Principles and Surgical Technique of Cervical Laminoplasty

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COI: HOYA CORPORATION
Laminoplasty is usually performed for patients with cervical myelopathy.

Cervical myelopathy is caused related to the narrow spinal canal.

Within the narrow spinal canal, the spinal cord is compressed due to both static and dynamic stress mechanisms.

As a result, the spinal cord gradually becomes degenerated and atrophied.
Biomechanism causing cervical myelopathy

a: before compression   b: acute anterior compression
c: chronic anterior compression
d: chronic anterior compression combined with acute posterior compression

Pathological changes of cervical myelopathy

a: C3 segment
b: C5 segment
c: C8 segment

Wada E. et al. NEW MOOK Orthopedic Surgery No.6:12-21, 1997
Pathological changes of cervical myelopathy

a: C2 segment
b: C6 segment
c: T1 segment

Wada E. et al. NEW MOOK Orthopedic Surgery No.6:12-21,1997
Two–type stress mechanisms causing myelopathy and the treatment for them

Dynamic mechanism

Orthosis
Stabilization surgery

Static mechanism

Decompression surgery
Laminectomy
Laminoplasty
Anterior decompression
Why has laminoplasty been developed in Japan?

Narrower spinal canal in Japanese peoples

Higher prevalence rate of OPLL (ossification of the posterior longitudinal ligament) in Japanese peoples

Recognition of some disadvantages of laminectomy
Antero-posterior diameter of cervical spinal canal

At C5 level in Japanese peoples (mean)

Males: 16.1 ± 1.4 mm
Females: 15.2 ± 1.5 mm

(cf. 17.5 ± 5 mm in western peoples)

Patients with canal stenosis (mean − 2SD)

Males: ≤ 14 mm
Females: ≤ 13 mm

**Prevalence rate of cervical OPLL**

<table>
<thead>
<tr>
<th>Country</th>
<th>Prevalence Rate</th>
<th>Reference 1</th>
<th>Reference 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>about 3% (1.8 - 4.1%)</td>
<td>1987 Ohtsuka, 1996 Shingyouchi, 1996 Sakou</td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>0.2 - 1.8%</td>
<td>1990 Ryu, 1994 Harata</td>
<td></td>
</tr>
<tr>
<td>Korea</td>
<td>0.95%</td>
<td>1994 Harata</td>
<td></td>
</tr>
<tr>
<td>USA</td>
<td>0.12%</td>
<td>1994 Harata</td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>0.10%</td>
<td>1994 Harata</td>
<td></td>
</tr>
<tr>
<td>Italy</td>
<td>1.8%</td>
<td>1984 Terayama</td>
<td></td>
</tr>
</tbody>
</table>

It can be said that the prevalence rate of cervical OPLL is higher in Japan than the western countries.
Classification of the type of OPLL

<table>
<thead>
<tr>
<th>Type</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous</td>
<td>27.3%</td>
</tr>
<tr>
<td>Segmental</td>
<td>39%</td>
</tr>
<tr>
<td>Mixed</td>
<td>29.2%</td>
</tr>
<tr>
<td>Localized</td>
<td>7.5%</td>
</tr>
</tbody>
</table>

Cervical myelopathy due to OPLL

Tomography  MRI  CT
Disadvantages of laminectomy

1. Progression of kyphotic alignment of the cervical spine, especially in younger patients
   1987 Kurokawa

2. Progression of OPLL, probably because of traction force due to kyphotic-toward alignment change of the cervical spine
   1988 Hoshino, Hirabayashi

3. Invasion of scar tissues into the spinal canal, resulting in re-compression of the spinal cord
   2013 Taguchi
Principles of cervical laminoplasty

To decompress the spinal cord posteriorly for patients combined with:

- spinal canal stenosis at multiple levels
- anterior space occupying lesion at two or more levels

To preserve the posterior anatomical structures as much as possible

To steadily maintain the enlarged spinal canal
History of Laminoplasty

In 1973, the idea of cervical laminoplasty was first introduced by Oyama and co-workers by the name of “Expansive lamina-Z-plasty”.

Thereafter, various methods of cervical laminoplasty have been developed in Japan.

At present, they gradually become common around the world.

However, there remain some issues to be mentioned and resolved.
Expansive lamina-Z-plasty

Tinned laminae are opened in a shape of zigzag, resulting in obtaining a wide spinal canal.

The surgical methods are broadly divided into two types from the viewpoint of the site of osteotomy.

**ODL**
(Open-door laminoplasty)

**DDL**
(Double-door laminoplasty)
Materials to maintain enlarged space

Thread

Autogenous bone (spinous process, iliac bone)

Hydroxyapatite spacer

Titanium plate and screws

Screw and wire

Silicon spring
Factors influencing postoperative clinical results

Ages of patients

Duration of clinical course

Preoperative neurological conditions, especially muscle atrophy

Preoperative systemic conditions, especially osteoarthritis of the lower extremities, fracture of the spine, systemic neurological diseases, metabolic diseases, vascular diseases, etc.
Issues of this presentation

To show the surgical technique in DDL, because central splitting of the spinous process is technically demanding.

To compare the two methods: ODL and DDL

- postoperative enlargement of the spinal canal
- change of sagittal alignment of the cervical spine

From the anatomical study, to estimate the cause of postoperative C5 palsy, which sometimes occurs but its cause is even now unclear.
Issue 1  Surgical technique

Double-door laminoplasty  (DDL)

(views from the cranial side)
Trigonal shape osteotomy at the cranial base of the lamina

Central splitting from the caudal side of each spinous process.
trigonal shape osteotomy at the cranial base of the lamina
central splitting of the spinous process
Important technical points in splitting spinous processes

Lighting from the cranial side to obtain bright surgical field.

To attend the changes in color of the osteotomy site from red of cancellous bone, white of the inner cortex, and finally yellow of the yellow ligament and extradural fat tissue.

To attend the changes in sound and tactile sensation delivered from the air-drill at the time of complete osteotomy of the inner cortex of lamina.

To often check the degree of osteotomy by touching with a probe.
Formation of lateral gutters
Decompression of the spinal canal

dome shape osteotomy of C7 lamina

dura mater

yellow ligament to be resected

C6 spinous process

Maechenbaum

Fixation of STSS spacer

(thread)

STSS spacer

decompressed dura mater and spinal cord

(lateral gutter)

yellow ligament

(view from the cranial side)

STSS spacer

bird’s-eye view
transverse view
frontal view
axial view
Features of STSS spacer

Both the axial and frontal sections are trapezoidal.

The shape of contact surface to the split spinous process is parallelogram, resulting in obtaining a wider area.

Well adapted to the widened space because of the same shape.

During the fixation to the split spinous process, a spacer rotates slightly in the sagittal plane, resulting in more firmly stabilized parallel to each spinous process.
(view from the cranial side)
Restoration of tension of the Semispinalis muscles

C2 spinous process

Rectus capitus major

Obliques capitus inferior

Dome-shaped osteotomy of C2

Flavum at C2/C3

Semispinalis

C3

DDL for cervical spondylotic myelopathy 46 y.o. M
DDL for cervical spondylotic myelopathy
DDL for cervical spondylopathic myelopathy
Open-door Laminoplasty

After making longitudinal grooves along the lamina-facet junction line bilaterally, the inner cortex is severed at the open side. Next, the spinous processes are pushed toward the hinge side and the hypertrophied ligamentum flavum is resected.
ODL for cervical spondylotic myelopathy  54 y.o.  F
ODL for cervical spondylotic myelopathy
Open-door laminoplasty
Postoperative rehabilitation

Immediately after surgery, muscle exercises begin during bed rest.

After a few days, move around using a walker or wheelchair is allowed wearing a soft neck collar.

At the end of 1 month, the collar is discarded.
Inappropriate candidates for Laminoplasty

Large OPLL ($B/A \times 100 \geq 50-60\%$, or $B \geq 7\text{mm}$)

Local kyphosis at the most affected level

Hypermobility at the most affected level

Iwasaki M. Spine and Spinal Cord 26(11), 1047-54, 2013
Comparison of enlargement of the spinal canal after cervical laminoplasty: open-door type and double-door type

Shigeru Hirabayashi · Hironobu Yamada · Takao Motosuneya · Yoshinobu Watanabe · Makoto Miura · Hiroya Sakai · Takashi Matsushita

Open-door type

Double-door type
Spacer used in standard ODL

a = 12 mm at C5 and C6 levels
Spacer used in standard DDL

\[ a = 19 \text{ mm at C5 and C6 levels} \]

The fixation depth is about 8 mm superficial from the inner cotex of the lamina.
Spinal canal space and inclination angle investigated

(using soft program of computer: Image J)

Tension-band laminoplasty (TBL)
(One method of ODL)

Double-door laminoplasty (DDL)
<table>
<thead>
<tr>
<th>Clinical study</th>
<th>Patients</th>
<th>M / F</th>
<th>Age</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TBL for OPLL</strong></td>
<td>13</td>
<td>10 / 3</td>
<td>51 - 83</td>
<td>60.1</td>
</tr>
<tr>
<td><strong>TBL for CSM</strong></td>
<td>20</td>
<td>12 / 8</td>
<td>31 - 83</td>
<td>63.7</td>
</tr>
<tr>
<td><strong>DDL for CSM</strong></td>
<td>20</td>
<td>17 / 3</td>
<td>29 - 89</td>
<td>62.8</td>
</tr>
</tbody>
</table>

TBL: Tension-band laminoplasty (one method of open-door type)
OPLL: Ossification of the posterior longitudinal ligament
CSM: Cervical spondylotic myelopathy
Increased inclination angle of the C5 lamina

\[ (\,^\circ\,) \]

\[ \begin{align*}
\text{DDL} & : 19.0 \pm 1.4 \\
\text{TBL} & : 10.1 \pm 1.1
\end{align*} \]

\[ p < .0001 \]
Increased inclination angle of the C6 lamina

- DDL: 19.4 ± 8.0
- TBL: 9.2 ± 5.2

p < .0001
Expansion ratio of the spinal canal at the C5 level

n.s.

148.2 ± 34.2

148.9 ± 28.2
Expansion ratio of the spinal canal at the C6 level

\[ p < .05 \]

DDL

140.3 ± 28.8

TBL

159.0 ± 33.9
Results

1. The mean inclination angle at C5 and C6 level was about 20 degree in DDL, and about 10 degree in TBL (hinge side). It was significantly larger in DDL than TBL (p <0.0001).

2. At C5 level, the expansion ratio was about 150% in both DDL and TBL. There was no significant difference between them.

3. At C6 level, the expansion ratio was about 140% in DDL and about 160% in TBL. It was significantly larger in TBL than DDL (p <0.05).
Significance of the Maintenance of the Spinous Process and the Stability of an Artificial Spacer in Double-door Laminoplasty --- Figure Analyses

Shigeru Hirabayashi, Keitaro Murata, Iwao Yamamoto, Makoto Miura, Takashi Matsushita

*J. Spine Res. 2 : 66-72, 2011*
Shape of the spinal canal at C5 and C6 level

original shape  after DDL  after ODL

A: distance from the inner cortex of lamina
to the center of a spacer

by Delmas & Pineau

DDL: double-door laminoplasty
ODL: open-door laminoplasty
The expansion ratio of the spinal canal in DDL depends on both the depth of a spacer (A) and the width of a spacer (B).

<table>
<thead>
<tr>
<th>B</th>
<th>A</th>
<th>0</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>10</th>
<th>12</th>
<th>14</th>
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<tbody>
<tr>
<td>19 mm</td>
<td>233</td>
<td>220</td>
<td>209</td>
<td>200</td>
<td>192</td>
<td>185</td>
<td>178</td>
<td>173</td>
<td></td>
</tr>
<tr>
<td>18 mm</td>
<td>227</td>
<td>214</td>
<td>204</td>
<td>195</td>
<td>187</td>
<td>180</td>
<td>174</td>
<td>169</td>
<td></td>
</tr>
<tr>
<td>15 mm</td>
<td>207</td>
<td>196</td>
<td>187</td>
<td>179</td>
<td>172</td>
<td>166</td>
<td>161</td>
<td>157</td>
<td></td>
</tr>
<tr>
<td>12 mm</td>
<td>186</td>
<td>176</td>
<td>169</td>
<td>163</td>
<td>157</td>
<td>153</td>
<td>149</td>
<td>145</td>
<td></td>
</tr>
</tbody>
</table>

(%)
The expansion ratio of DDL using a spacer with 18 mm in width and 8 mm in depth is almost the same as that of ODL using a spacer with 12 mm in width.
In ODL (TBL), the expansion of the spinal canal depends on the width of a spacer.

In DDL, the expansion depends on both the width and depth of a spacer.

The comparison of the expansion ratio in both ODL and DDL performed by figure analysis well corresponded to the clinical results.
Technical advantages

Open-door laminoplasty (ODL)
Easier decompression procedure

Double-door laminoplasty (DDL)
Easier fixation of spacers
Direct visual confirmation of bilateral decompression
Appropriate indications

**Open-door laminoplasty (ODL)**
- CSM combined with radiculopathy
- Severe prominence of OPLL
- Patients with tiny spinous processes

**Double-door laminoplasty (DDL)**
- Usual CSM
- Small and slight prominence of OPLL
- Combined fixation using instrument
RA with C1-C2 instability and spinal canal stenosis of the cervical spine adequate indication of DDL.
Conclusions

Even now, it is unclear what is the least expansion ratio of the spinal canal to obtain adequate decompression of the spinal cord.

It is the best for a surgeon to perform surgery by his or her most familiar method.

However, it is necessary to recognize the features and limits of each surgical method.
Issue 4

Change of sagittal alignment of the cervical spine

Cervical spondylotic myelopathy followed more than 1 year
operated level: C3 - C6 or C7
measure: C2-C7 angle

<table>
<thead>
<tr>
<th></th>
<th>DDL</th>
<th>ODL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients</td>
<td>37</td>
<td>20</td>
</tr>
<tr>
<td>M / F</td>
<td>33 / 4</td>
<td>8 / 12</td>
</tr>
<tr>
<td>Age (average)</td>
<td>34 - 87 (64.1)</td>
<td>44 - 85 (68.9)</td>
</tr>
<tr>
<td>Operated laminae</td>
<td>5 laminae: 12</td>
<td>5 laminae: 15</td>
</tr>
<tr>
<td></td>
<td>4 laminae: 25</td>
<td>4 laminae: 5</td>
</tr>
</tbody>
</table>
DDL (37 patients)

Postoperative change toward kyphosis

Preop. lordosis

Postoperative change toward lordosis

Preop. kyphosis
DDL

<table>
<thead>
<tr>
<th>More lordosis</th>
<th>Preope. lordosis</th>
<th>Less lordosis</th>
<th>Kyphosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients</td>
<td>11</td>
<td>(33)</td>
<td>16</td>
</tr>
<tr>
<td>Average angle</td>
<td>5.6°</td>
<td>(14.0°)</td>
<td>8.3°</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Less kyphosis</th>
<th>Preope. kyphosis</th>
<th>More kyphosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients</td>
<td>1</td>
<td>(4)</td>
</tr>
<tr>
<td>Average angle</td>
<td>7.1°</td>
<td>(10.7°)</td>
</tr>
</tbody>
</table>
ODL (20 patients)

Postoperative change toward kyphosis

Postoperative change toward lordosis

Preope. lordosis

Preope. kyphosis
Less lordosis

Kyphosis

More lordosis
Preope. lordosis

Less lordosis

Kyphosis

or

patients
6
15
8
1

Average change angle
4.6°
(11.9°)
2.9°
16.3°

Preope.kyphosis

More kyphosis

patients
(5)

Average change angle
(5.9°)

5

10.0°
Results

1. Almost all patients in both DDL and ODL had lordotic alignment of the cervical spine preoperatively.

2. In both types, the preoperative lordorsis changed toward less lordosis or kyphosis postoperatively in about 10 degrees in about 60% of patients.

3. The change toward more kyphosis in patients with preoperative kyphosis was also about 10 degrees.
Anatomical Analyses and Thoughts on the Cause of Postoperative C5 Palsy

Shigeru Hirabayashi, Hiromu Yamamoto, Ryutaro Shiboi
Makoto Miura, Takashi Matsushita, Nobuyuki Tsuzuki

Definition of postoperative C5 palsy

De novo or increasing muscle weakness at mainly the C5 lesion with slight or without sensory disturbance after cervical surgery
Two theories concerning of the cause

nerve root injury
    (distraction, compression)

segmental spinal cord disorder
    (ischemia, recirculation)

It is unclear yet which of these is correct.
Classification of the conjectured causes of C5 palsy

Intraoperative

- Obvious technical failure
  - (direct injury or heat to nerve tissues by an air drill, compression to the spinal cord by using an inappropriate spacer, etc)
  - Unknown

Postoperative

- Nerve root injury
  - Obviously observed compression
  - Unknown

- Segmental spinal cord disorder (Unknown)
Purpose and method

Anatomical study using 25 cadavers to prove our estimation that the C5 palsy may occur by distraction and compression of the spinal nerve at near the foramen

To consider a countermeasure to prevent C5 palsy after cervical laminoplasty
Results
Distance of each nerve root composed of the brachial plexus

Among the cervical nerve roots composed of the brachial plexus, the distance between the division from the dura mater and the exit of the foramen is shortest at the C5 nerve root.

→ The capacity of moving freely is estimated to be smallest at the C5 nerve root.
The anterior rootlet of the cervical nerve enters into the foramen anterocaudal side of the posterior rootlet.
Anterior rootlet adjacent to the tip of the superior facet

The anterior rootlet runs adjacent to the tip of the superior facet where the foramen is narrowest.
Medial branch of the posterior ramus

After dividing from the posterior ramus proper near the exit of the foramen, the medial branch runs posteriorly in contact with the lateral side of the facet joint column.
Medial branch of the posterior ramus running in the shortest distance

The running line of the medial branch corresponds to a diagonal line of a parallelogram that is formed at the lateral side of the facet joint column.
Muscle branch of the medial branch of the posterior ramus

The medial branch finally divides into the capsule branch of the facet joint and the muscle branch of the multifidus muscles.
Summary of our results

- Among the roots composed of the brachial plexus, C5 nerve root runs in the shortest distance.

- Anterior rootlet runs adjacent to the narrowest part of the foramen.

- Medial branch of the posterior ramus runs in the shortest distance in contact with the lateral side of the facet joint column.
Discussion
Features of C5 palsy (343 cases)

One-half of the patients were accompanied by sensory disturbance or intolerable pain at the C5 lesion.

92 % of patients had hemilateral palsy and only 8 % had bilateral palsy.

Almost all palsy occurred within a week after surgery, and in rare patients, it occurred 2 or 4 weeks later.

In rare patients, palsy occurred at the C6, C7, and C8 lesion alone or combined.
Incidence of C5 palsy in C-spine surgery

Over all 4.6% (in 48 reports)

Approach
anterior 4.3%
posterior 4.7%
open-door 5.3%
double-door 4.3%

Disorders (in 17 reports)
OPLL 8.3%
CSM 5.6%

There were no significant differences between two types.

Prognosis

Finally, in severe cases (MMT 0-2), 71% recovered up to MMT 4.

In slight cases (MMT 3 or 4), 96% recovered up to MMT 5.
### Duration to recovery

<table>
<thead>
<tr>
<th></th>
<th>severe case (MMT 0-2)</th>
<th>slight case (MMT 3 or 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within 3m.</td>
<td>4 %</td>
<td>48 %</td>
</tr>
<tr>
<td>3—6m.</td>
<td>52 %</td>
<td>30 %</td>
</tr>
<tr>
<td>Over 6m.</td>
<td>44 %</td>
<td>22 %</td>
</tr>
</tbody>
</table>

About 60% of severe cases and about 80% of slight cases recovered within 6 months.

Incompatible with theory of segmental spinal cord disorder

The affected lesion is very limited (C5 segment, hemilateral).

In cases with sensory disturbance combined, that segment is the same of motor segment.

The palsy occurs not immediately but within a week after surgery.
Anastomoses of the artery and vein within the spinal cord are very rich. Affection of very limited area is thought to seldom occur by ischemia or recirculation that the theory of segmental spinal cord disorder is based on.

Artery of the spinal cord  (by Austin GA)

CA: central artery,  VSA: ventral spinal artery,  DSA: dorsal spinal artery
Thoughts on the mechanism in the theory of nerve root injury

The anterior rootlets of the cervical nerve seem to tend to mechanically be stretched and compressed in the foramen.

This effect is thought to be largest in the C5 nerve root because the running distance there is shortest and therefore the degree of free movement is most limited.
Length of the posterior ramus proper

C3  5
C4  3
C5  3
C6  5
C7  7
C8  10 (mm)

If elastic fibers with two different lengths are elevated at the center up to the same height, the distraction ratio is larger in the shorter fiber than the longer one.
Proof using a trigonometric function

\[ L = A \tan \alpha = B \tan \beta \quad A > B, \quad \text{therefore} \]
\[ \tan \alpha < \tan \beta, \quad \text{that is,} \quad \alpha < \beta \]
\[ \frac{a}{A} = \sec \alpha, \quad \frac{b}{B} = \sec \beta \]
\[ \sec \alpha < \sec \beta, \quad \text{therefore finally} \]
\[ \frac{a}{A} < \frac{b}{B} \]
Anterior prominence of facet joint

<table>
<thead>
<tr>
<th></th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
<th>C7</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>58%</td>
<td>87%</td>
<td>83%</td>
<td>58%</td>
<td>26%</td>
</tr>
<tr>
<td>B</td>
<td>42%</td>
<td>13%</td>
<td>17%</td>
<td>42%</td>
<td>74%</td>
</tr>
</tbody>
</table>

In patients with hypertrophied facet joint due to degenerative changes, the influence of these stretches and compressions becomes larger, because the medial branch of the posterior ramus runs posteriorly in contact with the lateral side of the facet joint column.
Lateral retraction of multifidus muscle

a: multifidus muscle,  b: facet joint,  c: anterior rootlet,  d: spinal nerve, e: anterior ramus  f: posterior ramus proper,  g: medial branch,  h: muscle branch, i: capsular branch  j: lateral branch

Hirabayashi S, ISRN Orthopedics Volume 2011, Article ID 637185, 7 pages, 2011
If the multifidus muscles (a) is severely retracted laterally during posterior surgery, not only the medial branch of the posterior ramus (g) but also the anterior (e) and posterior rami (f) and the anterior rootlet (c) are simultaneously stretched and compressed against adjacent structures.
Conclusions

Based on our anatomical analysis using 25 cadavers, we have concluded that this palsy is most likely caused by the C5 nerve root compression and stretch near the exit of the foramen.
To prevent and decrease the postoperative C5 palsy, it is recommended that too severe lateral stretch of the multifidus muscles for a long time must be avoided.

During laminoplasty, intermittent relaxation of tension of the hooks to the muscles may be one method of solution.
Welcome to Japan!
Thank you for your attention