The role of laminoplasty in cervical spine diseases. Evidences from a literature review

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Abstract

Anterior decompression at multiple disc spaces, multilevel corpectomy, laminectomy with or without fusion, and laminoplasty have all been performed to treat cervical diseases such as the ossification of the posterior longitudinal ligament (OPLL) and the cervical spondylotic myelopathy (CSM). Laminectomy has been the most used technique to decompress spinal cord in such conditions. Nonetheless, spinal deformity, instability, progressive kyphotic deformity and late neurological deterioration are not infrequent complications after laminectomy. Laminoplasty techniques have been developed to overcome these problems but there are no definitive data supporting the superiority of laminoplasty over laminectomy in OPLL and CSM. In this study the available literature about laminoplasty, with particular attention to comparative works (laminoplasty vs laminectomy) was reviewed. Thirty-eight articles were analyzed. Twenty-three were papers reporting the results of laminoplasty in OPLL and CSM, 7 articles compared two different types of laminoplasty technique and 8 studies were comparative works between laminoplasty and laminectomy. Laminoplasty was reported as safe and effective in decompressing spinal cord, preserving the range of motion and the good clinical results at long follow-up. Moreover, laminoplasty has been found to arrest the progression of myelopathy, also in elderly and debilitated patients, with low incidence of postoperative axial pain and kyphotic deformity at follow-up. Among different laminoplasty techniques, the mini-plates fixation seems to provide the best results compared to suture fixation. Moreover, most of the comparative studies suggest that laminoplasty is associated with shorter hospital stay, greater functional improvement and with fewer late complications (including the need of further stabilization) compared to laminectomy. Nonetheless, skip laminectomy seems a promising technique in terms of good results and low complications, although more comparative prospective studies are needed to confirm this evidence.

1. Introduction

Various surgical procedures have been proposed for the treatment of multilevel cervical spinal cord compression caused by ossification of the posterior longitudinal ligament (OPLL) or for the decompression of a cervical spondylotic myelopathy (CSM). Anterior decompression at multiple disc spaces, multilevel corpectomy, laminectomy with or without fusion and laminoplasty have all been performed to treat multilevel disease. Although laminectomy effectively decompresses the spinal cord in patients with OPLL or multilevel CSM, it has been associated to complications such as instability and progressive kyphotic deformity, particularly when extensive resection of facet joints has been performed (Goel et al.,1988; Kaptain et al.,2000; Mikawa et al.,1987; Sim et al.,1974). To prevent these cervical laminectomy complications (spinal deformity, instability, compression by "laminectomy membrane," and late neurological deterioration), laminoplasty techniques have been reported as an alternative to laminectomy. While a better outcome has been suggested when laminoplasty is performed as surgical approach to remove an intradural tumor (Montano et al., 2014), there is no agreement on its usefulness when laminoplasty is used to decompress spinal cord in degenerative cervical pathology. A variety of laminoplasty procedures have been described. Generally in these procedures, the laminae are preserved, but the size of the spinal canal is expanded because the laminae are positioned more posteriorly. A lot of papers have been published on this topic. Moreover, good reviews are available in the literature (Ratliff et al.,2003; Duetzmann et al.,2015) evidencing that laminoplasty can be a valid surgical option to decompress cervical spinal cord. However, there are no definitive data supporting the superiority of laminoplasty over laminectomy as well as the superiority of a specific technique among laminoplasty procedures.

The aim of this work was to review the available literature analyzing the results of papers on laminoplasty in cervical spinal cord compression with

particular attention to comparative works (laminoplasty vs laminectomy).

2. Material and Methods

A literature search was made in the PubMed and Cochrane database including the following terms: laminoplasty, cervical myelopathy, cervical stenosis, laminectomy, cervical posterior decompression. The data were searched up through April 2016. Articles on *1)* laminoplasty in degenerative cervical spinal cord compression, *2)* comparing two different laminoplasty techniques in degenerative cervical spinal cord compression and *3)* comparing laminoplasty and laminectomy in degenerative cervical spinal cord compression, were included in this review. Series with tumors, trauma, infection, combined anterior and posterior surgeries and articles that included instrumented fusion were excluded. Articles with a number of patients fewer than 10 and articles with no information about patients follow-up (FU) were also excluded from the analysis. Meeting abstracts/proceedings, case report and editorials were additionally excluded. Reference lists from the selected studies were checked to identify additional eligible articles. The lack of a statistical analysis was not considered an exclusion criterion.

3. Results

Thirty-eight articles were eligible for the analysis. Five were prospective works (Okada et al.,2009; Sivaravan et al.,2010; Sakaura et al.,2011; Machino et al.,2013; Machino et al.,2015) and 33 retrospective papers (Satomi et al.,1994; Morimoto et al.,1997; Kohno et al.,1997; Edwards et al., 2000; Satomi et al.,2001; Seichi et al.,2001; Iwasaki et al.,2002; Handa et al.,2002; Kawaguchi et al.,2003a; Kawaguchi et al.,2003b; Kamizono et al.,2003; Wang et al.,2004; Ogawa et al.,2004; Chiba et al.,2006; Shigematsu et al.,2010; Kimura et al.,2011; Zhang H et al.,2012; Yeh et al.,2014; Oichi et al.,2016; Sakaura et al.,2016, Asgari et al.,2009; Chen et al.,2012; Zhang SM et al.,2012; Wang et al.,2014; Hu et al.,2014; Chen et al.,2015; Shiraishi et al.,2003; Kaminsky et

al.,2004; Yukawa et al.,2007; Hardman et al.,2010; Nurboja et al.,2011; Della Pepa et al.,2014; Nakano et al.,1988).

Of them, 23 were papers reporting the results of laminoplasty in cervical spinal cord compression (2983 patients; mean follow-up: 67.18±46.41 months; Table 1), 7 articles compared two different types of laminoplasty's techniques (336 patients; mean follow-up: 25.33±18.74 months; Table 2) and 8 studies were comparative works between laminoplasty and laminectomy (762 patients; mean follow-up: 40.08±39.58 months; Table 3).

4. Discussion

4.1. Laminoplasty for cervical spinal cord decompression

Cervical laminoplasty was developed for the treatment of CSM and OPLL in order to prevent some complications associated to laminectomy such as instability and progressive kyphotic deformity. Various studies have been published. Unfortunately, they differ in terms of study design, laminoplasty technique utilized and evaluation of results and complications. Among these studies only three were prospective studies (Sakaura et al.,2011; Machino et al.,2013; Machino et al., 2015).

Open door laminoplasty was reported as a safe procedure in decompressing the spinal cord in CSM and OPLL preserving the range of motion (Morimoto et al.,1997) with good results maintained at 5 years FU (Satomi et al.,1994). Moreover the same findings at 10 years FU using the French door laminoplasty technique in patients with CSM and OPLL were observed (Seichi et al.,2001). These results were confirmed by Kohno et al. in CSM patients with a reported favorable outcome at 5 years FU (Kohno et al.,1997). Moreover, it was reported that laminoplasty could be useful in arresting the progression of myelopathy (Edward et al.,2000). After these initial enthusiastic works, further studies investigated the role of some factors as potential prognosticators of good outcome in laminoplasty patients. In this setting, young age and less severe pre-existing myelopathy were reported as predictors of good clinical outcome in OPLL patients

(Iwasaki et al,2002). Moreover, in a large study involving 204 patients with CSM and OPLL, a better outcome was reported in patients younger than 60 years at the time of operation and whose symptoms lasted less than one year (Satomi et al.,2001). These results were also confirmed in a larger series of 301 OPLL patients in which pre- and post-surgery severity of myelopathy were significantly related to the occupational recovery (Kamizono et al.,2003). Thus, an early surgical treatment with laminoplasty in patients with CSM and OPLL has been advised (Satomi et al.,2001, Ogawa et al.,2004, Zhang H et al.,2012) also in elderly and debilitated patients (Wang et al.,2004; Kawaguchi et al.,2003). For these patients (elderly patients) a shorter duration of symptoms and a less severe degree of stenosis were reported as significant prognostic factors of good outcome (Handa et al.,2002). Prospective studies are expected to provide better evidences compared to retrospective ones. Among analyzed works, three of them were prospective (Sakaura et al.,2011, Machino et al.,2013, Machino et al.,2015). A satisfactory long-term neurologic outcome after C3–C6 laminoplasty with preservation of the muscles attached to the C2 and C7 spinous processes was reported by Sakaura et al. This procedure was associated with lower incidence of postoperative axial neck pain and kyphotic deformity at 5 year FU (Sakaura et al.,2011). In a large prospective study of 520 CSM patients an improvement of symptoms was reported in 493 patients (94.8%) after double-door laminoplasty with a FU of at least of 12 months (Machino et al.,2013). On this basis, this technique was considered safe, reliable, and effective for treating patients with CSM. In another large prospective study, the usefulness of this procedure was confirmed also in elderly patients (Machino et al.,2015). The association of cervical spondylolisthesis with CSM and OPLL and its role on neurological outcome after laminoplasty remains an interesting issue to be clarified in the future. While previous evidences suggested that spondylolisthesis did not affect neurological recovery in CSM patients (Shigematzu et al.,2010), a large

recent study (Oichi et al.,2016) identified anterolisthesis, but not retrolisthesis, as significant risk factor and predictor of poor neurological outcome after cervical laminoplasty (Oichi et al.,2016).

4.2. Comparative studies on different laminoplasty techniques

In this literature review only 7 studies comparing laminoplasty techniques among them were found (Chen et al.,2015; Chen et al.,2012; Asgari et al.,2009; Wang et al.,2014; Hu et al.,2014; Okada et al.,2009; Zhang SM et al.,2012). All these studies focused on the effectiveness of these procedures on CSM.

Okada et al., compared the open door and french-door techniques and found no significant differences in functional scores and recovery rates at final follow-up between the two procedures (Okada et al.,2009). This suggests that both open door and french-door laminoplasties could be similarly effective in decompressing the spinal cord. Moreover, these Authors reported that perioperative complications occurred more frequently in open-door laminoplasty than in French-door laminoplasty and that axial pain was improved in French-door laminoplasty more than in open-door laminoplasty. These results can suggest that French-door laminoplasty could be more beneficial than open-door laminoplasty in patients with cervical compressive myelopathy.

Another issue investigated in these comparative studies is the fixation method of the laminae. Some studies have reported that the mini-plates fixation was efficient to avoid reclosure of the laminae (Hu et al.,2014) and secure all levels with mini-plates is effective in maintaining the expansion of spinal canal (Wang et al.,2014). In two different articles the modified open-door laminoplasty using titanium mini-plates fixation was reported more effective than suture fixation in improving axial symptoms, preventing the loss of cervical curvature, preserving more range of motion and reducing the incidence of reclosure of the opened laminae (Chen et al.,2012; Chen et al.,2015).

4.3. Comparative studies between laminoplasty and laminectomy

In this review, 8 comparative studies between laminoplasty and laminectomy were analyzed. All these studies reported the results in patients with CSM. Only one paper included patients with OPLL (Nakano et al.,1988). It has been evidenced that laminoplasty is associated with shorter hospital stay and greater functional improvement (Hardman et al.,2010) with fewer late complications (Kamisky et al.,2004) compared to laminectomy. Moreover, Della Pepa et al., reported a significantly higher risk to develop kyphotic deformity during the follow-up in patients submitted to laminectomy and suggested that laminoplasty can prevent the need of further stabilization (Della Pepa et al.,2014). Nonetheless, Nurboja et al., in their series of 268 patients observed no clear benefit of cervical laminoplasty over laminectomy in the treatment of CSM in terms of sagittal alignment preservation, axial pain decreasing and quality of life improvement (Nurboja et al.,2012). Surprisingly, in this study it was evidenced that cervical laminectomy seems to be associated with less axial pain than laminoplasty when more than 3 vertebral levels are decompressed. Skip laminectomy is a recently developed procedure. In skip laminectomy, standard laminectomies are performed at selected levels, combined with partial laminectomies of the cephalad halves of laminae at other selected levels removing the ligamentum flavum without detaching the semispinalis cervicis and multifidus muscles from the adjacent spinous processes (Shiraishi, 2002). In a comparative study, Shiraishi et al., reported a statistically significant worsening of axial pain in laminoplasty compared with skip laminectomy (Shiraishi et al.,2003). Moreover, in the laminoplasty subgroup, three patients had C5 paresis while none occurred in the skip laminectomy subgroup. It was observed that skip laminectomy was less invasive on the posterior extensor structures, including the deep extensor muscles, and was effective in preventing postoperative morbidities. Sivaraman et al. in a study including 50 patients (25 skip

laminectomy and 25 laminoplasty) reported a better outcome in terms of blood loss, operative times, axial pain scores, range of motion with skip laminectomy compared to laminoplasty, although the degree of decompression with both techniques was similar (Sivaravan et al.,2010). Nonetheless, other authors suggested no differences in terms of operative invasiveness, postoperative range of motion, axial pain and surgical outcomes between skip laminectomy and laminoplasty (Yukawa et al.,2007).

5. Conclusion

Laminoplasty seems to be safe and effective in decompressing cervical spinal cord in CSM and OPLL also in elderly and debilitated patients. There are no clear data showing the superiority of a specific laminoplasty technique, although the mini-plates fixation seems to provide the best results in maintaining the expansion of spinal canal, improving axial symptoms, preventing the loss of cervical curvature, preserving more range of motion and reducing the incidence of reclosure of the opened laminae. Although laminoplasty seems to be associated with shorter hospital stay, greater functional improvement, fewer late complications, fewer risk of developing post-operative kyphotic deformity compared to laminectomy, there is a lack of prospective comparative studies to strengthen these evidences. Skip laminectomy seems a promising technique but more prospective comparative studies are needed to confirm the efficacy of this procedure.

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Table 1: Studies reporting the results of laminoplasty in cervical spine diseases

Author/year	Surgical technique	Cases(no.)	Pathology	Mean FU (mos)	Conclusions
Satomi et al.,1994	Open door laminoplasty	61	43 OPLL 18 CSM	93	Open door laminoplasty is safe and leads to good results that are maintained for over 5 years
Morimoto et al.,1997	Open door laminoplasty	20	OPLL	36	Open door laminoplasty is safe and preserve the normal range of motion
Kohno et al.,1997	French door laminoplasty	22	CSM	60	French door laminoplasty can be expected to provide a favorable outcome
Edwards et al.,2000	T-saw laminoplasty	18	CSM	24	T-saw laminoplasty appears to be a safe and effective method of arresting the progression of myelopathy
Satomi et al.,2001	Unilateral open door laminoplasty	204	106 OPLL 88 CSM 10 disk herniation	96	Patients older than 60 years at the time of operation and whose symptoms lasted over 1 year were significantly associated with lower recovery rate from clinical symptoms
Seichi et al.,2001	French door laminoplasty	60	35 OPLL 25 CSM	120	French door laminoplasty is a reliable procedure for individuals with CSM
Iwasaki et al.,2002	Open door laminoplasty	64	OPLL	120	Factors related to better clinical results were younger age at operation and less severe preexisting myelopathy
Handa et al., 2002	Open door laminoplasty	61	CSM	12	Predictive factors for clinical outcome in the elderly patients were the duration of symptoms and the severity of stenosis
Kawaguchi et al.,2003 (a)	En bloc laminoplasty	89	CSM 20 >70yrs; 69 < 70yrs	N.R.	Surgical decompression for CSM was beneficial even in elderly patients older than 70 years
Kawaguchi et al.,2003 (b)	En bloc laminoplasty	126	CSM	120	Satisfactory results were maintained for more than 10 years after surgery
Kamizono et al.,2003	Open door laminoplasty	301	OPLL	96	Occupation, pre- and post-operative severity of myelopathy were significantly related with occupational recovery
Wang et al.,2004	Open door laminoplasty	204	CSM	16	The advantages of this procedure may be especially important when treating elderly, debilitated patients
Ogawa et al.,2004	Open door laminoplasty	72	OPPL	114	Early surgery is recommended
Chiba et al.,2006	Open door laminoplasty	80	CSM	168	Segmental motor paralysis, kyphosis, OPLL progression, and late deterioration due to age-related degeneration remain challenging problems

Shigematsu et al.,2010	Bilateral open door laminoplasty	32	CSM 15 with degenerative spondylolisthesis; 17 without degenerative spondylolisthesis	36	Degenerative spondylolisthesis did not influence neurological recovery. Good neurological improvement for CSM patients with degenerative spondylolisthesis
Sakaura et al.,2011	C3-C6 laminoplasty	31	OPLL	60	Outcome of C3-6 laminoplasty were satisfactory. The incidence of axial neck pain and loss of cervical lordosis is low at 5 years FU
Kimura et al.,2011	Double door laminoplasty using hydroxyapatite spacers	68	CSM	120	The long-term results of double-door laminoplasty using hydroxyapatite spacers were satisfactory
Zhang H et al.,2012	Open door laminoplasty	79	CSM	12	CSM should be treated early
Machino et al.,2013	Double door laminoplasty	520	CSM	33	Modified double door laminoplasty is a safe, reliable, and effective procedure for patients with CSM
Yeh et al.,2014	Extended open door laminoplasty	104	CSM	24	Extended open door laminoplasty secured with titanium miniplates without bone grafting is a safe and effective surgical method for treating most patients with CSM
Machino et al.,2015	French door laminoplasty	505	CSM non-elderly (201; <65 years), young-old (186; 65–74 years) old-old (118; ≥75 years)	24	Laminoplasty for CSM is beneficial in elderly patients
Oichi et al.,2016	Open door laminoplasty	125	CSM	24	Anterolisthesis is a significant risk factor for poor neurological outcome
Sakaura et al.,2016	Uni or bilateral open door laminoplasty	137	CSM 85 bilateral 52 unilateral	70	In patients with CSM with more severe developmental spinal canal stenosis at C7, accelerated degeneration at the caudal segment resulting from restricted C3-C6 range of motion after C3-C6 laminoplasty might lead to late neurological deterioration

Table 2: Studies focusing on comparison of two different types of laminoplasty

Author/year	Surgical technique	Cases(no.)	Pathology	Mean FU (mos)	Conclusions
Asgari et al.,2009	Open door vs bilateral cutting	13	CSM	N.R.	Open door seems to be superior to bilateral cutting
Okada et al.,2009	Open door vs french door	40	CSM	26	French-door laminoplasty more beneficial than open door laminoplasty
Chen et al.,2012	Open door laminoplasty with titanium miniplates vs suture fixation	54	CSM 29:titanium miniplates 25: suture fixation	24	The open door laminoplasty with titanium miniplates fixation is superior
Zhang SM et al.,2012	Open door laminoplasty with titanium miniplates vs conventional open door laminoplasty	34	CSM 16: titanium miniplates 18: conventional	6	Both surgical protocols are effective on preventing reclose of opened laminae. Miniplates fixation reduces the occurrence of axial symptoms and loss of cervical curvature
Wang et al.,2014	Open door laminoplasty with titanium miniplates (all levels fixation vs alternating levels fixation)	83	CSM 51: alternating levels 32: all levels	24	All levels fixation is more effective in maintaining the expansion of the spinal canal
Hu et al.,2014	Open door laminoplasty with titanium miniplates vs suture fixation	55	CSM 25: titanium miniplates 30: suture fixation	12	Titanium miniplates fixation is more effective than suture fixation in preventing laminar closure
Chen et al.,2015	Open door laminoplasty with titanium miniplates vs suture fixation	57	CSM 34: titanium miniplates 23: suture fixation	60	Miniplates fixation preserves more cervical range of motion and better cervical alignment and stability avoiding lamina reclosure

Table 3: Studies comparing laminoplasty with laminectomy

Author/year	Surgical technique	Cases(no.)	Pathology	Mean FU(mos)	Conclusions
Nakano et al.,1988	Laminectomy vs open door laminoplasty	14: laminectomy 75: open door	CSM OPLL	N.R.	No significant differences
Shiraishi et al.,2003	Skip laminectomy vs open door laminoplasty	43: skip laminectomy 51: open door	CSM	24	Skip laminectomy is less invasive and reduces the risk of persisting axial pain, reduction of neck motion and loss of cervical lordosis
Kaminsky et al.,2004	Laminectomy vs laminoplasty	22: laminectomy 20: laminoplasty	CSM	60	Fewer late complications in laminoplasty
Yukawa et al.,2007	Skip laminectomy vs French door laminoplasty	20: skip laminectomy 21: laminoplasty	CSM	12	No significant differences
Sivaravan et al.,2010	Skip laminectomy vs laminoplasty	25: skip laminectomy 25: laminoplasty	CSM	24	Skip laminectomy effective in reducing postoperative morbidities
Hardman et al.,2010	Laminectomy vs laminoplasty	49: laminectomy 72: laminoplasty	CSM	4	Shorter hospital stay and greater functional improvement in laminoplasty
Nurboja et al.,2012	Laminectomy vs laminoplasty	268	CSM	120	Laminoplasty for 4 or more levels was associated with more axial pain
Della Pepa et al.,2014	Laminectomy vs open door laminoplasty	24: laminectomy 33: open door	CSM	36,6	Open door laminoplasty decreases the incidence of spinal deformity and prevent subsequent spinal stabilization.

