ENDOSCOPIC DECOMPRESSIVE SURGERY FOR LUMBAR SPINAL STENOSIS: ANALYSIS OF CLINICAL OUTCOME AND PREDICTIVE FACTORS

BY

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LIST OF **FIGURES, TABLES & ABBREVIATIONS**

LSS : Lumbar spinal stenosis

VAS : Visual Analogue Scale

ODI : Oswestry Disablility Index

MRC : Medical Research Council

ULBD : Unilateral hemi-laminotomy and bilateral decompression

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ABSTRAK

PEMBEDAHAN PENYAHMAMPATAN ENDOSKOPI UNTUK STENOSIS TULANG BELAKANG LUMBAR: ANALISIS KEPUTUSAN KLINIKAL DAN FAKTOR-FAKTOR RAMALAN

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Konteks Latar Belakang : Pendekatan endoskopik adalah salah satu pendekatan yang mengekalkan matlamat pembedahan manakala ia mengurangkan kemusnahan tisu cagaran. Keberkesanan dan keselamatannya telah dibincangkan dalam banyak kajian. Untuk pengetahuan kita, terdapat beberapa kajian dilakukan untuk lumbar stenosis berkaitan dengan keputusan dan isu-isu berkaitan dalam pembedahan tulang belakang endoskopik, bagaimanapun terdapat kekurangan sastera yang menilai hasil pembedahan penyahmampatan tulang belakang lumbar.

Tujuan : Untuk menilai hasil keputusan pembedahan endoskopik untuk stenosis lumbar dan untuk menentukan faktor-faktor ramalan.

Kajian Rekabentuk : Satu kajian kohort retrospektif pesakit stenosis tulang belakang lumbar degeneratif yang menjalani pembedahan perkutaneus endoskopik menggunakan pendekatan satu hala untuk penyahmampatan dua hala.

Sampel Pesakit : Enam puluh pesakit dengan stenosis tulang belakang lumbar menjalani pembedahan penyahmampatan antara 2009 dan 2013.

Kaedah : Antara 2009 dan 2013, pembedahan endoskopik interlaminar Destandau telah digunakan dalam operasi lumbar stenosis tulang belakang di Hospital Universiti Sains Malaysia. Hasil klinikal telah diukur sebelum dan selepas pembedahan untuk Skala Analog Visual (VAS) untuk sakit belakang dan kaki, penggredan motor, deria, Indeks Kurangupaya Oswestry (ODI), and kriteria MacNab. Kohort berkenaan dibahagikan kepada dua kategori: hasil yang cemerlang dan baik telah dikumpulkan ke dalam kategori berjaya dan hasil yang sederhana dan teruk telah dikumpulkan ke dalam kategori tidak berjaya. Ujian paired-t dan ujian tepat Fisher telah digunakan untuk analisis statistik.

Keputusan : Purata umur pesakit adalah 60.82 tahun. Purata tempoh susulan adalah 30.1 bulan (julat antara 17.2 hingga 43 bulan). Terdapat 23 (38.3%) lelaki dan 37 (61.7%) perempuan. Purata masa pembedahan adalah 183.6 minit (julat antara 124.8 minit hingga 242.4 minit). Purata kehilangan darah adalah 150.18ml (julat antara 30.82 ml hingga 269,54 ml). Purata tinggal di hospital selepas pembedahan adalah 2.45 hari (julat antara 1.34 hari hingga 3.56 hari). Kebanyakan pembedahan endoskopik yang terlibat adalah pesakit pada tahap L4 / L5 sebayak 51 pesakit (52.6%), diikuti oleh L3 / L4 sebanyak 19 pesakit (19.6%), L5 / S1 sebanyak 24 pesakit (24.7%), dan L2 / L3 sebanyak 3 pesakit (3.1%). VAS untuk sakit belakang dan sakit kaki dan ODI untuk sebelum dan selepas pembedahan adalah statistik yang signifikan ($p < 0.001$). Pengurangan neurologi adalah statistik yang tidak signifikan. Berdasarkan kriteria Macnab, 88.4% menunjukkan hasil cemerlang dan baik dan 11.7% menunjukkan keputusan yang sederhana. Dalam siri kami, faktor-faktor ramalan yang menjejaskan hasil klinikal menunjukkan tiada hubungan yang signifikan. Untuk komplikasi, 13.3% daripada pesakit mempunyai koyakan dura; 1.6% mempunyai kecederaan akar saraf, kesalahan tahap dan kelewatan penyembuhan luka; 11.6% mempunyai disestesia kaki; 11.6% mempunyai stenosis berulang; dan 1.6% dan 6.6% telah mengalami pengurangan motor dan deria masing-masing.

Kesimpulan : Pembedahan endoskopi stenosis lumbar adalah pembedahan yang selamat. Ia mempunyai hasil yang sangat baik dari segi mengurangkan sakit belakang dan kaki, serta meningkatkan kualiti hidup, di samping tinggal di hospital untuk tempoh lebih pendek dan mobilisasi awal.

Professor Madya Dato' Abdul Halim Bin Yusof: Penyelia

ABSTRACT

ENDOSCOPIC DECOMPRESSIVE SURGERY FOR LUMBAR SPINAL STENOSIS: ANALYSIS OF CLINICAL OUTCOME AND PREDICTIVE FACTORS

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BACKGROUND CONTEXT : Endoscopic approach is one of the approaches that maintained the aim of surgery while minimize the collateral tissue destruction. Its efficacy and safety have been advocated by numerous studies. To our knowledge, there are number of studies done for lumbar stenosis with regards to the outcome and related issues in endoscopic spine surgery, however there are lacked of literature that evaluate the outcome of the decompressive lumbar spine surgery.

PURPOSE : To assess the outcome result of endoscopic surgery for lumbar stenosis and to determine it's predictive factors .

STUDY DESIGN : A retrospective cohort study of patients with degenerative lumbar spinal stenosis who underwent endoscopic percutaneous surgery using unilateral approach for bilateral decompression.

PATIENT SAMPLE : Sixty patients with lumbar spinal stenosis underwent endoscopic decompressive surgery between 2009 and 2013.

METHODS : Between 2009 and 2013, 60 eligible patients who undergone endoscopic interlaminar decompressive spine surgery (Destandau's method) for lumbar degenerative spinal stenosis in Hospital Universiti Sains Malaysia were selected for the study. The clinical outcome was measured pre and post-operative for Visual Analogue Scale (VAS) for back and leg pain, motor grading, sensory, Oswestry Disability Index (ODI), and MacNab's criteria. The cohort was group into two categories: excellent to good result was grouped into favourable category and fair to poor result was grouped into unfavourable category. Paired t-test and Fisher exact test was used for statistical analysis.

RESULTS : Mean age of patients were 60.82 years old. The mean follow-up period was 30.1 months (range 17.2 to 43 months). There were 23 (38.3%) male and 37 (61.7%) female. The mean operation time was 183.6 minutes (ranging from 124.8 minutes to 242.4 minutes). Mean blood loss was 150.18ml (ranging from 30.82 ml to 269.54 ml). Post-operative hospital stay mean was 2.45 days (ranging from 1.34 days to 3.56 days). Most frequently involved level were L4/L5 in 51 patients (52.6%), followed by L3/L4 in 19 patients (19.6%), L5/S1 in 24 patients (24.7%), and L2/L3 in 3 patients (3.1%). VAS for back pain and leg pain and ODI for pre and post operation was statistically significant ($p<0.001$). Reduction in neurology is statistically insignificant. Based on Macnab's criteria, 88.4% showed excellent to good outcome and 11.7% showed fair outcome. There was no significant predicitive factor for the outcome. As for complication, 13.3% of patients had dural tear; 1.6% had nerve root injury, wrong level and delay wound healing; 11.6 % had leg dysesthesia; 11.6% had recurrent stenosis; and 1.6% and 6.6% had reduced motor and sensory respectively..

CONCLUSIONS : Endoscopic decompressive lumbar stenosis surgery is a safe surgery. It has an excellent outcome in term of reducing the back and leg pain, and improve quality of life beside a shorter hospital stay and early mobilization.

Associate Professor Dato' Dr Abdul Halim Bin Yusof: Supervisor

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CHAPTER1

1.0 INTRODUCTION

1.1 Problem Statement

Lumbar spinal stenosis (LSS) is a disease pathology that arises from various sites such as bony, discal, capsular or ligamentary structures. With those combination factors, the lumbar spinal canal can be compressed and produce the classical, clinical symptoms of neurogenic claudication and radiculopathy. And even worse, the compression may lead to Cauda Equina syndrome if the compression is severe enough to compress the whole spinal canal. Various hypotheses are trying to explain regarding the onset of pain, which include mechanical neural and vascular, inflammatory and biomechanical components (Benini, 1993; Cinotti *et al.*, 1997; Komp *et al.*, 2011).

The treatment for lumbar lumbar stenosis is decompressive surgery, as open decompressive surgery has been the gold standard since decades. Recently the evolution of endoscopic surgery has been taking place in the decompressive surgery arena. The evolution of minimally invasive lumbar decompression has been started since 1960's. Despite the conventional open decompression, Kambin had used the posterior transcanal endoscopic using Craig cannula in 1973 (Kambin and Gellman, 1983). Stand-alone non-visualized posterolateral percutaneous nucleotomy was first introduced by Hijikata in 1975 (Hijikata *et al.*, 1975) and followed by Kambin and Gellman's (Kambin and Gellman, 1983) who reported 9 cases in 1983. In 1985, nucleotomy by using shaver 2.8mm in diameter was used by Onik (Onik *et al.*, 1985). Injecting dye (indigo carmine) was then used to blue stain the pathological nucleus pulposus and annular fissure in 1989 by Schreiber (Schreiber *et al.*, 1989). In 1998, Kambin used the transforaminal approach biportally to excise central herniation and non-migrated sequestrated disc fragments in 59 cases (Kambin *et al.*, 1998).

Therefore, endoscopic decompression embarks on reducing soft tissue damage, enhances visualization to tackle the disc pathology and aids in socioeconomic problem, as it requires minute cost of surgery as compared open decompression.

In term of tissue damage, a study was done by Shin by comparing microendoscopic discectomy (MED) and standard microscopic discectomy (MD) group (Shin *et al.*, 2008). The mean CPK-MM levels were lower in MED group than for the MD group at 3 days and 5 days post operatively ($p<0.05$). Similarly the visual analogue score (VAS) for postoperative backpain were lower than MED in both 1 day and 5 days ($p<0.01$). Therefore, they concluded that MED causes less muscle damage and backache.

Very few studies were done on endoscopic spine surgery and of that most of them were related to endoscopic discectomy rather than lumbar stenosis. HUSM is among the center for endoscopic spine surgery in this region of South East Asia hence there is a need to study the clinical outcome of this surgical approach.

1.2 Justification of the Study

There is no literature in English language on the study of percutaneous endoscopic unilateral approach bilateral decompression for lumbar spinal stenosis using the technique described by Destandau. All the studies related with Destandau technique were done on endoscopic discectomy, similarly the studies on endoscopic surgery using other system such as Wolf system by Reutten et al were done on disc surgery.

This study was designed due to the reason that at the moment, there is minimal literature done on the clinical outcome of endoscopic lumbar stenosis surgery for Asian population, respectively. Although the surgery was reported in the Western population, the outcome result was not well documented. As for Korean group, most of the studies that had been done were on endoscopic lumbar discectomy surgery per se. Secondly, this study was to determine the clinical outcome of endoscopic surgery by using unilateral hemi-laminotomy and bilateral decompression approach for lumbar spinal stenosis. This approach was initially popularized for microscopic discectomy and later on assimilated into endoscopic surgery.

1.3 Benefit of the study

The overall aim of this study is to evaluate the successful outcome together with the factors in which may contribute in the outcome of the surgery. Hence, this study is designed to evaluate the clinical outcome along with our experience & complications of endoscopic decompression surgery in lumbar stenosis. We hope a better scoring system can be formulated in evaluating prognosis and outcome of surgery, which may help as a guideline in delivering optimum surgery.

CHAPTER2

2.0 LITERATURE REVIEW

2.1 Lumbar Spinal Stenosis

2.1.1 Pathoanatomy

Lumbar spinal stenosis (LSS) is a spectrum of disease, which is caused by the congenital of process of degeneration, as described by Arnold (Arnoldi *et al.*, 1976). It is defined as narrowing of osteo-ligamentous spinal canal causing compression of the thecal sac and caudal nerve roots (Stauff *et al.*, 2007). Anatomically, the normal adult lumbar spinal canal dimensions include AP diameter ranging from 11.5 to 30mm and width ranging from 17 to 42mm. Average height of the neural foramen in lumbar spine is between 20 and 23mm with average of foraminal width of 8 to 10mm (Glaser *et al.*, 2004). The nerve roots occupy approximately 30% of neural foramen (Hasue *et al.*, 1989).

As for the site of stenosis, it may occur it 3 part different zones in spinal column, which are central, lateral recess and the foramen. All this tight zones are surrounded by bone and soft tissue, in which if any anomaly come from the adjacent structures, these zones can be compromised and cause compression.

Central zone refers to middle column of spinal canal between lateral border of dural sac. The lateral recess defined as the area between lateral border of dural sac to the medial aspect of pedicle. Last but not least, the border of foraminal zone consists of cephalad pedicle superiorly, caudal pedicle inferiorly, the facet joint dorsally and the vertebral body/disc space ventrally. There are multiple factors that may contribute to the canal stenosis (Table 1).

Most researchers believed that the intervertebral disc is the first structure that is responsible for the pathology of degenerative LSS (Glaser *et al.*, 2004; Herkowitz *et al.*; Truumees, 2004). The degenerative process usually begins as early as late teens or early twenties. Kirkaldy-Willis has described the degenerative cascades in details (Kirkaldy-Willis *et al.*, 1978). First stage involves increase in water content in the nucleus pulposus and predisposed it to generalized bulges and focal herniation through the cartilaginous end plate of adjacent vertebrae (Schmorl's nodules) (Williams *et al.*, 2007). As the time progresses, the nucleus pulposus becomes dehydrated in which results in loss of disc height and space. With further loss of water and proteoglycans, the disc becomes brittle and fibrotic and is unable to provide the necessary elasticity for proper support of the vertebral column, a process known as disc desiccation (Verbiest, 1954). As these degenerative cascades continue, they may lead to further narrowing of the spinal canal centrally, in the lateral recesses, and/or in the foraminal zone. Additionally, hypertrophy and infolding of the ligamentum flavum and hypertrophy of the lamina can worsen the progression of lumbar spinal stenosis by encroaching on the spinal canal dorsally.

It is very difficult, objectively to correlate between spinal canal dimension in relation to appearance and severity of the LSS. Hasegawa demonstrated that posterior disc height of less than 4 mm and foraminal height of less than 15 mm have been shown to compress the nerve root in 80% of patients (Hasegawa *et al.*, 1995). Other study shows in majority of patients (90%) who have spinal canal cross sectional area of less than 100 mm^2 are symptomatic (Bolender *et al.*, 1985).

Biomechanically, lumbar spine is dynamic structure integration. The spinal canal undergoes significant change of diameter based on the position and activity of the patient. These dynamic changes leads to narrowing of the canal with extension and axial compression (Penning, 1992). In lumbar extension (increase lordosis), the interlaminar space decrease and ligamnetum flavum infolds, futher narrowing the spinal canal. In addition to the decrease canal, degeneration process exaggerates the dynamic changes in lumbar spine. In LSS, moving from flexion position to extension position can cause decrease in cross-sectional area by 32% to 67% in symptomatic patients (Schönström *et al.*, 1989). In axial loading, only slight pronounced effect on cross-sectional area was found by this author.

2.1.2 Nerve Root Pathophysiology

The cauda equina and proximal portion of nerve roots are nicely enfolded in the dura sleeve and are suspended in cerebrospinal fluid. The nerve root sheath is very thin and lacks of diffusion barrier. Therefore, the endoneural space is continuous with subarachnoid space. With increase of lumbar lordosis while standing or walking in LSS, subarachnoid obstruction can occur and the nerve root is effectively becomes surrounded by the diffusion barrier of arachnoid. Diffusion of oedema fluid into the subarachnoid space becomes impaired, resulting in an increase in endoneurial fluid pressure and the occurrence of a so-called “compartment syndrome” (Moon *et al.*, 2014).

This compartment syndrome can lead to vascular impairment of the nerve. Ischaemia and venous stasis can occur simultaneously (Yoshizawa *et al.*, 1991). When the sudden compressive force exceeds arterial pressure in the nerve

(200mmHg), the arterial circulation is shut down while the gradual compressive force induces venous stasis leading neural oedema (Rydevik and Lundborg, 1977). This viscous cycle continues until the body position of the position remains stationery.

Bony structures	**Soft Tissue Structures**
Facet joint osteophytes Lamina thickening Vertebral osteophytes Spondylolisthesis Hyperthrophy of spondylosis defect Congenital or developmental anomalies of facet joint	Ligamentum flavum hyperthrophy Bulging annulus or fragment of nucleus pulposus Facet joint thickening and synovitis Ganglion of facet joint

Table 2.1 Anatomical structures responsible for canal narrowing

2.1.3 The Double Crush Phenomenon

This phenomenon is encountered in LSS. Various study predominantly in pigs has shown that compression at two levels has more than an additive compression effect on compromising the nerve function, even if both areas of compression are of relatively low pressure (K. Ollmarker, 1992). This may due to the production of a region of the nerve with venous stasis. Following compression, the affected dorsal nerve root ganglion can caused the release of inflammatory mediators such as substance P and vasoactive intestinal peptide. This pain neurotransmitter will further deteriorate the compression by increasing vascular permeability and leads to edema.

2.2 Diagnosis of Lumbar Spinal Stenosis

2.2.1 Clinical Presentation

Low back pain and leg pain are the common symptoms that manifest in LSS. They are usually associated with change in motor, sensory and reflex (Truumees, 2004). Presentation is usually in sixth or seventh decade. The low back pain is often exacerbated by activity and relieved by rest. Unilateral limb pain and weakness sometimes occur, but rare. This is symptom is due to severe lateral recess stenosis or disc herniation, suggests the presence of mechanically and inflammatorily stimulated lumbar and sacral nerve root (Onel *et al.*, 1993).

Neurogenic claudication or cauda equina type intermittent claudication is the symptom of bilateral lower limb numbness or sensory disturbance, which becomes worse on walking and eventually makes it impossible to continue walking. The symptom relieved with sitting and forward flexion (Garfin *et al.*, 1999). This is usually occur if the compression occur at the center of thecal sac, where the compression is already occur more than one spinal level of stenosis (Porter and Ward, 1992).

In rare instance, bowel or bladder dysfunction and priapism (Baba *et al.*, 1994) has been described. The patient might complain of urinary incontinence and feeling of urgency. Cauda equina syndrome is rare but can occur (Amundsen *et al.*, 1995; Turner *et al.*, 1992).

As per physical examination, while patient is in standing position, the patient might have forward flexed position, or “simian stance”. A positive lumbar extension test is demonstrated when patient is asked to extend the spine for 30 to 60 seconds and the symptom reproduced. Usually it is not common to have spinal tenderness. There is also paravertebral and gluteal spasm during palpation.

Motor and sensory examination might reveal some findings. For motor examination, most commonly affected muscles are tibialis anterior (L4) and extensor hallucis longus (L5) (Baba *et al.*, 1994). Deep tendon reflexes, Babinski’s reflex and clonus will be negative. If any of these signs is positive, the surgeon must look for cervical tandem stenosis or other neurological disorder (Garfin *et al.*, 1999).

Stress neurological examination can be done for examining patient after symptoms reproduce. The patient is asked to walk until the pain is occurred. This test is useful if the initial examination revealed normal findings as the stenotic spine become dynamically aggravated while patient is walking (Garfin *et al.*, 1999).

2.2.2 Imaging in Lumbar Spinal Stenosis

(i) Plain radiograph

This should be AP and lateral of lumbosacral spine and coned view of lumbosacral junction. A systematic analysis of each radiograph should be examined for signs of disc degeneration, facet arthrosis, sagittal and coronal alignment and rotational deformity (Fahy and Nixon, 2001). A sagittal diameter of 12mm is considered as narrow (relative stenosis) and a diameter of 10mm or less is considered as severely narrow (absolute stenosis) (Verbiest, 1954; Verbiest, 1976).

(ii) Computed Tomography (CT) Scan

The cut for the CT scan film should be within 3mm from L3 to L5/S1 junction. This is particularly to ensure the abnormalities can clearly delineated such as facet abnormalities or stenosis secondary to degenerative osteophytes fracture. Apart form that, spinal canal shape and intracanal ligament ossification are all observed in plain CT. Unfortunately, the degree of stenosis caused by soft tissue could be underestimated. CT myelogram could also demonstrate deviation of dural sac.

(iii) Magnetic Resonance Imaging (MRI)

The role of MRI is to provide diagnosis of lumbar stenosis, armamentarium for pre-operative planning, assessing the number of spinal level involved and to exclude other spine disease (Moon *et al.*, 2014). Schonstorm et al reported that the cross-sectional area of dural sac to be more reliable diagnostic measure and have defined cross-sectional area of more than $100mm^2$ as the narrowest point as normal, $76mm^2$ to $100mm^2$ as moderately stenotic, and less than $76mm^2$ as severely stenotic (Schonstrom *et al.*, 1985). Central stenosis and lateral recess stenosis can be clearly seen on MRI.

2.3 Management of Lumbar Spinal Stenosis

2.3.1 Non- surgical Treatment

This is the first line of treatment, which should be conducted in nearly all patients with LSS. These include patient education, reassurance, analgesics and non-steroidal anti-inflammatory drugs as tolerated. Apart from that, physical exercise and therapy including back core exercise for endurance and strength should be prescribed. Flexion orthosis can be helpful, but prolonged usage can lead to additional muscle weakness.

Athiviraham et al described a prospective comparative study on 125 patients; objectively to determine whether surgery is better than the medical/inventional method. At two-year follow up, the mean improvement in Roland Morris Disability Questionnaire (RMDQ) scores for decompression, decompression with fusion and medical/inventional treatment were 6.9, 6.1 and 1.2 respectively (Athiviraham and Yen, 2007). They concluded majority of patients who choose surgery will experience significant improvement in function, but will have residual symptoms. Hence, they should be counseled about realistic expectation.

Patient selection is the utmost important factor for determining good clinical outcome (Moon *et al.*, 2014). The good prognostic factors are as follows; adequate decompression is achieved, facet joint stability is maintained, early decompression surgery is performed, and postoperative corset is worn and exercise can be performed. On top of those, the poor prognostic factor includes; persistence of back pain as predominating symptoms, multilevel decompression, prolonged delay to surgery after onset of symptoms, and preoperative presence of significant neurological deficit including urinary symptoms. All these prognostic factors are essential for the surgeon to provide realistic expectations of result of decompression surgery so that the patient can be counseled appropriately.

With regards to multilevel stenosis, decompressive surgery is still having significant effect in most of patients. Park et al described retrospective comparative study to determine the impact of multilevel stenosis on surgical and medical/interventional treatment outcome. When comparing surgical to medical/inventional treatment for one, two and three level isolated stenosis, there was significant effect in most outcomes measures within each subgroup (Park *et al.*, 2010).

Severity and chronicity of stenosis plays a role in determining the outcome of decompressive surgery. Amundsen et al has conducted a case control of 100 patients with symptomatic LSS. They were divided into three groups; 19 patients with severe symptoms receiving surgical treatment (decompression without fusion and brace postoperatively), 50 patients with moderate symptoms received medical/inventional management and 31 with moderate to severe symptoms were randomly selected. At 10 years follow-up, patients with moderate to severe symptoms at presentation will receive a good result (90%) as compared to medical/inventional patients (40%). They also discovered good outcome with decompression for severely stenosed patient (80% to 90%) of the time and patient with moderate symptoms will have good result with medical/inventional treatment about 70% of the time (Amundsen *et al.*, 2000).

Over a time, more surgeons are embarking the endoscopic decompressive surgery for lumbar stenosis. Being compared to the conventional open decompression, the endoscopic decompression is mainly focusing on reducing soft tissue damage, enhances visualization to tackle the disc pathology and aids in socioeconomic problem, as it requires minute cost of surgery as compared to open decompression.

2.4 Endoscopic Decompression Surgery

2.4.1 Introduction

The classical lumbar decompressive surgery and discectomy for lumbar spinal stenosis are well established in spine surgery for decades. There are several pros and cons. Apart from its advantages such as providing a big exploration site, it also provide easiness in practice especially for new surgeon for their learning curve, and also enabling the surgeon to recognize other present pathologies; they also entail some disadvantages such as prolonged hospital stay, abundant tissue damage, delayed mobilization, and high risk of epidural fibrosis and instability. All the abovementioned disadvantages led the researchers to develop less invasive discectomy interventions such as chemonucleolysis, percutaneous nucleotomy, microdiscectomy, endoscopic guided discectomy, and transforaminal or interlaminar full-endoscopic discectomy (Choi *et al.*, 2006; Hijikata, 1989; Onik *et al.*, 1985).

The evolution of minimally invasive lumbar decompression has been started since 1960's. In 1975 Hijikata developed the percutaneous discectomy technique by using fluoroscopy, which is the basis for minimal invasive surgery technique (Hijikata, 1989). This technique was later on improved by Onik by means of adding a new aspiration probe (Onik *et al.*, 1985). By the end of 1970s, together with the contributions of researchers such as Yasargil, Caspar and Williams, microscopic discectomy period involving the use of a microscope in discectomy operations had started. Ultimately with this technique, it was possible for the patient to have smaller incisions, less muscle dissection, less epidural fibrosis, less postoperative pain, early mobilization, and early return to work. Today, this technique is still used as a gold standard in the surgical treatment of lumbar degenerative disc disease. Microscopic discectomy was less invasive than conventional discectomy procedures; nevertheless, they it was an open procedure and had important drawbacks like limited site for operation and epidural fibrosis rates reaching up to 20% in the literature (Teli *et al.*, 2010).

In 1980's, Kambin developed posterolateral arthroscopic lumbar microdiscectomy (Kambin, 1992). Within similar period of time, Hausmann and Forst defined the method of using a nucleoscope to control the residual fragment after discectomy (Kambin and Zhou, 1996). All these studies accelerated the development of endoscopic techniques. Schreiber and Suizawa suggested using double port in percutaneous endoscopic discectomy (Schreiber and Suezawa, 1986). Approaching end of 1990's, the microendoscopic discectomy method of Foley and Smith was defined as a facilitating method for the surgeon since it enabled the use of the devices that were employed in microlumbar discectomy (Foley *et al.*, 1999). In late 1990's, Destandau developed a new endoscopic system called ENDOSPINE operating tube (Destandau, 1999). In 2002, Young and Tsou improved the percutaneous transforaminal endoscopic technique by means of using highresolution endoscope and flexible bipolar radiofrequency probe under local anesthesia (Yeung and Tsou, 2002).

All these studies had facilitated the involvement of endoscopic discectomy technique in neurosurgery practice by the end of 1990s. The most minimally invasive method that is known today among various surgical interventions aiming at sufficient decompression of neural structures and causing minimum tissue damage, which is the basic purpose of lumbar degenerative disc disease surgery, is reported as full-endoscopic transforaminal discectomy (Kambin, 1992; Kambin and Zhou, 1996; Ruetten *et al.*, 2009) and full-endoscopic interlaminar discectomy (Destandau, 1999; Kaushal and Sen, 2012; Komp *et al.*, 2011; Ruetten *et al.*, 2009)

Numerous advantages pertaining to the usage of endoscopic surgery, which are the off-axis anatomical structures can be visualized and every hidden corner at the spine structure can be visualized clearly. These images can be improved with a high-definition camera and monitor. The orthopaedic arthroscopy surgeon may have more familiarize with the system as technique is as same as the arthroscopy procedure.

Figure 2.2 Classic, microscopic and endoscopic discectomy fields of view (adapted from Serdar H. Full-Endoscopic Interlaminar Lumbar Discectomy – Minimally Invasive Spine Surgery: Current Aspects)

2.4.2 Endoscopic Interlaminar (Destandau) Surgery

The procedure of endoscopic decompression can be done with transforaminal (posterolateral), interlaminar (posterior) or anterior approach. However, the endoscopic anterior surgery is mainly done in cervical discectomy (Jho's procedure) and not been done neither in thoracic nor lumbar spine (Jho, 1996).

The evolution of endoscopic interlaminar surgery was revolutionized by Destandau in 1999 (Destandau, 1999). The system consisted of ENDOSPINE operating tube, which is positioned on the lamina after incising the skin and subcutaneous tissue. The working insert has an integrated channel for the telescope.

There are two additional channels, one for suction tube and the other one for the operating instruments. There is a nerve root retractor for allowing the nerve to be medialized thus removing any fragile structure form operating view. The 12^{o}-working angle between working channel and telescope channel enables the surgeon to see the tips of the instruments and use the suction tube as second instrument.

Figure 2.3 DESTANDAU working insert with the adjustable nerve root protector. Operating Tube accomodates working channel with diameter of 8 mm and irrigation channel, for use with HOPKINS Telescope (taken from Destandau endoscopic approach with the mobile ENDOSPINE operating tube; ENDOWORLD® CV 2 8.1 06/2015-E)

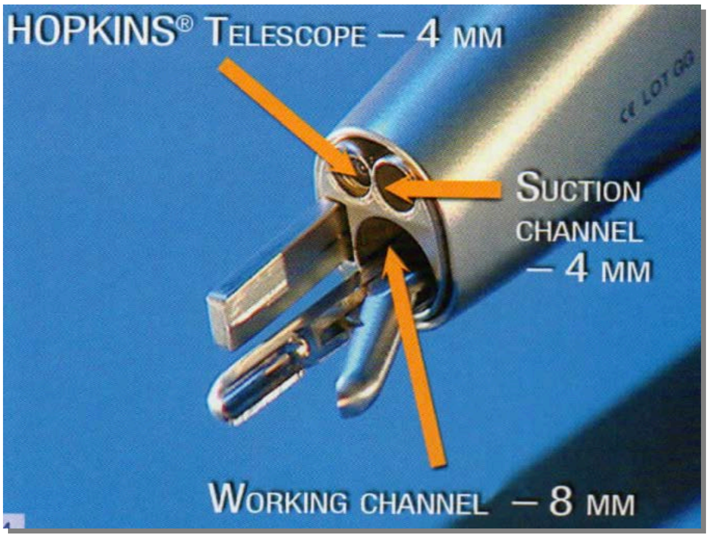

Figure 2.4 The three channels of ENDOSPINE operating tube Telescope (taken from Destandau endoscopic approach with the mobile ENDOSPINE operating tube; ENDOWORLD® CV 2 8.1 06/2015-E)

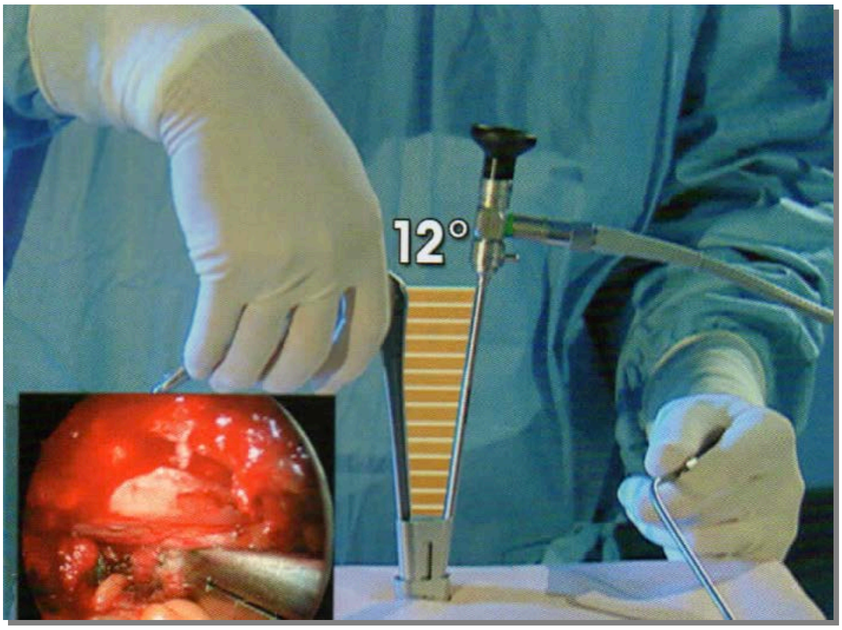

Figure 2.5 The angle between the working channel and the one used by the telescope measures 12^{o} Telescope (taken from Destandau endoscopic approach with the mobile ENDOSPINE operating tube; ENDOWORLD® CV 2 8.1 06/2015-E)

The HOPKINS 0^o-telescope offers a wide field of vision of the operating area without distortion and emits the light generated by cold light source and transmitted to the endoscope via a fiber optic light cable. The entire procedure is performed under constant video-endoscopic control via monitor screen. By resecting part of the superior lamina, the facet and ligamentum flavum, the nerve root and the herniated disc can be seen. The disc can be taken out and microdiscectomy is performed.

2.4.3 Advantages of Endoscopic Interlaminar Surgery

Interlaminar endoscopic dissection is precisely the same approach that has been used for standard open surgery. The only major difference is the size of the wound via mini-open surgery and degree of traumatization to the corresponding soft tissue. This makes the procedure well established. The so-called motion preservation surgery can be accomplished as the facet is resected with diminutive amount, not to mention on its impact on conservation the posterior stabilizing structure that is important for spine biomechanics.

Besides the advantages of minimal invasive, the endoscopic interlaminar surgery also has several additional benefits;

1) Enhance visualization adequacy as if the eyes are inside the spine structures; comparing to microscope where image blockage would be a drawback