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Management of cervical polyradiculopathy through multisegmental laminoforaminotomies

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KEYWORDS

Cervical disc;
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Abstract *Introduction:* Posterior cervical laminoforaminotomy and discectomy remain as viable options for the treatment of foraminal stenosis or lateral herniated discs with radiculopathy. In contrast to the anterior approach, it does not entail fusion.
Objective: Is to assess the clinical outcome of multisegmental laminoforaminotomies in patients suffering cervical polyradiculopathy.
Methods: Thirty-six patients suffering from cervical polyradiculopathy were operated through multisegmental laminoforaminotomies.
Results: A total of a hundred-twenty-one laminoforaminotomies were performed with an average of 2.7 segments (range 2–4) and 3.36 ± 1.3 laminoforaminotomies per patient (range 2–6). Bilateral foraminotomies on the same level were performed in 21 levels. An excellent and good outcome according to modified Odom's criteria was reported in thirty patients (83.3%), while 5 patients (13%) had a fair outcome and finally with a case of poor outcome (2.7) due to the occurrence of C5 palsy.
Conclusion: Cervical laminoforaminotomy is an effective technique in addressing multisegmental cervical radicular compression. Moreover, this technique eliminates the need of fusion and possible internal fixation, which are essential if the alternative anterior procedure was performed; thus, reducing the overall cost and morbidity.

1. Introduction

The posterior cervical approach has been used for many decades for the treatment of degenerative cervical disc disease, although it has been widely replaced by the anterior cervical procedures which gained prominence, posterior cervical foraminotomy still provides symptomatic relief in about 90% of patients with radiculopathy from foraminal stenosis at a lower cost than the anterior procedure.[1–5]

The keyhole foraminotomy, as first described by Spurling and Scoville,[6] has been used by many authors.[7–10] Posterior laminoforaminotomy and discectomy may be performed unilaterally at one or more levels, bilaterally at one or more

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levels (fenestration approach), or in combination with a laminectomy or laminoplasty. It has the advantage of avoiding possible complications met with the anterior approaches including swallowing difficulty and recurrent laryngeal nerve palsy. Posterior approaches also obviate the need for fusion, preserving the motion segment at the affected level, and may reduce adjacent segment disease.[3,5,11–13]

2. Patients and methods

Thirty-six patients suffering from cervical polyradiculopathy were operated through multisegmental laminoforaminotomies. The offending pathology was multisegmental cervical disc prolapse, whether unilateral or bilateral; soft or osteophytic complexes, compromising the foramina. Patients with single level affection, central herniations, other neurological disorders, myelopathic manifestations or those previously operated for cervical spinal pathologies or with signs of instability were excluded from this study.

Preoperative imaging included MRI and X-rays (anteroposterior, lateral and dynamic) of the cervical spine; computed tomography was performed when ossification of the posterior longitudinal ligament was to be excluded in certain patients. Electrophysiological assessment was also performed to assess the offended roots.

After patient positioning, the incision was centered over the affected vertebral levels. Two adjacent spinous processes were marked, and a localising radiograph was obtained. After confirmation of the correct level, subperiosteal dissection was performed to expose the lamina and facet joint. The mid facetal point was marked before any bone removal was attempted to avoid excessive facet drilling. The foraminotomies were performed, using the operating microscope and a high-speed 3-mm diamond burrs, under constant irrigation (using chilled saline to avoid thermal injury), to an eggshell thickness. The remaining cortical bone and ligamentum flavum are removed using a curette or Kerrison's punch to reveal the underlying fibroareolar layer. The extent facetectomy depended on the extent of compression in relation to the affected nerve root. The extent of medial facetectomy never exceeded half of the facet joint, mostly limited to the medial quarter.

The epidural venous plexus was coagulated using bipolar cautery, beginning medially and extending along the nerve root sleeve. It was then divided sharply to expose the thecal sac and exiting nerve root. The disc fragments were sequestered through both the annulus fibrosus and the posterior longitudinal ligament. The most common location of the disc fragments were in the axilla of the nerve roots (Fig. 1).

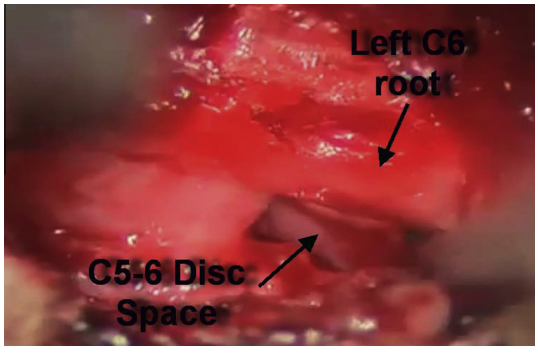

Figure 1 A microscopic view of a C5-6 laminoforaminotomy, revealing the disc space after the disc fragment was removed from the axilla of the C6 root.

Patients were followed clinically and radiologically (mainly dynamic X-rays of the cervical spine) on monthly intervals for the first three post-operative months then every 6 months. The final outcome was assessed according to modified Odom's criteria[14] for clinical outcome.

3. Results

Twenty-six males and ten females were included in the study; the mean age was 49.6 ± 11.7 years (range 26–69 years) (Table 1). The mean preoperative duration of symptoms was 15.8 ± 9.4 months (4–36 months). The main presenting complaint was radicular pain which was present in all cases. C6-7 level was the most frequently affected level where 29 patients had unilateral affection and 8 had bilateral affection, with resultant C7 radicular compression, next was C5-6 (C6 radiculopathy) affected unilaterally in 25 patients and bilaterally in 5, then C4-5 (C5 radiculopathy) 14 patients had unilateral affection and 4 had bilateral affection, followed by C7-T1 (C8 radiculopathy) where 6 patients had unilateral affection and 4 had bilateral affection and lastly C3-4 (C4 radiculopathy), there where no cases involving C2-3 (Table 2).

Sensory affection was present in 31 patients in the form of parasthesia of the affected dermatome or clinically detectable hypothesia. Motor weakness was detected in 28 patients. Neck pain was the least presenting complaint, which was present in 25 patients. All patients failed to respond to conservative medical and physical therapy.

A total of a hundred-twenty-one laminoforaminotomies were performed with an average of 2.7 segments (range 2–4) and 3.36 ± 1.3 laminoforaminotomies per patient (range 2–6). Bilateral foraminotomies on the same level were performed in 21 levels; four patients had been operated for four levels (2 patients had bilateral foraminotomies in one of the levels and 2 patients had bilateral foraminotomies in two levels); nine patients of which were operated for three levels (7 patients had bilateral foraminotomies in one of the levels and 2 patients had bilateral foraminotomies in two levels); and four patients were operated for two levels, where in each a bilateral foraminotomy was performed in one of the levels.

In 47 (38.8%) foraminotomies, the *foraminal stenosis* was caused by an osteophytic complex and hypertrophy of the ligamentum flavum. In 55 (45.5%) a soft disc fragment was detected in addition (*Mixed type*). While in 19 (15.7%) the offending pathology was a *soft disc fragment* (Table 3).

The follow-up period ranged from 10 to 48 months with a mean of 28 months. Radicular pain had improved immediately postoperatively in distribution of the roots compressed by soft disc herniations. While 80% of roots compressed by mixed disc herniations had immediate complete resolution, and the remaining showed gradual resolution of pain over a period of 1 month. Improvement of radicular numbness was less impressive in patients with foraminal stenosis; wherein five patients there was exacerbation of pain in the first three post-operative days possibly due to irritation and manipulation of the roots.

Table 1 Age and sex distribution of the patients under study.

Age (years)	Males	Females	Total
	No. of patients (%)	No. of patients (%)	
18–29	2 (5.6%)	1 (2.8%)	3 (8.3%)
30–39	4 (11.1%)	1 (2.8%)	5 (13.8%)
40–49	7 (19.5%)	2 (5.6%)	9 (25%)
50–59	8 (22.2%)	3 (8.3%)	11 (30.7%)
60–70	5 (13.8%)	3 (8.3%)	8 (22.2%)
Total	26 (72.2%)	10 (27.8%)	36 (100%)

Table 2 Distribution of the laminoforaminotomies according to the level and laterality.

	Unilateral	Bilateral	Total No. of foraminotomies
	No.	No. (level × 2)	
C3-4	5	–	5
C4-5	14	4 × 2	22
C5-6	25	5 × 2	35
C6-7	29	8 × 2	45
C7-T1	6	4 × 2	14
Total No. of foraminotomies	79	42	121

Table 3 Cause for radicular compression in the performed foraminotomies.

Compressive element	*N* (%)
Soft disc herniation	19 (15.7%)
Mixed disc herniation	55 (45.5%)
Foraminal stenosis	47 (38.8%)

The motor function was improved in 97% of patients at the last follow up of the patients, although it did not necessarily improve to normal. Three cases had de novo motor deterioration in the immediate postoperative period, two of which were related to C5 myotome and one related to C6 myotome. One of the former and the latter patient improved at the end of the first month and were generally satisfied by their overall outcome. The other case with C5 palsy had persistence of his motor deficit, which was partially improved by the end of the sixth month, unfortunately this patient was re-operated a year end half later through an anterior cervical discectomy and fusion with anterior plate fixation not for instability but for adequate ventral decompression.

Improvement of radicular numbness was less impressive, with only 40% of the patients had immediate improvement. There was a gradual improvement or numbness in most patients over a period of months ranging from 2 to 16 months. Of the original 29 patients with numbness, four patients were left with a residual numbness, causing minimal discomfort. All patients who failed to achieve full motor and sensory recovery had long duration of symptoms and preoperative deficit.

Although five patients had postoperative cervical pain, it was minimal and was strictly limited to incision or muscle discomfort. No correlation was found between the number of levels and the bilaterality of the laminoforaminotomy and the occurrence of neck pain. There were no radiological signs of spinal instability in any of these patients.

An excellent and good outcome according to modified Odom's criteria was reported in thirty patients (83.3%), while 5 patients (13%) had a fair outcome and finally with a case of poor outcome (2.7) due to the occurrence of C5 palsy (Table 4).

As all patients improved with no relapses, special follow-up imaging studies (CT or MRI) were not performed routinely (Fig. 2). Follow-up dynamic X-rays and lateral films did not reveal any signs of instability or loss of cervical lordosis.

4. Discussion

Though contemporary neurosurgeons may be more familiar with anterior approaches for the treatment of cervical herniated discs and foraminal stenosis, the posterior laminoforaminotomy and discectomy remain as viable options for the treatment of foraminal stenosis or lateral herniated discs with radiculopathy. Several long-term series have reviewed the effectiveness of anterior cervical discectomy and fusion in the treatment of cervical radiculopathy. In general, satisfaction rates are 90% for patients with single level surgery, with results diminishing as the number of operated levels increases.[15–17]

The posterior approach has some advantages compared to an anterior approach, and these include; (1) avoiding damage of vital structures liable to injury with the anterior approach (trachea, oesophagus, internal carotid artery, vertebral artery and recurrent laryngeal nerve and sympathetic chain), (2) preventing the structural and biomechanical damage to the remaining vertebral disc by preserving it, thus preserving the motion segment. (3) In contrast to the anterior approach, which usually entails fusion, complications associated with bone graft as well as degenerative changes of the adjacent joint are also avoided.[1,13,18–21]

Alternatively, several published studies have stated that the results of open posterior laminoforaminotomy as a treatment modality for radiculopathy caused by laterally herniated discs

Table 4 Outcome according to modified Odom's criteria for clinical outcome.

Operated levels				Outcome				*P*
Levels	No. of patients	Foraminotomy		Excellent	Good	Fair	Poor	
Two levels	13	Unilat.	9	4	3	2	–	0.132
		Bil. single level	4	2	2	–	–	
		Bilat. double level	–	–	–	-	–	
Three levels	18	Unilat.	9	4	4	1	–	0.226
		Bil. single level	7	4	2	1		
		Bilat. double level	2	1	1	–		
Four levels	5	Unilat.	1	–	1	–	–	0.74
		Bil. single level	2	–	1	–	1	
		Bilat. double level	2	–	1	1	–	
Total	36			15	15	5	1	

Bil. single level = patients had bilateral foraminotomies in one of the levels.
Bilat. double level = patients had bilateral foraminotomies in two of the levels.
Modified Odom's criteria for clinical outcome.
Excellent – All preoperative symptoms and abnormal findings improved.
Good – Minimal persistence of preoperative symptoms (neck tenderness only, otherwise no symptoms).
Fair – Abnormal findings improved. Definite relief from some preoperative symptoms. Other symptoms slightly improved (residual root irritation with transient pain).
Poor – Symptoms and signs unchanged or worse.

and/or foraminal stenosis, are comparable outcomes with those of the anterior approach.[2,22,23]

With the increase in the number of cervical spine surgeries being performed, especially for degenerative changes in elderly patients, it is important that we work to adopt new techniques that minimise approach-related morbidity for the patients. The degenerative changes tend to be multisegmental and to address such pathologies through the anterior approach, often requires fixation in order to achieve fusion, if more than two levels are to be addressed.[24,25]

Bone fusion is the type of bone healing, which is limited by a variety of factors. The early inflammatory stage may be adversely altered by the administration of anti-inflammatory medications and of steroid agents.[26,27] Vascularisation of the tissue and overall healing in the first few weeks is often impaired by nicotine.[28] Radiation and systemic illnesses such as diabetes mellitus, rheumatoid arthritis, and osteoporosis are recognised inhibitors of successful bone healing and fusion.[29] Advanced age also limits an individual's healing potential specially in post menopausal women.[30] Furthermore, the number of bone marrow stem cells drops considerably during aging.[31] A combination of factors therefore must be considered when attempting to induce a successful fusion in older patients, which would be the problem with multisegmental discs managed through the anterior approach in these patients.

Figure 2 Post operative reconstructed three dimensional computed tomography, illustrating a right laminoforaminotomy at C6-7 & C5-6 levels and bilateral laminoforaminotomy at C4-5 level (three levels with bilateral single level).

Kornith et al.[32] stated that the results of posterior cervical foraminotomy for single level lateral or foraminal soft-disc protrusion causing radiculopathy are comparable with anterior microdiscectomy and probably less invasive because of fewer complications.

Henderson et al.[22] and Jodicke et al.[33] emphasised that in the cases of radiculomyelopathy the lateral discs associated with spondylosis or medial disc protrusion; posterior foraminotomy had a significant risk of surgical failure and necessitates a second surgery in 8–14% of the cases. However this could not be substantiated in this study.

Postoperative instability and loss of lordosis after posterior foraminotomy also have been reported, and some cases needed the posterior fusion.[34] But this is only the case if more than 50% of the facet joint is resected and this should be avoided.[35]

One of the reported major disadvantages of the posterior technique in comparison with the anterior is short-term and potentially long-term axial neck pain. Immediate postoperative neck pain is due to the surgical procedure, including the incision, muscle dissection, muscle retraction, and bony resection.[36–39] In contrast to posterior laminectomy, laminoforaminotomies tend to preserve the spinous process especially the C7 spinous process and its associated nuchal attachments which have been shown to have decreased rates of axial symptoms.[40–45] Neck pain was not a major issue in this study due to its minimal nature. Steinberg and German[46] stated that minimally invasive posterior cervical approaches were associated with similar neck pain and disability to ACF.

Ziewacz et al.[47] consider the use of microendoscopic posterior cervical foraminotomy/discectomy for patients with one or two level unilateral radiculopathy due to foraminal stenosis related to osteophytes or a lateral soft herniated disc, but not for patients needing bilateral decompression or multi-level (>3 level) decompression due to the amount of muscular tissue disruption and need for multiple facetectomies which may lead to instability. In this study none of the cases had radiographic signs of instability nor did the multiplicity or bilaterality have an identifiable effect on the stability or the clinical outcome.

Choi et al.[48] reported that they had a motor palsy in 3 (2.8%) of 106 patients who underwent posterior cervical foraminotomy, however, C5 motor palsy, which occurred in 2 of 9 (22.2%) of C4/5 posterior foraminotomy in their series. Michael Webb et al.[49] advised pediculotomy in cases where the neural foraminal volume is limited or when excessive nerve root retraction is anticipated to achieve adequate removal of the offending lesion. This especially was helpful when addressing C4/5 segment as the C5 nerve root usually covers the entire disc space and therefore needs more excessive retraction than any other nerve root.[48,50] This might explain the incidents of C5 palsy met within this study, since in both cases the extruded fragments and osteophytic complexes tethered the roots necessitating some degree of retraction and excessive manipulation of the root.

5. Conclusion

Cervical laminoforaminotomy is an effective technique in addressing multisegmental segmental cervical radicular compression. Not needing to fuse the patients or applying instrumentation reduced the overall cost of the procedure. Bilateral foraminotomies even if done multi-segmentally had no effect on the stability if less than 50% of the facet was violated.

Conflict of interest

We have no conflict of interest to declare.

References

1. Chang J, Park H, Choi S. Posterior cervical inclinatory foraminotomy for spondylotic radiculopathy preliminary. *J Korean Neurosurg Soc* 2011;**49**(5):308–13.
2. Epstein NE. A review of laminoforaminotomy for the management of lateral and foraminal cervical disc herniations or spurs. *Surg Neurol* 2002;**57**:226–34.
3. Heary RF, Ryken TC, Matz PG, Anderson PA, Groff MW, Holly LT, et al. Cervical laminoforaminotomy for the treatment of cervical degenerative radiculopathy. *J Neurosurg Spine* 2009;**11**:198–202.
4. Jagannathan J, Sherman JH, Szabo T, Shaffrey CI, Jane JA. The posterior cervical foraminotomy in the treatment of cervical disc/osteophyte disease: a single-surgeon experience with a minimum of 5 years clinical and radiographic follow-up. *J Neurosurg Spine* 2009;**10**:347–56.
5. Tumialan LM, Ponton RP, Gluf WM. Management of unilateral cervical radiculopathy in the military: the cost effectiveness of posterior cervical foraminotomy compared with anterior cervical discectomy and fusion. *Neurosurg Focus* 2010;**28**(5):E17.
6. Spurling RG, Scoville WB. Lateral rupture of the cervical intervertebral disc: a common cause of shoulder and arm pain. *Surg Gynecol Obstet* 1944;**78**:350–8.
7. Aldrich F. Posterolateral microdiscectomy for cervical monoradiculopathy caused by posterolateral soft cervical disc sequestration. *J Neurosurg* 1990;**72**:370–7.
8. Collias JC, Roberts MP. Posterior operations for cervical disc herniations and spondylotic myelopathy. In: Schmidek HH, Sweet WH, editors. *Operative neurosurgical techniques*. 2nd ed. Philadelphia: Grune & Stratton; 1987. p. 1347–58.
9. Epstein JA, Lavine LS, Aronson HA, Epstein BS. Cervical spondylotic radiculopathy: the syndrome of foraminal constriction treated by foraminotomy and the removal of osteophytes. *Clin Orthop* 1965;**40**:113–22.
10. Fager CA. Management of cervical disk lesions and spondylosis by posterior approaches. *Clin Neurosurg* 1977;**24**:488–507.
11. Ishihara H, Kanamori M, Kawaguchi Y, Nakamura H, Kimura T. Adjacent segment disease after anterior cervical interbody fusion. *Spine J* 2004;**4**(6):624–8.
12. Kim KT, Kim YB. Comparison between open procedure and tubular retractor assisted procedure for cervical radiculopathy: results of a randomized controlled study. *J Korean Med Sci* 2009;**24**:649–53.
13. Rodrigues MA, Hanel RA, Prevedello DM, Antoniuk A, Araujo JC. Posterior approach for soft cervical disc herniation: a neglected technique? *Surg Neurol* 2001;**55**(1):17–22.
14. Odom GL, Finney W, Woodhall B. Cervical disk lesions. *JAMA* 1958;**166**:23–8.
15. Bhatia NN. Long-term outcomes and complications following anterior and posterior cervical spine surgery. *Semin Spine Surg* 2008;**21**(3):177–84.
16. Yang KC, Lu XS, Cai QL, Ye LX, Lu WQ. Cervical spondylotic myelopathy treated by anterior multilevel decompression and fusion. *Clin Orthop* 1987;**221**:161–4.
17. Zhang ZH, Yin H, Yang K, Zhang T, Dong F, Dang G, et al. Anterior intervertebral disc excision and bone grafting in cervical spondylotic myelopathy. *Spine* 1983;**8**:16–9.
18. Fessler RG, Khoo LT. Minimally invasive cervical microendoscopic foraminotomy: an initial clinical experience. *Neurosurgery* 2002;**51**(Suppl. 5):S37–45.
19. Hilibrand AS, Robbins M. Adjacent segment degeneration and adjacent segment disease: the consequences of spinal fusion? *Spine J* 2004;**4**(Suppl. 6):190S–4S.
20. Hunter LY, Braunstein EM, Bailey RW. Radiographic changes following anterior cervical fusion. *Spine* 1980;**5**:399–401.
21. Olsewski JM, Garvey TA, Schendel MJ. Biomechanical analysis of facet and graft loading in a Smith–Robinson type cervical spine model. *Spine* 1994;**19**:2540–4.
22. Henderson CM, Hennessy RG, Shuey Jr HM, Shackelford EG. Posterior-lateral foraminotomy as an exclusive operative technique for cervical radiculopathy: a review of 846 consecutively operated cases. *Neurosurgery* 1983;**13**:504–12.
23. Lawton CD, Smith ZA, Lam SK, Habib A, Wong RH, Fessler RG. Clinical outcomes of microendoscopic foraminotomy and decompression in the cervical spine. *World Neurosurg* 2012, S1878-8750(12)01440-4.
24. Bose B. Anterior cervical instrumentation enhances fusion rates in multilevel reconstruction in smokers. *J Spinal Disord* 2001;**14**(1):3–9.
25. Epstein NE. Anterior cervical diskectomy and fusion without plate instrumentation in 178 patients. *J Spinal Disord* 2000;**13**(1):1–8.
26. Sawin PD, Dickman CA, Crawford NR, Melton MS, Bichard VK, Sonntag VK. The effects of dexamethasone on bone fusion in an experimental model of posterolateral umbar spinal arthrodesis. *J Neurosurg* 2001;**94**:76–81.
27. Simon AM, Manigrasso MB, O'Connor JP. Cyclo-oxygenase 2 function is essential for bone fracture healing. *J Bone Miner Res* 2002;**17**:963–76.

28. Daftari TK, Whitesides Jr TE, Heller JG, Goodrich AC, McCarey WC, Hutton WC. Nicotine on the revascularization of bone graft. An experimental study in rabbits. *Spine* 1994;**19**:904–11.
29. Kalfas IH. Principles of bone healing. *Neurosurg Focus* 2001;**10**(4).
30. Fawcett DW. *Bloom and Fawcett, a textbook of histology*. New York: Chapman and Hall; 1994. p. 194–233.
31. Service RF. Tissue engineers build new bone. *Science* 2000;**289**:1498–500.
32. Korinth MC, Kruger A, Oertel MF, Gilsbach JM. Posterior foraminotomy or anterior discectomy with polymethyl methacrylate interbody stabilization for cervical soft disc disease: results in 292 patients with monoradiculopathy. *Spine* 2006;**31**:1207–14.
33. Jodicke A, Daentzer D, Kastner S, Asamoto S, Boker DK. Risk factors for outcome and complications of dorsal foraminotomy in cervical disc herniation. *Surg Neurol* 2003;**60**:124–9.
34. Nakagawa H. Surgical strategies in the management of cervical degenerative disorders. *World Neurosurg* 2013;**79**(2):294–5.
35. Zdeblick TA, Zou D, Warden KE. Cervical stability after foraminotomy. A biomechanical in vitro analysis. *J Bone Joint Surg Am* 1992;**74**:22–7.
36. Fehlings MG, Gray RJ. Posterior cervical foraminotomy for the treatment of cervical radiculopathy. *J Neurosurg Spine* 2009;**10**:343–4.
37. Grieve JP, Kitchen ND, Moore AJ, Marsh HT. Results of posterior cervical foraminotomy for treatment of cervical spondylitic radiculopathy. *Br J Neurosurg* 2000;**14**:40–3.
38. Hosono N, Yonenobu K, Ono K. Neck and shoulder pain after laminoplasty. A noticeable complication. *Spine* 1996;**21**:1969–73 Phila Pa 1976.
39. Ratliff JK, Cooper PR. Cervical laminoplasty: a critical review. *J Neurosurg* 2003;**98**:230–8.
40. Gala VC, O'Toole JE, Voyadzis JM, Fessler RG. Posterior minimally invasive approaches for the cervical spine. *Orthop Clin North Am* 2007;**38**:339–49.
41. Hilton Jr DL. Minimally invasive tubular access for posterior cervical foraminotomy with three-dimensional microscopic visualization and localization with anterior/posterior imaging. *Spine J* 2007;**7**:154–8.
42. Hosono N, Sakaura H, Mukai Y, Fujii R, Yoshikawa H. C3-6 laminoplasty takes over C3-7 laminoplasty with significantly lower incidence of axial neck pain. *Eur Spine J* 2006;**15**:1375–9.
43. Kawaguchi Y, Kanamori M, Ishiara H, Nobukiyo M, Seki S, Kimura T. Preventive measures for axial symptoms following cervical laminoplasty. *J Spinal Disord Tech* 2003;**16**:497–501.
44. Ruetten S, Komp M, Merk H, Godolias G. Full-endoscopic cervical posterior foraminotomy for the operation of lateral disc herniations using 5.9-mm endoscopes: a prospective, randomized, controlled study. *Spine* 2008;**33**:940–8.
45. Takeuchi T, Shono Y. Importance of preserving the C7 spinous process and attached nuchal ligament in French-door laminoplasty to reduce postoperative axial symptoms. *Eur Spine J* 2007;**16**:1417–22.
46. Steinberg JA, German JW. The effect of minimally invasive posterior cervical approaches versus open anterior approaches on neck pain and disability. *Int J Spine Surg* 2012;**6**(1):55–61.
47. Ziewacz JE, Mummaneni PV. Microendoscopic cervical foraminotomy and discectomy: are we there yet? *World Neurosurg* 2013. http://dx.doi.org/10.1016/j.wneu.2013.01.100.
48. Choi KC, Ahn Y, Kang BU, Ahn ST, Lee SH. Motor palsy after posterior cervical foraminotomy: anatomical consideration. *World Neurosurg* 2013;**79**(2):405.e1–4.
49. Michael Webb K, Kaptain G, Sheehan J, Jane JA. Pediculotomy as an adjunct to posterior cervical hemilaminectomy, foraminotomy, and discectomy. *Neurosurg Focus* 2012;**12**(1).
50. Hwang JC, Bae HG, Cho SW, Cho SJ, Park HK, Chang JC. Morphometric study of the nerve roots around the lateral mass for posterior foraminotomy. *J Korean Neurosurg Soc* 2010;**47**:358–64.