Overview of Laminoplasty

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Abstract

Anterior cervical decompression and fusion (ACDF) and laminectomy used to be the only available surgical options for patients with myelopathy caused by ossification of posterior longitudinal ligament (OPLL). Laminoplasty was devised to address problems associated with ACDF; i.e., intraoperative nerve injury, cerebrospinal fluid leakage, pseudarthrosis, and other graft-related complications, and those associated with laminectomy; i.e., development of postoperative instability and kyphosis, and recurrent myelopathy due to scar formation. This simple, less invasive, yet innovative, procedure obtained widespread acceptance, initially in Japan, and gradually spread out to the world. There are many modified procedures available but can ultimately be summarized into two basic techniques: open-door and spinous process splitting laminoplasty. There is no significant difference in clinical outcomes between the two, and it is the surgeon's preference whether to choose one or the other. Best candidates for laminoplasty are those with multilevel OPLL and developmental spinal stenosis whose cervical alignment is lordosis. Because OPLL itself remains inside the spinal canal, the type, size, and shape of the ossified mass should also be taken into account when deciding indications. Through continuous efforts to establish the definite indications and to improve and refine the surgical techniques, surgical outcomes have improved significantly and issues such as postoperative axial pain, development of kyphosis, and segmental motor weakness have partly been resolved but not completely. Postoperative progression of OPLL remains as an unsolved problem, and indications of prophylactic decompression are still under debate.

Keywords

Ossification of the posterior longitudinal ligament (OPLL) · Laminoplasty · Open-door laminoplasty · Spinous processes splitting laminoplasty · Anterior cervical decompression and fusion (ACDF) · Laminectomy · Axial pain · Kyphosis · Segmental motor weakness · Prophylactic decompression

Anterior cervical decompression and fusion (ACDF) was the preferred treatment for patients with ossification of the posterior longitudinal ligament (OPLL) among the majority of surgeons because it was considered logical to address the anteriorly placed pathology directly from an

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anterior approach. The biggest advantage of ACDF is that ossified ligaments can be extirpated or floated anteriorly to obtain direct spinal cord decompression [1, 2]. However, anterior procedures are technically demanding especially when OPLL involves multiple levels, and perioperative complications; e.g., intraoperative nerve injury, cerebrospinal fluid leakage, airway obstruction, pseudoarthrosis with or without dislodgement of the grafted bone, have been reported [3, 4]. The long-term results of ACDF also revealed that recurrent myelopathy due to the development of adjacent segment pathology was not uncommon, especially in those with developmental spinal stenosis [5].

Until late 1960s, conventional laminectomy that totally removes laminae with attached ligamentous structures was the only available posterior procedure for cervical myelopathy caused by multilevel OPLL; however, surgical outcomes were not always satisfactory due to inherent traumatic nature of laminectomy using rongeurs [6]. After the introduction of a high-speed drill, a Japanese spine surgeon, Kirita devised a sophisticated technique in which the laminae were thinned and divided at the midline followed by total resection of the laminae to achieve safe and simultaneous decompression of the spinal cord [7]. This procedure brought significant improvement in the surgical results and reduced the rate of postoperative complications; however, problems inherent to total removal of the posterior anatomical structures, e.g., the development of postoperative kyphosis, vulnerability of the exposed spinal cord, and recurrent stenosis due to scar formation, remained unsolved [8].

Laminoplasty has evolved in Japan to address such problems by preserving the laminae to cover the spinal cord and retain stability. In 1973, Hattori and his coworkers devised an expansive Z-plasty of the laminae in which the spinal canal was reconstructed by the preserved laminae; however, this procedure did not gain widespread acceptance because of its technical complexity [9]. Inspired by Kirita's method, Hirabayashi developed his own en bloc laminectomy in which bony gutters were made at the bilateral junction of the laminae and facet joints using a high-speed drill followed by en bloc resection of the laminar block. During this procedure, Hirabayashi noticed that the dural pulsation was already present when he lifted one side of the lamina, even before removing the whole lamina. This observation has led to the advent of "expansive open-door laminoplasty" in which the ventral cortex of the gutter at one side was left to act as a hinge and the other side was lifted, similar to opening a book cover [10–12].

Laminoplasty has a biomechanical advantage over laminectomy because it leaves most part of the laminae and the spinous processes with the supra- and interspinous ligaments intact contributing to postoperative stability [13]. Moreover, laminoplasty has less surgical impact on the patient resulting in fewer complications [3, 14, 15]. Instability, disc herniation, and spondylotic changes in the adjacent levels, which are often seen 10–20 years after ACDF that occasionally require salvage surgeries, are seldom seen after laminoplasty [12]. This simple and safe procedure gradually gained advocacy among Japanese spine surgeons.

Provoked by Hirabayashi's concept of laminoplasty, development of various modified procedures has followed. Among them, the spinous process splitting laminoplasty devised by Kurokawa also gained widespread popularity because secure reconstruction of the spinal canal could be achieved by placing the bone grafts between the opened laminae, thereby reinforcing stability of the cervical spine [16]. There are several modifications of the open-door procedure using a bone graft, bone graft substitutes, or miniplates in the opened space [17, 18]. Spinous process splitting laminoplasty has also been modified by placing a long strut bone graft or bone graft substitutes [19]. Tomita, et al. used threaded wire saw, which they devised for total spondylectomy, to split the spinous processes [20]. All these various laminoplasty procedures can be classified into three types: Z-plasty, open door, and midsagittal splitting, but currently, open-door and midsagittal splitting types are mainly performed. There are advocates for both types, some claiming that the midsagittal splitting type has less epidural bleeding, whereas

others stated that open-door type is safer because the gutters are formed at the lateral portions of the spinal canal where spinal cord compression is milder than the central portion [12]. However, no significant difference has been reported in the surgical outcomes between the two procedures to date and it is mostly the surgeons' preference whether to choose one or the other [21]. Even though numerous modified techniques have been devised to date, it should always be reminded that these two fundamental yet innovative techniques, open-door laminoplasty by Hirabayashi and spinous process splitting laminoplasty by Kurokawa, form the basis of the following modified procedures and yet remain as the most viable options.

Overall clinical results of expansive laminoplasty for OPLL have been reported to be 40–60% expressed by the recovery rate calculated using the Japanese Orthopaedic Association scoring system for the treatment of cervical myelopathy [12, 21]. Such favorable postoperative results brought a remarkable increase in the number of patients undergoing laminoplasty. However, to obtain favorable results, patient selection is the key. Some problems including postoperative axial pain, development of postoperative kyphosis, and segmental motor weakness have partly been resolved although not completely. Other problems are yet to be solved, i.e., postoperative progression of ossification and indications of prophylactic decompression.

22.1 Indications of Laminoplasty for OPLL

Best candidates of laminoplasty are those who have multilevel OPLL with developmental spinal stenosis and lordosis in whom sufficient posterior shift of the spinal cord is expected [12]. The biggest concern of laminoplasty for OPLL is the fact that the ossified mass remains intact inside the spinal canal, and, therefore, the type (continuous, segmental, mixed), size, and shape of OPLL must also be taken into account. If the ossified mass is large (canal occupying ratio >60%, thickness >7.2 mm) or a beak type with a sharp tip, optimal decompression may not be expected [22, 23]. In patients with segmental or mixed type OPLL, in whom ROM is preserved, the dynamic factor may lead later to neurological deterioration [24]. For these patients, ACDF or posterior instrumented fusion with pedicle screws or lateral mass screws may be considered. Fujiyoshi, et al. recommended to use K-line, which is the line connecting the midpoints of the spinal canal AP diameters at C2 and C7, to determine whether the patients should be treated anteriorly or posteriorly. If a patient has kyphosis and the tip of ossification extends beyond the K-line, the patient should be treated anteriorly or if treated posteriorly, fusion should be supplemented [25].

22.2 Axial Pain

Severe axial pain that occurs immediately after surgery is a common problem after laminoplasty. Although, in most cases, the symptom is alleviated spontaneously or by conservative treatments, such as injection of local anesthetics into the region of tenderness or an external support by a brace, some patients complain prolonged pain [26]. Preservation of the C7 spinous process where several paraspinal muscles attach has been reported to result in decrease of axial pain [27]. Shiraishi, et al. devised a sophisticated technique in which selected laminae are removed after minimal detachment of the muscles yet providing adequate decompression of the spinal cord and named it "skip laminectomy" although this technique is indicated mainly for spondylotic myelopathy [28]. After the report by Shiraishi, many studies on similar less invasive techniques followed in an attempt to reduce postoperative pain and preserve neck motion [29, 30].

22.3 Postoperative Kyphosis

In addition to the direct decompression effect by the posterior displacement of the laminae, laminoplasty has an indirect total decompression effect resulting from the dorsal shift of the spinal cord as long as patient's cervical alignment is maintained in lordosis [31]. In such case, the

decompression effect of laminoplasty is equivalent to laminectomy and is comparable to ACDF [13, 15]. In patients with kyphosis, recovery of myelopathy was unfavorable than that in patients with lordotic curvature [32]. Baba, et al. reported that neurologic improvement was associated with the degree of posterior cord migration on MR images and postoperative neurologic improvement was correlated to the volume of the enlarged bony canal, which was predominant in patients with lordosis [33]. Sodeyama, et al. also reported that critical value of posterior cord migration for good recovery of myelopathy was 3 mm on average [34]. All these studies emphasize the importance of preserving the lordotic curvature in patients undergoing laminoplasty.

Continuous efforts have been made to preserve preoperative lordosis and to prevent postoperative kyphosis. Insertion of the semispinalis cervicis muscle to the C2 spinous processes should be preserved whenever possible because this muscle has a crucial role in preserving the postoperative lordosis [35, 36]. If decompression at C3/4 segment is necessary, C3 dome laminoplasty is recommended instead of expanding the C3 lamina to leave the C2 spinous process untouched.

In CSM patients, development of mild postoperative kyphosis is acceptable because in CSM patients redundancy of the spinal cord induced by multilevel disc space narrowing attenuate compression force on the spinal cord thereby providing acceptable results. However, in OPLL patients, because the ossified ligaments often hold the disc space and the spinal cord remains in tension and is, therefore, more vulnerable to compression induced by kyphosis [37].

However, Hirabayashi also stated that severe kyphotic deformity or instability after expansive laminoplasty requiring salvage anterior fusion has never been experienced in their clinic although postoperative reduction in lordosis, which may be the consequence of progressive atrophy of the nuchal muscles, was seen in 5% of the patients after expansive laminoplasty [12]. The exact impact of the cervical alignment on the clinical results of laminoplasty should be determined in future studies.

22.4 Segmental Motor Weakness

Motor weakness that occurs mainly in C5 or C6 segments, usually without sensory disturbance, is the most common neurological complication after any type of laminoplasty. Friction heat generated by drilling of the gutters, a traumatic use of surgical instruments including air drills and Kerrison rongeurs, and the fall of the laminae into the canal after hinge breakage, a stretch of the nerve roots by the tethering effect induced by the posterior shift of the spinal cord, have been the proposed causes of this palsy [38, 39]. Involvement of micro-circulatory events has also been implied in the literature [40]. Although there is no established way to prevent this palsy, spontaneous recovery can be expected in most cases within 2 years after surgery. Tsuji, et al. have reported that selected laminoplasty in which the reduced number of levels was decompressed has led to the decrease in the incidence of C5 segmental palsy maybe due to limited posterior shift of the spinal cord, resulting in less tethering effect of the nerve roots [41].

22.5 Postoperative Progression of OPLL

OPLL itself is not removed after expansive laminoplasty, and there remains a possibility of postoperative progression of the ossified lesion, possibly due to biologic stimulation attributable to surgical invasion, biomechanical stresses, and hereditary disposition [42]. Therefore, when performing laminoplasty in patients with OPLL, it is necessary to expand the sagittal spinal canal sufficiently over the range of one vertebral level above and below the stenotic level and, at the same time, to obtain enough width of the expansion of the spinal canal [11].

22.6 Prophylactic Decompression

So far, there is no effective way to regenerate the spinal cord once it is damaged beyond its healing capacity. The only available solution presently is

to operate on a patient with myelopathy before the spinal cord is damaged irreversibly [12, 43]. Therefore, to obtain better surgical outcomes, early surgical decompression is recommended before the spinal cord deteriorates irreversibly, especially in young patients with a narrow spinal canal even if their myelopathy is not severe. This early-stage surgery is made possible by the reliability of the surgery. Laminoplasty is a reliable procedure, which has an equivalent decompression effect as ACDF and laminectomy, and is considered to maintain a more stable spine than laminectomy. It is also much safer and easier than ACDF against severely deteriorated spinal cord resulting in fewer complications. There is, however, no consensus on whether prophylactic decompression is justified for a patient with mild myelopathy or even before one develops myelopathy. This needs to be further discussed in future studies [44–46].

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