts the endoscopic decompression procedure into a hybrid between "outside-in" and "inside-out". Pain generators residing below the dural sac may be treated more effectively with the "inside-out" approach. The "outside-in" approach may be more appropriate for foraminal lateral recess stenosis that is primarily caused by facet joint hypertrophy and upward migration of the SAP. Both techniques have common elements and converge at the same endpoint—finding and treating the pain generator.

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Footnote

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Ethical Statement: The author is accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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