A Prospective, Randomized Trial Comparing Expansile Cervical Laminoplasty and Cervical Laminectomy and Fusion for Multilevel Cervical Myelopathy

BACKGROUND: Controversy exists as to the best posterior operative procedure to treat multilevel compressive cervical spondylotic myelopathy.

OBJECTIVE: To determine clinical, radiological, and patient satisfaction outcomes between expansile cervical laminoplasty (ECL) and cervical laminectomy and fusion (CLF).

METHODS: We performed a prospective, randomized study of ECL vs CLF in patients suffering from cervical spondylotic myelopathy. End points included the Short Form-36, Neck Disability Index, Visual Analog Scale, modified Japanese Orthopedic Association score, Nurick score, and radiographic measures.

RESULTS: A survey of academic North American spine surgeons (n = 30) demonstrated that CLF is the most commonly used (70%) posterior procedure to treat multilevel spondylotic cervical myelopathy. A total of 16 patients were randomized: 7 to CLF and 9 to ECL. Both groups showed improvements in their Nurick grade and Japanese Orthopedic Association score postoperatively, but only the improvement in the Nurick grade for the ECL group was statistically significant ($P < .05$). The cervical range of motion between C2 and C7 was reduced by 75% in the CLF group and by only 20% in the ECL group in a comparison of preoperative and postoperative range of motion. The overall increase in canal area was significantly ($P < .001$) greater in the CLF group, but there was a suggestion that the adjacent level was more narrowed in the CLF group in as little as 1 year postoperatively.

CONCLUSION: In many respects, ECL compares favorably to CLF. Although the patient numbers were small, there were significant improvements in pain measures in the ECL group while still maintaining range of motion. Restoration of spinal canal area was superior in the CLF group.

KEY WORDS: Cervical, Fusion, Laminoplasty, Myelopathy

Achiving the extensive decompression necessary to treat cervical spondylotic myelopathy (CSM) surgically while preserving adequate cervical spine lordosis, range of motion (ROM), and stability has challenged spine surgeons for many years. Multilevel anterior cervical decompression and instrumented fusion is a treatment option that was very popular throughout the 1990s. An anterior decompressive procedure and fusion is the most appropriate surgical procedure in the presence of anterior compression limited to 1 or 2 vertebral body levels, particularly if there is a significant kyphosis.1,2 Good to excellent clinical results have been achieved in up to 90% of patients undergoing this procedure. Because high rates of pseudoarthrosis, adjacent-level disease, dysphagia, and instrumentation failure are seen when these constructs span multiple cervical
levels, multilevel anterior approaches appear to be used less frequently.\textsuperscript{3,6} Posterior decompressive approaches are regaining popularity, particularly in elderly patients with a retained cervical lordosis.\textsuperscript{7,8} Multilevel cervical laminectomies had been the posterior procedure of choice in the treatment of CSM.\textsuperscript{9,10} A high incidence of postlaminectomy kyphosis,\textsuperscript{11-14} segmental instability, and associated postoperative neurological deterioration has been cited for the reduction in the use of the procedure. The importance of limiting ROM to address the dynamic components of spondylotic myelopathy has also been considered a reason for the gradual decline of this procedure. Expansile laminoplasty and multilevel laminectomies with instrumented fusion have become more popular therapeutic options in cases of multilevel spinal stenosis with myelopathy.\textsuperscript{15-17} Supporters of expansile laminoplasty claim that because the laminae are elevated en bloc, the risk of neurological injury with surgical instruments is avoided, especially in cases with severe stenosis.\textsuperscript{18,19} Expansile laminoplasty is proposed to provide postoperative spine stability by preserving the bony arch and the posterior tension band, thereby reducing the incidence of postoperative kyphosis without subjecting the patient to the risks of instrumentation.\textsuperscript{20,21} Proponents of multilevel laminectomies with instrumented fusion contend that it deals most optimally with the pathophysiology responsible for spondylotic myelopathy. The decompression addresses the static factors, and the instrumented fusion eliminates the dynamic factors, halting the progression of spondylosis. It also offers immediate spine stability, thus reducing the risk of postoperative kyphosis more effectively than laminoplasty.\textsuperscript{17} Given the controversy, we sought to design a prospective, randomized pilot study to assess several clinical and radiographic end points between the 2 procedures in the treatment of CSM.

**MATERIALS AND METHODS**

**Survey**

We initiated our study by conducting a survey of 30 spine surgeons to gauge which posterior decompressive procedure is being used most frequently in North America (Figure 1A) to treat CSM. An evaluation of current trends would permit us to design the study to include the most frequently used surgical procedures. We polled spine surgeons, who were trained in either neurosurgery or orthopedic surgery, with the following characteristics: a minimum of 5 years of experience, distinct training backgrounds, and practicing in large academic centers with training programs for fellows and/or residents or with a significant role in teaching at a national level. They were asked to answer a patient management question and to select a posterior-only surgical approach (Figure 1B). The question simply stated, “In a patient who has symptomatic cervical myelopathy and the following \{magnetic resonance image\}, what is your preferred posterior surgical procedure A) multi-level cervical laminectomies, B) cervical laminoplasty, C) multi-level cervical laminectomies with instrumented fusion?”

**Study Design**

This prospective, randomized study was conducted at University of Miami Miller School of Medicine after approval by the Human Subjects Committee and Institutional Review Board (IRB No. 200573488). All surgeries were performed at Jackson Memorial Hospital by 1 of the 3 senior authors (A.D.L., n = 10; S.V., n = 5; M.W., n = 1) who are faculty members within the Department of Neurosurgery. Written informed consent was obtained from all enrolled patients.

**Patient Population**

Patients considered for the study were at least 35 years of age and had at least \(\geq 3\) levels of cervical spinal cord compression with accompanying signs and symptoms of myelopathy, with or without radiculopathy. Major exclusion criteria included active systemic infection, metabolic bone disease such as osteoporosis, known allergy to titanium, concomitant conditions requiring steroid treatment, diabetes mellitus requiring insulin treatment, obesity (body mass index \(> 30\%\)), and pregnancy. The following conditions were also exclusionary criteria: axial neck pain as the solitary symptom, previous cervical spine surgery, current treatment for either thoracic or lumbar spine disease, and pending litigation or worker’s compensation. Patients were also screened for and excluded if they had a neurological or medical condition that could interfere with the postoperative management and/or follow-up, including Alzheimer disease, Parkinson disease, active malignancy, and unstable cardiac disease. Imaging characteristics that were exclusionary included preoperative cervical spine instability documented as angle of kyphosis (Cobb angle) \(> 15^\circ\) and/or listhesis \(> 3\) mm, ankylosing spondylitis, diffuse idiopathic skeletal hyperostosis, and diffuse ossification of the posterior longitudinal ligament. Patients requiring \(> 3\) foraminotomies for symptomatic foraminal stenosis were also excluded.

**Recruitment and Randomization Process**

Potential patients were identified and screened by the principal investigators. The treating surgeon explained the randomization process, potential surgical procedures, and required imaging and follow-up to all potential candidates in detail. Once the candidate agreed to participate, informed consent was obtained, and the patient was randomized to 1 of the 2 surgical treatment arms. Selection of the procedure was from a sealed envelope maintained by the study coordinator. The card possibilities were either a expansile cervical laminoplasty (ECL) or a cervical laminectomy and fusion (CLF). Patients were randomized on a 1:1 randomization schedule. Outcome measures were collected preoperatively, at 3 months, and at the 1-year follow-up. Annual follow-ups were scheduled to determine long-term results.

**Surgical Intervention**

At the initial part of each procedure (ECL and CLF), the patient is placed in the supine position with the neck minimally extended, and endotracheal intubation is performed usually via an awake fiberoptic intubation. Each patient receives preincisional intravenous antibiotics. Neurophysiological monitoring includes somatosensory evoked potentials,\textsuperscript{22} motor evoked potentials,\textsuperscript{23} and electromyography.

Our open-door ECL procedure was based on the open-door variant described by Hirabayashi et al\textsuperscript{24} and Vitarbo et al.\textsuperscript{25} The midline fascia is incised, and subperiosteal dissection is used to reflect the soft tissue structures of the spinous processes, lamina, and mesial portions of the
facets bilaterally, taking care to preserve the facet capsules from the caudal portion of C2 to the rostral limit of T1. In all cases, the caudal third of the C2 lamina and the rostral third of the T1 lamina are removed. Troughs are then drilled at the lamina-facet junction bilaterally from C3 to C7. On the open-door side, all 3 layers of bone are drilled completely, and the laminoplasty construct is elevated toward the opposite side. The opposite trough with its deeper cortical surface intact serves as a “hinge” for the door. Cervical foraminotomies, when performed (maximum of 3), usually were performed on the side of the open door. Cadaveric rib allograft is used to prepare 3 struts, which ranged in length from 14 to 18 mm. Grooves are then made transversely along the cut surfaces of the rib grafts, approximating the thickness of the cut lamina. The precut rib allografts are placed between the lamina of C3, C5, and C7 and their respective facets and serve to hold the construct open as a slight “closing” force secures the graft in position. The lateral masses of C3, C5, and C7 are decorticated, and the autograft is placed posterolaterally, predominantly on the closed side to create an intersegmental fusion at these levels. The decompression extends somewhat rostral and caudal to the maximum levels of compression so that the spinal cord does not migrate back and become entrapped or kinked at the rostral or caudal levels (lamina) of the decompression. In the CLF group, the treating surgeon decided preoperatively on the levels at which to perform the decompression and fusion. A minimum of 4 disk levels were decompressed and then instrumented. The decompression never extended above or below the levels fused so as not to create a situation of instability. The decompression was performed via a midline approach, and the laminae were removed with a combination of rongeurs, curettes, and a high-speed drill. Cervical foraminotomies (maximum of 3), if necessary, were then performed. The decompressed levels were then instrumented with lateral mass (cervical) and, when indicated, pedicle screws (thoracic) and rod fixation. Autologous laminectomy bone was saved and used as bone graft material and placed over the lateral masses of the fused levels after decortication. In both procedures, patients were maintained in a Miami J collar for a period of 10 to 12 weeks.

Outcome Measures

The self-reported measures used were the Medical Outcomes Study Short Form SF-36 (General Health Survey), the Neck Disability Index (NDI), and an analog pain scale for neck, arm, and interscapular pain rated 1 to 10 with 10 being the most severe pain level. In addition to a complete neurological exam, myelopathy was graded with the Nurick scale and the modified Japanese Orthopedic Association (mJOA) scale. Radiographic data collected included the cervical spine curvature index (CI) on lateral neutral, flexion, and extension films from C2 to C7 (Figure 2A) using the modified Ishihara CI. A CI value > 0 suggests a lordotic cervical spine, and a CI value < 0 suggests a cervical kyphosis. In addition, the ROM was calculated by subtracting the angle measured from the superior endplate of C3 and inferior endplate of C7 between flexion and extension. Radiographic data collected included the cervical spine curvature index (CI) on lateral neutral, flexion, and extension films from C2 to C7 (Figure 2A) using the modified Ishihara CI. A CI value > 0 suggests a lordotic cervical spine, and a CI value < 0 suggests a cervical kyphosis. A CI value > 0 suggests a lordotic cervical spine, and a CI value < 0 suggests a cervical kyphosis.

Statistical Analysis

The data were analyzed with InStat and GraphPad Prism software. Preoperative and postoperative values for CI and ROM were analyzed with a 1-way analysis of variance and Tukey posttest. All other preoperative and 1-year postoperative values were analyzed with a paired t test.

RESULTS

Survey

The results of our survey indicated that the majority (70%) of spine surgeons in North America (Figure 1C) prefer laminectomy
with instrumented fusion over ECL (23%) to treat patients with multilevel cervical stenosis and myelopathy (Figure 1C). Multilevel cervical laminectomy was chosen as a surgical option by only 7% of the surgeons polled. The results of this survey prompted us to compare, head to head, the 2 posterior procedures most commonly used to treat multilevel CSM using objective outcome measures.

**Patients**

The study was designed, and Institutional Review Board approval was obtained in the fall of 2005. The first patient was enrolled in March 2006, and the last patient was enrolled in June 2008. Sixteen patients met inclusion criteria and were randomized to one of the treatment arms, including 7 male and 9 female patients. The enrolled study population represented 3.5% of all patients seen in clinic and 13% of all patients operated on with the diagnosis of cervical and cervicothoracic myelopathy.

The mean age of the entire study group was 59 years; age range was from 41 to 75 years. Nine patients, 5 men and 4 women, were randomized to ECL. Their mean age was 61 years, and their mean duration of symptoms was 17 months. Seven patients, 2 men and 5 women, were randomized to the CLF group. Their mean age was 55 years, and their mean duration of symptoms was 20 months. No patient in the study was lost to follow-up. Unlike the clinical data and the magnetic resonance imaging–based spinal canal area
measurements, for which we achieved 1-year follow-up data for all 16 patients, we were unable to collect complete x-ray data for all enrolled patients. The main problem related to the quality of exposure of the plain radiographs and the fact that the lower cervical segments could not be visualized in some patients. Additionally, there was some lack of patient compliance with scheduled x-ray appointments.

**Intraoperative and Perioperative Data**

Comparison of inpatient data revealed slightly more favorable results for the ECL group, none of which was statistically significant. The mean estimated blood loss was 500 cm³ for CLF and 405 cm³ for ECL. The mean operative time was 3.5 hours for CLF and 3 hours for ECL. The mean length of hospital stay was 4.7 days for CLF and 3.4 days for ECL. No complications were detected in either group. Specifically, there was no instance of worsening of myelopathy, C5 root palsy, rib allograft dislodgement, instrumentation failure or malposition, infection, hematoma, pseudoarthrosis, or screw loosening. There was no significant difference in narcotic use between groups (data not shown).

**Myelopathy Scores and Self-Reported Outcome Measures**

Both groups (ECL and CLF) showed improvements in their Nurick grade and mJOA score postoperatively. Only the improvement in the Nurick grade for the ECL group was statistically significant ($P < 0.05$) (Figure 3A). The mJOA score improved from 12.57 ± 1.2 (preoperatively) to 14.25 ± 0.96 (postoperatively) in the ECL group and from 12.57 ± 1.09 (preoperatively) to 13.57 ± 1.02 (postoperatively) in the CLF group (Figure 3B). There were no significant differences in baseline self-reported indexes between the 2 groups. The ECL group, however, showed a statistically significant ($P < 0.05$) improvement in self-reported outcome measures, including neck, interscapular, and arm pain, 1 year after surgery. Although the CLF group generally showed improvement in all self-reported outcome measures, none of these results was statistically significant (Figure 4A-4C). The SF-36 and the NDI were evaluated in both groups preoperatively and 1 year postoperatively (Figure 5A and 5B). Comparison of preoperative and postoperative SF-36 scores ($P < .05$) and NDI ($P < .05$) scores showed that they were significantly improved only in the laminoplasty group (1-way analysis of variance, repeated measures).

**Radiographic Data**

The CI was used to quantify lordosis in the preoperative and postoperative lateral images in neutral. The neutral CI was $-0.2$ in the ECL group and $-1.9$ in the CLF group, demonstrating a relatively straight spine from C2 to C7 preoperatively in both groups. As the cervical spine curvature becomes kyphotic, the numeric CI value becomes more negative. At 1 year, the neutral CI value was more negative (more kyphotic) for both groups on neutral lateral x-rays with ECL measured as $-4.63 \pm 4.79$ and CLF as $-6.26, \pm 4.70$. The mean adjacent segment angular measurement change above the decompression for the CLF and ECL groups were $2.9$ and $4.1$ (negative means more kyphosis) and below the decompression were $0.6$ and $0.1$, respectively. These values suggest that the loss of kyphosis particularly in the CLF group is due to adjacent-level changes because there was essentially no movement in the CLF group at the instrumented levels.

The difference in CI between flexion and extension ($\text{CI}_{\text{extension}} - \text{CI}_{\text{flexion}} = \text{CI}_{\text{difference}}$) was calculated, as well as the ROM (Figure 6A and 6B). A large, positive value for CI difference was taken to be suggestive of more preservation of ROM. At 1 year, the $\text{CI}_{\text{difference}}$ was greater for the ECL group, but these values were not statistically significant. The CI between CLF and ECL for preoperative and 1-year postoperative values in the ECL was only 16.8%, whereas it was 58.2% in the CLF group. The cervical ROM between C2 and C7 was reduced by 75% in the CLF group and by only 20% in the ECL group in a comparison of preoperative and 1-year postoperative ROM. The cervical ROM increased between the 3-month and 1-year films (Figure 6B) in the ECL group. The most likely explanation is that patient had just shed their collars at the 3-month visit and were able to regain some of the lost ROM that accompanies extended collar use. In contrast, the cervical ROM remained unchanged between 3 months and 1 year in the CLF group. Most residual movement seen in the CLF group was observed at the level above the fusion because the measured CI difference at the instrumented levels was essentially zero (Figure 6C).

The degree of decompression as measured by the percent change in thecal sac cross-sectional area was calculated (postoperative – preoperative/preoperative $\times 100 = \text{percent change in}$...
area) at the 3 most stenotic levels for each patient at 1 year postoperatively (Figure 7). The mean for this percentage change in area was significantly greater ($P < .001$) in the CLF group (76%) compared with the ECL group (34%). We also assessed the midsagittal diameter (in millimeters) of the cervical canal at the 3 worst levels, preoperatively vs 1 year postoperatively, between the ECL and CLF groups and found a similar difference. Interestingly, the adjacent level in several cases of CLF appeared to diminish even within 1 year of the fusion (Figure 8A-8D). The

The 3 most affected levels in the cervical laminectomy and fusion (CLF) group, a significant decrease in mobility of the neck was observed. Range of motion at the fused levels was minimal (C).

FIGURE 4. Neck (A), interscapular (B), and arm (C) pain evaluated by the Visual Analog Scale were significantly improved ($P < .05$) in only the expansile cervical laminoplasty (ECL) group (1-way analysis of variance, repeated measures). CLF, cervical laminectomy and fusion.

FIGURE 5. A and B, comparison of preoperative and postoperative scores. A. Short Form-36 (SF-36) scores ($P < .05$) and (B) Neck Disability Index ($P = .05$) scores were significant only in the expansile cervical laminoplasty (ECL) group (1-way analysis of variance, repeated measures). CLF, cervical laminectomy and fusion.

FIGURE 6. After 1 year, curvature index (CI), extension/flexion difference (A), and range of motion (B) were similar to preoperative values in the expansile cervical laminoplasty (ECL) group; however, in the cervical laminectomy and fusion (CLF) group, a significant decrease in mobility of the neck was observed. Range of motion at the fused levels was minimal (C).

FIGURE 7. Mean and standard error of the mean of the percent of change in the 3 most affected spinal segments in the cervical laminectomy and fusion (CLF; 76%) and expansile cervical laminoplasty (ECL; 34%) groups ($P < .001$).
reduction in spinal canal area below the area of decompression (mean \( \pm \) SEM) for the CLF and ECL groups was \(-0.262 \pm 0.12\) and \(-0.03 \pm 0.09\) cm\(^2\), respectively; although not statistically significant, this reduction supports the possibility of accelerated adjacent-level disease in the CLF group. Typical examples of cervical flexion extension views and midsagittal and cross-sectional area of the spinal canal in an ECL patient (Figure 9) and in a CLF patient (Figure 10) are demonstrated preoperatively and 1 year postoperatively.

**DISCUSSION**

**Background**

The natural history of CSM is poorly understood, and conservative management is largely empirical.\(^3^0\) No well-designed clinical studies have systematically evaluated the efficacy of nonsurgical management. Although conflicting evidence exists, the majority of available evidence suggests that CSM is largely a surgical disease, in the presence of symptoms and signs, appropriate radiographic evidence, and supportive studies. Decompressive cervical laminectomy effectively enlarges the functional spinal canal area. It does so at the expense of posterior stabilizing structures. Loss of cervical lordosis or development of kyphosis is seen in as many as 47% of patients; however, clinically significant malalignment and instability are less common.\(^9,14,32\) The crucial implication is that ensuing kyphosis and kyphotic malalignment of the spinal cord can result in secondary cord compression and poor outcome.\(^33\)

**Clinical and Radiographic Outcomes After ECL**

Asian surgeons developed the “laminoplasty” procedure in the late 1970s with numerous modifications since that time.\(^2^4,2^5,2^6,2^7,2^8,2^9\)
FIGURE 9. Cervical x-rays (flexion and extension views) and magnetic resonance image of the preoperative (A, C, E, G) and 1-year postoperative (B, D, F, H) patient treated with a cervical laminoplasty. Range of motion in the postoperative period (B, D) was very similar to that in the preoperative image (A, C) and the spinal canal was successfully decompressed (G and H).
FIGURE 10. Cervical x-rays (flexion and extension) and magnetic resonance image of the preoperative (A, C, E, G) and postoperative (B, D, F, H) patient treated with cervical laminectomy and fusion. Range of motion in the postoperative period (B, D) was reduced compared with that in the preoperative image (A, C), and the spinal canal was successfully decompressed (E, F, G, and H).
This procedure, by leaving the posterior stabilizing structures in situ, is believed to mitigate the development of kyphosis. In our study, the rib allografts are held in place by the closing force provided by the green stick fractured lamina from the hinged side. In our experience, displacement or sinkage of the graft into the spinal canal is rare. The allograft length (14-18 mm) should be adequate to increase the canal diameter, and there is a direct correlation between graft length and reconstituted canal area (M.Y. Wang, personal communication, 2011). Some surgeons prefer to stabilize the rib allograft with miniplates or sutures to the adjacent lamina and facet on the open side or to use a metallic spacer with screws to span the open door and facet joint. Expandable cervical laminoplasty has a low complication rate, which was confirmed in our study. This is particularly true compared with decompressive operations, which attempt to achieve the same number of levels of decompression and stabilization when tackled from the front. It is ideally suited for the elderly myelopathic, osteoporotic patient with multiple levels of stenosis. The majority of the studies examining clinical and radiographic outcomes for ECL are derived from the Japanese literature (87% of 46 articles cited). There were improvements in myelopathy scales in both treatment groups, but the Nurick score improvements were significant in only the ECL group in our study. Although substantial literature exists with long-term outcomes, an evaluation of the Japanese results, with their much higher incidence of ossification of the posterior longitudinal ligament, may not allow us to simply extend these findings to North Americans. Ossification of the posterior longitudinal ligament is associated with increased rigidity and thus may overestimate the restricted ROM attributable to the laminoplasty procedure. Both clinically and radiographically, published studies suggest that approximately 50% of the ROM is lost after laminoplasty, particularly in extension. We analyzed both ClDiff and ROM and found only an approximately 20% reduction in motion with laminoplasty at 1 year. The loss of mobility does not necessarily correlate with a poor outcome. It has been proposed that this may actually be beneficial in that it ameliorates ongoing mechanical stress or injury without being “rigid” and inducing stress and degeneration of adjacent levels.

A meta-analysis of overall recovery rates (JOA scores) using a variety of techniques for laminoplasty is approximately 55% to 65% unless associated with a decreased cervical curve index of >10. Clinically, studies have shown that clinical improvement directly correlates to degree of canal expansion and degree of posterior spinal cord migration. However, excessive expansion and irregular canal area may be associated with additional problems. It appears that optimal canal expansion approximates 4 to 5 mm in the sagittal diameter, correlating to an approximately 50% (vs 34% in our study) increase in canal area and facilitating a 3-mm dorsal shift of the spinal cord. Similarly, although canal area was significantly increased in the CLF group compared with the ECL group, neurological outcomes were similar. Retrospective studies indicate that increased canal diameters (beyond those above) are associated with an increased incidence of postoperative complications, specifically C5-6 paresis. Far more critical than canal expansion is subsequent cord expansion, with studies showing a direct correlation between JOA scores and spinal cord area.

**Clinical and Radiographic Outcomes After CLF**

Posterior cervical fusion techniques have evolved rapidly over the last 2 decades. On-lay bone fusion techniques and facet wires have been supplanted by plate screw and more recently rod screw instrumentation. Although no instrumentation procedure is without potential complications, the anatomic and technical nuances of lateral mass screws are familiar to all spine surgeons. Increasing familiarity with upper-thoracic pedicle screw anatomy and the relatively large size of the pedicles in this area of the thoracic spine have allowed most spine surgeons to bridge the cervical thoracic junction with fewer complications. The ease of use of top-loading screw-rod systems over screw-plate constructs particularly over multiple levels has increased the comfort level in deploying a rigid fixation strategy as part of the treatment of multilevel CSM. Because of concerns about segmental instability and/or kyphosis after a simple laminectomy and less commonly for a correction of deformity, posterior instrumented cervical fusion has been increasingly used by spine surgeons in North America (70% of academic centers in our study). There are relatively few published data on clinical and radiographic outcomes of CLF in the treatment of CSM. A recent review was able to identify only 11 articles. Although the majority of the articles are from the United States, all are retrospective in nature (class III) and had relatively short radiographic and clinical follow-up. Only 5 articles were larger studies (> 20 patients) using modern fixation techniques in a patient cohort without preexisting instability or deformity. Most articles suggest improvements in neurological function (76%-97%) with retention of alignment. Our results also suggest improvement in neurological function with respect to both Nurick and JOA scores. The hypothesis that fusion may result in greater neurological recovery than maintenance of motion has yet to be proven. A rigid fusion comes at a cost in terms of instrumentation, time in the operating room, and length of stay, all of which were increased in the CLF group. The concept that pain can potentially be reduced by the addition of a rigid fusion is not demonstrated in our results. There may be issues related to adjacent-level disease in the CLF group, although longer follow-up is required. Our experience with laminoplasty supports the concept that adjacent-level disease is exceedingly uncommon. Finally, the restricted ROM in the CLF group compared with preoperative studies appears impressive.
Comparison of Cervical Laminoplasty With Other Posterior Decompressive Procedures

Only 1 article in the literature directly compares CLF and ECL in multilevel cervical stenosis and myelopathy. Heller and colleagues retrospectively reviewed independently matched cohorts of 13 patients with CSM undergoing laminoplasty and 13 undergoing laminectomy with instrumented fusion. They analyzed clinical parameters, including Nurick grade, pain level, and radiographic parameters such as the ratio of spinal canal to vertebral body, segmental listhesis, cervical lordosis, ROM, and complications. Their major findings included greater improvement in Nurick scores in the laminoplasty (2.3-1.1) cohort compared with the laminectomy and fusion group (2.2-1.5) but without statistical significance. There was no difference in axial pain level scores. There was a greater incidence of complications and reduced ROM in the laminectomy and fusion patients compared with the laminoplasty patients. Complications in the CLF group included a deep wound infection (n = 1), adjacent-level disease requiring anterior decompression and fusion (n = 1), moderate cervical kyphosis (n = 1), iliac crest harvest-site pain (n = 2), neurological deterioration (n = 2), pseudoarthritis (n = 5), and instrumentation failure (n = 2). There were no complications in the ECL group. The study is considered a class III comparative study and may have had a selection bias for kyphosis in the CLF group.

Although the above study represents the only direct comparison of CLF and ECL, several studies have compared ECL and laminectomy. Herkowitz published a retrospective review comparing clinical and radiographic outcomes in patients with radiculopathy and myelopathy undergoing laminectomy (n = 12), anterior fusion (n = 18), and laminoplasty (n = 15). He graded clinical outcome as excellent, good, or poor using a subjective scale and used radiographs to assess ROM, lordosis, and myelographic appearance of the neural elements. In comparing the dorsal decompressive procedures specifically, he found better clinical results with laminoplasty with half the percentage of complications (25% vs 13%); however, he also found that cervical ROM was more limited in laminoplasty patients than in patients receiving cervical laminectomy. Matsunaga et al. compared postoperative kyphosis rates between ECL (7%) and laminectomy (34%) but did not address functional outcome. Nakano et al. found no difference in functional outcome between ECL (n = 75 patients) and laminectomy (n = 14 patients).

Discussion of Results

Although many of the articles mentioned offer relevant and unique data about these procedures, most studies are limited by the fact that they are retrospective reviews with small numbers of patients and therefore are subject to significant constraints inherent to a class III study. Essentially, there is a paucity of strong data in the literature to support one of these procedures over the other in treating CSM. Their use varies in frequency from institution to institution and is highly subject to individual surgeon practice biases. Although prospective randomized studies remain the gold standard in medicine to establish superiority of surgical treatment options, significant challenges remain in recruiting patients to possible surgical arms. As witnessed in the present study, patients are reluctant to be randomized, prefer “the surgeon” to make the decision, may have 1 or multiple exclusion criteria, and resist entry because of the requirement for repeated follow-up and additional imaging studies.

Our data demonstrate that CLF is selected much more frequently than ECL or laminectomy by spine surgeons working primarily in academic centers for multilevel CSM. One of the most important aspects of this preference is its potential influence on the next generation of spine surgeons. Although the costs of the 2 procedures were not specifically addressed in this study, the addition of instrumentation and increased operative time in our institution results in CLF being a significantly more expensive procedure than ECL. We use relatively inexpensive rib allograft as a spacer. Titanium spacers can be used as an alternative. There was a paucity of complications in both groups, so it appears that the procedures described are safe. We specifically had no instances of C5 root palsy, which has been reported as a potential outcome in both CLF and ECL.

Axial neck and parascapular pain is common in CSM and has been a topic of intense debate among proponents and detractors of the cervical laminoplasty procedure. Interestingly, the only comparative study between CLF and ECL looking at pain severity as measured by narcotic intake and functional restriction (Robinson scale) found no difference. The causative factors for pain after a posterior decompressive procedure are complex and include issues related to the extensive posterior dissection and detachment of the cervical musculature, muscular atrophy, cervical alignment, radiculopathy leading to pain referred to the neck and shoulder girdle, and length of time of immobilization. There is a general tendency in the field of spine surgery to associate fusion with a potential treatment for neck pain. Although there is evidence for fusion in the treatment of single-level diskogenic neck pain, evidence that fusion improves neck pain after multilevel cervical decompression is lacking. In our study, neck and parascapular pain appeared to respond to both surgeries, but the Visual Analog Scale, NDI, and SF-36 showed that laminoplasty appeared to be superior in reducing pain. The minimally clinically important difference (MCID) is an attempt to find clinically meaningful change by calculating concrete values that determine the importance of an observed outcome as being clinically significant, ie, the smallest difference that patients perceive as beneficial. A review of the literature with regard to MCID and spine outcomes shows that most published data are related to lumbar spine fusion surgery, and in a single article, an MCID was found after cervical spine fusion surgery. Anchor-based approaches for patient-reported outcomes have not been validated in the setting of posterior cervical decompressive surgery; thus, we do not know what change of score constitutes an MCID. In the Carreon et al. study, a 4.1-point increase in SF-36 Physical Component Score would constitute this MCID.
and a 3-point decrease in arm or neck pain would detect an MCID. In our ECL group, there was a 19-point increase in SF-36 Physical Component Score and a 8.25-point reduction in NDI, as well as a reduction in neck and arm pain of 3.5 and 2.9, respectively, all of which would have reached MCID using their study criteria.

Neurological improvement after posterior decompressive surgery is often quantified with either Nurick grade or mJOA score. The Nurick score is a unidimensional instrument that focuses on ambulatory status, whereas the mJOA assesses hand, gait, and urinary function. Improvements in each of these scores were observed in both surgical treatment arms (ECL and CLF) in our study and were remarkably similar to improvements reported in the literature.19-36,46,49-52 We performed a power calculation using the available results in our 16 patients as well as a literature review to predict the appropriate sample size required to detect a statistically significant difference between treatment groups with respect to recovery from myelopathy. Independent calculations were done with both the JOA and the Nurick scores because they are the 2 end-point measures of myelopathy that are most consistently documented in the literature. Given the pilot data, a repeated-measures analysis of variance determined that a “test of within-subjects effects” is powered currently to 8% for JOA score and 12% for Nurick score. To achieve a study that was powered to 80%, thereby limiting our type II error, and to determine statistical significance between treatment groups, we would need approximately 110 (JOA score) or 130 (Nurick score) patients in each treatment group. This single-center trial was ended because of slow enrollment. The power analysis suggests that obtaining a definitive answer on the best procedure for cervical spondylotic myelopathy requires a multisurgeon/multicenter trial. There are no published reports with respect to MCID with either the Nurick or JOA myelopathy scores.

CONCLUSION

This article provides prospective, randomized data comparing clinical and radiographic outcome data on 2 commonly used procedures in the treatment of CSM in a small group of North American patients. The results suggest that patients may benefit from both procedures and that the complication rates are low. The relatively small number of patients in each treatment arm limits the strength of the comparative aspects of the study; however, ECL demonstrated improvements in several outcome measures, including pain, NDI, SF-36, and ROM. Improvements in neurological function were seen in both groups despite a statistically greater increase in canal area in the CLF group.

Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

REFERENCES

1. Chagas H, Domingues F, Aversa A, Vidai Fonseca AL, de Souza JM. Cervical spondylotic myelopathy: 10 years of prospective outcome analysis of anterior decompression and fusion. Surg Neurol. 2005;64(suppl 1):S1:30-S1:35; discussion S1:35-36.

2. Herkowitz H. A comparison of anterior cervical fusion, cervical laminectomy, and cervical laminoplasty for the surgical management of multiple level spondylotic radiculopathy. Spine (Phila Pa 1976). 1998;13(7):774-780.

3. Hilibrand AS, Carlson GD, Palumbo MA, Jones PK, Bohlin HH. Radiculopathy and myelopathy at segments adjacent to the site of a previous anterior cervical arthrodesis. J Bone Joint Surg Am. 1999;81(4):519-528.

4. Macdonald RL, Fehlings MG, Tator CH, et al. Multilevel anterior cervical corpectomy and fibular autograft fusion for cervical myelopathy. J Neurosurg. 1997;86(6):990-997.

5. Ratliff JK, Cooper PR. Cervical laminoplasty: a critical review. J Neurosurg. 2003;98(3)(suppl):230-238.

6. Vaccaro AR, Falafry SP, Scuderi GJ, et al. Early failure of long segment anterior cervical plate fixation. J Spinal Disord. 1998;11(5):415-417.

7. Morpeth JF, Williams MF. Vocal fold paralysis after anterior cervical disectomy and fusion. Laryngoscope. 2000;110(1):43-46.

8. Riley LH III, Skolasky RL, Albert TJ, Vaccaro AR, Heller JG. Dysphagia after anterior cervical decompression and fusion: prevalence and risk factors from a longitudinal cohort study. Spine (Phila Pa 1976). 2005;30(22):2564-2569.

9. Jenkins DH. Extensive cervical laminectomy: long-term results. Br J Surg. 1973;60(11):852-854.

10. Nurick S. The natural history and the results of surgical treatment of the spinal cord disorder associated with cervical spondylotic. Brain. 1972;95(1):101-108.

11. Barzdorf U, Barzdorf A. Analysis of cervical spine curvature in patients with cervical spondylosis. Neurosurgery. 1988;22(5):827-836.

12. Albert TJ, Vaccaro A. Postlaminectomy myelopathy. Spine (Phila Pa 1976). 1998;23(24):2738-2745.

13. Kaprain GL, Simmons NE, Reploge RE, Pohreskin L. Incidence and outcome of lephtonic deformity following laminectomy for cervical spondylotic myelopathy. J Neurosurg. 2000;93(2)(suppl):199-204.

14. Kato Y, Iwasaki M, Fuji T, Yonenobu K, Ochi T. Long-term follow-up results of laminectomy for cervical myelopathy caused by ossification of the posterior longitudinal ligament. J Neurosurg. 1998;89(2):217-223.

15. Ishida Y, Suzuki K, Ohnori K, Kitaka Y, Hartori Y. Critical analysis of extensive cervical laminectomy. Neurosurgery. 1989;24(2):215-222.

16. Matsunaga S, Sakou T, Nakami K. Analysis of the cervical spine alignment following laminoplasty and laminectomy. Spinal Cord. 1999;37(1):20-24.

17. Houten JK, Cooper PR. Laminectomy and posterior cervical plating for multilevel cervical spondylotic myelopathy and ossification of the posterior longitudinal ligament: effects on cervical alignment, spinal cord compression, and neurological outcome. Neurosurgery. 2003;52(5):1081-1087; discussion 1087-1088.

18. Lee TT, Manzano GR, Green BA. Modified open-door cervical expansive laminoplasty for spondylotic myelopathy: operative technique, outcome, and predictors for gait improvement. J Neurosurg. 1997;86(1):64-68.

19. Satoro K, Ninou Y, Kohno T, Hiraibayashi K. Long-term follow-up studies of open-door expansive laminoplasty for cervical stenotic myelopathy. Spine (Phila Pa 1976). 1994;19(5):507-510.

20. Tsuza K, Abe R, Sakai K, Iizuka T. Tension-band laminoplasty of the cervical spine. Int Orthop. 1996;20(5):275-284.

21. Morimoto T, Okuno S, Nakase H, Kawaguchi S, Sakaki T. Cervical myelopathy due to dynamic compression by the laminectomy membrane: dynamic MR imaging study. J Spinal Disord. 1995;12:172-173.

22. Bouchard JA, Bohlin HH, Biro C. Intraoperative improvements in somatosensory evoked potentials: correlation to clinical outcome in surgery for cervical spondylotic myelopathy. Spine (Phila Pa 1976). 1996;21(5):589-594.

23. Calancie B, Harris W, Bronson JG, Alexeeva N, Green BA. “Threshold-level” multipulse transcranial electrical stimulation of motor cortex for intraoperative monitoring of spinal motor tracts: description of method and comparison to somatosensory evoked potential monitoring. J Neurosurg. 1998;88(3):457-470.

24. Hiraibayashi K, Watanabe K, Wakano K, Suzuki N, Satoro K, Ishii Y. Expansive open-door laminoplasty for cervical spinal stenotic myelopathy. Spine (Phila Pa 1976). 1983;8(7):693-699.

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25. Vitarbo E, Sherth RN, Levi AD. Open-door expansive cervical laminoplasty. *Neurosurgery*. 2007;60(1 suppl 1):S154-S159.

26. King JT Jr, Roberts MS. Validity and reliability of the Short Form-36 in cervical spondylotic myelopathy. *J Neurosurg*. 2002;97(2 suppl):180-185.

27. Vernon H, Mior S. The Neck Disability Index: a study of reliability and validity. *J Manipulative Physiol Ther*. 1991;14(7):409-415.

28. Yonenobu K, Akiyama K, Nakahara T, Taketomi A, Eymery K, Shimizu K. Interobserver and intraobserver reliability of the Japanese Orthopedic Association scoring system for evaluation of cervical compression myelopathy. *Spine (Phila Pa 1976)*. 2001;26(17):1890-1894; discussion 1895.

29. Aita I, Wadano Y, Yabuki T. Curvature and range of motion of the cervical spine after laminoplasty. *J Bone Joint Surg Am*. 2000;82(12):1743-1748.

30. Brain WR, Northfield D, Wilkinson M. The neurological manifestations of cervical spondylotic myelopathy. Brain. 1952;75(2):187-225.

31. Hukuda S, Mochizuki T, Ogata M, Shichikawa K, Shimomura Y. Operations for cervical spondylotic myelopathy: a comparison of the results of anterior and posterior procedures. *J Bone Joint Surg Br*. 1985;67(4):609-615.

32. Rogers I. The treatment of cervical spondylotic myelopathy by mobilisation of the cervical cord into an enlarged spinal canal. *J Neurosurg*. 1961;18(4):490-492.

33. Kawakami M, Tamaki T, Iwaski H, Yoshida M, Ando M, Yamada H. A comparative study of surgical approaches for cervical compressive myelopathy. *Clin Orthop Relat Res*. 2000;381:129-136.

34. Ishib T, Tsujii H. Technical improvements and results of laminoplasty for compressive myelopathy in the cervical spine. *Spine (Phila Pa 1976)*. 1985;10(8):729-736.

35. Kurokawa T. Enlargement of the spinal canal by sagittal splitting of spinal processes [in Japanese]. *Beratosa Szekeiga*. 1982;2:234-240.

36. Sechi A, Takeshita K, Ohishi I, et al. Long-term results of double-door laminoplasty for cervical stenotic myelopathy. *Spine (Phila Pa 1976)*. 2001;26(5):479-487.

37. Edwards CC II, Heller JG, Silcox DH III. T-Saw laminoplasty for the treatment of cervical stenotic myelopathy. *Surg Neurol*. 2005;63(6):505-510; discussion 510.

38. Edwards CC II, Heller JG, Silcox DH III. T-Saw laminoplasty for cervical stenotic myelopathy: a magnetic resonance imaging study. *Neurosurgery*. 1996;43(9):626-632.

39. Sassa S, Engelbrecht HA, DuPlessis SJ, Hurlrett RJ. Suspended laminoplasty for the treatment of cervical decompression and intradural access: results, advantages, and complications. *J Neurosurg Spine*. 2004;1(1):80-86.

40. Nakano N, Nakano T, Nakano K. Comparison of the results of laminectomy and laminoplasty for cervical spondylotic myelopathy. *Surg Neurol*. 2003;59(3):370-373; discussion 373.

41. Nakano N, Nakano T, Nakano K. Comparison of the results of laminectomy and laminoplasty for cervical spondylotic myelopathy. *Orthop Relat Res*. 2002;15(3):287-295.

42. Shaffrey CI, Wiggins GC, Piccirilli CB, Young JN, Lovell LR. Modified open-door laminoplasty for multilevel cervical OPPL. *J Spinal Disord*. 1997;10(4):296-298.

43. Edwards CC II, Heller JG, Silcox DH III. T-Saw laminoplasty for the management of cervical spondylotic myelopathy: clinical and radiographic outcome. *Spine (Phila Pa 1976)*. 2000;25(14):1788-1794.

44. Wang MY, Shah S, Green BA. Clinical outcomes following cervical laminoplasty for 204 patients with cervical spondylotic myelopathy. *Surg Neurol*. 2004;62(6):487-492; discussion 492-493.

45. Miller G, Ermusus AM, Lind CRP. CG-clip expansive open-door laminoplasty: a technical note. *Br J Neurosurg*. 1999;13(4):405-408.

46. Motimoto T, Matsumiya T, Hidaka Y, Tsukita K, Tabata T, Iwamoto T. Expansive laminoplasty for cervical spondylotic myelopathy in OPPL. *J Spinal Disord*. 1997;10(4):296-298.

47. Nakano N, Nakano T, Nakano K. Comparison of the results of laminectomy and open-door laminoplasty for cervical spondylotic myeloradiculopathy and ossification of the posterior longitudinal ligament. *Spine (Phila Pa 1976)*. 1988;13(7):792-794.

48. Vittorso E, Pezzini G, Piccirilli CB, Young JN, Lovell LR. Modified open-door laminoplasty for treatment of neurological deficits in younger patients with congenital spinal stenosis: analysis of clinical and radiographic data. *J Neurosurg*. 1999;90(2 suppl):170-177.

49. Wang MY, Green BA, Coscarella E, Baskaya MK, Levi AD, Guest JD. Minimally invasive cervical expansive laminoplasty: an initial cadaveric study. *Neurosurgery*. 2003;53(2 suppl):370-373; discussion 373.

50. Urabe J, Green BA, Vannini S, Mozzi K, Guest JD, Levi AD. Acute traumatic central cord syndrome: experience using early surgical decompression with open-door expansive cervical laminoplasty. *Surg Neurol*. 2005;63(3):505-518; discussion 510.

51. Matsuzaki AD, Anderson PA, Groff MW, et al. Cervical laminoplasty for the treatment of cervical degenerative myelopathy: *J Neurosurg Spine*. 2009;11(2):150-156.

52. Nikolaidis I, Fournos IP, Sandrocko PA, Stratham PF. Surgery for cervical radioluency or myelopathy. *Cochrane Database Syst Rev*. 2010;2011: CD001466.

53. Kumar VG, Rea GL, Mervis LJ, McGregor JM. Cervical spondylotic myelopathy: functional and radiographic long-term outcome after laminectomy and posterior fusion. *Neurosurgery*. 1999;44(4):771-777; discussion 777-778.

54. Heller JG, Edwards CC II, Murakami H, Rosed GE. Laminoplasty versus laminotomy and fusion for multilevel cervical myelopathy: an independent matched cohort analysis. *Spine (Phila Pa 1976)*. 2001;26(12):1330-1336.

55. Huang RC, Girardi FP, Poynton AR, Cammisa FP Jr. Treatment of multilevel cervical spondylotic myelopathy with posterior decompression and fusion with lateral mass plate fixation and local bone graft. *J Spinal Disord Tech*. 2003;16(12):123-129.

56. Morio Y, Yamamoto K, Teshima R, Nagashima H, Hagiwa H. Clinicoradiologic study of cervical laminoplasty with posterolateral fusion or bone graft. *Spine (Phila Pa 1976)*. 2000;25:190-196.

57. Wang MY, Green BA, Vittorso E, Levi AD. Adjacent segment disease: an uncommon complication after expansive cervical laminoplasty: case report. *Neurosurgery*. 2003;53(3 suppl):770-772; discussion 772-773.

58. Wieser ES, Wang JC. Surgery for neck pain. *Neurosurgery*. 2007;60(1 supp 1):S51-S56.

59. Carreon LY, Glassman SD, Campbell MJ, Anderson PA. Neck Disability Index, Short-Form-36, Physical Component Summary, and pain scales for neck and arm pain: the minimum clinically important difference and substantial clinical benefit after cervical spine fusion surgery. *Spine J*. 2010;10(6):469-474.

60. Ganchel RJ, Lurie JD, Mayer TG. Minimally clinically important difference. *Spine (Phila Pa 1976)*. 2010;35(19):1719-1743.

61. Samaa G, Edelman D, Rothman ML, Williams GR, Lipscomb J, Marchar D. Determining clinically important differences in health status measurements. *Pharmacoeconomics*. 1999;15(2):141-155.

62. Ware JE, Kosinski M, Keller SD. SF-36 Physical and Mental Health Summary Scales: A User Manual. Boston, MA: The Health Institute, New England Medical Center; 1994.

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The authors present the results of a randomized clinical trial of clinical and radiographic outcomes among patients with multilevel cervical spondylotic myelopathy after expansile cervical laminoplasty (ECL) or cervical laminectomy and fusion. In this single-center trial, 16 patients with ≥ 3 levels of cervical spinal cord compression and myelopathy were randomized to one of the intervention groups during the 27-month study period. Baseline and follow-up clinical and radiographic outcomes were recorded and analyzed.

There were small differences in perioperative outcomes (operative time, blood loss, length of stay) that seem to favor ECL, but no statistical analyses were presented. Improvements in Nurick grade and modified Japanese Orthopedic Association scores were seen for both groups after surgery; the change in Nurick grade was statistically significant for the ECL cohort. Improvements in neck pain and general health-related quality of life indexes were seen for both treatment arms, although statistical significance was reached only for the ECL cohort. Patients in the ECL cohort, on average, maintained a greater proportion of cervical motion as evaluated on flexion/extension radiographs.

This is a very small "pilot" study for a possible future randomized clinical trial. The authors post hoc power calculations demonstrate that, at a significance level of 0.05, a study would need to be 7 to 8 times larger to achieve a power of 80%. With such a small study population, the likelihood of an uneven distribution of prognostic factors between the treatment arms is very high, even if statistical analysis of a few demographic and clinical variables shows "no significant difference." The results of this study must be interpreted, therefore, as preliminary and in need of further exploration in additional larger trials.

The results of tests of statistical significance also must be interpreted cautiously and in the context of the effect size. A numerical difference on a 100-point scale may be statistically significant but not clinically important. Unfortunately, for the outcome instruments used in the present study there are not reliable data regarding the minimally important clinical difference.

A final, significant limitation of this study is that its findings apply to only a very narrow subset of patients with cervical spondylotic myelopathy. Only 13% of patients treated at the study center for cervical spondylotic myelopathy during the study period were enrolled in the trial. The authors do not reveal how many patients were eligible for the trial but were not offered or refused enrollment. A trial with such restricted generalizability has a proportionally limited usefulness to the practicing neurosurgeon. A downside of such trials is the very real risk of misinterpretation, particularly if 1 intervention is superior on some measured outcomes. There is a very real possibility of such a study being improperly interpreted to indicate that 1 treatment is "better" than the other, even though the result applies only to a narrow group of patients.

The authors are to be commended for designing and conducting a single-center surgical randomized clinical trial. The study’s small size and limited generalizability mean that its results must be interpreted and applied cautiously. In the end, follow-up studies may confirm what this investigation seems to demonstrate, that both laminoplasty and laminectomy and fusion are viable options for the surgical treatment of multilevel cervical spondylotic myelopathy.

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