SIGNIFICANT REDUCTION IN THE INCIDENCE OF C5 PALSY AFTER CERVICAL LAMINOPLASTY USING CHILLED IRRIGATION WATER

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Possible cause for C5 palsy

- Inadvertent nerve injury  
  *Satomi et al. Spine 1994*
- So-called tethering theory in which dorsal shift of the cord concomitant with posterior decompression  
  *Tsuzuki et al. Spine 1996*
- Segmental spinal cord dysfunction  
  *Chiba et al. Spine 2002*
- Reperfusion theory  
  *Hasegawa et al. Spine 2007*
- Friction-generated heat from a high speed drill  
  *Hosono et al. J Bone Joint Surg (Br) 2009*

Existing knowledge about C5 palsy

1. **Wide distribution** of affected nerves
2. Identical rate of incidence in anterior surgeries as posterior surgeries
3. Higher rate of incidence in patients whose laminae were **drilled laterally** than in those whose laminae were drilled medially
4. **Latent period** between the surgery and the onset of palsy
5. Rate of incidence **in proportion to the operated levels** in anterior surgeries
6. Higher rate of incidence in patients with ossification of the **posterior longitudinal ligament (OPLL)** than in those with spondylosis
The temperature rose up to 174°C with a diamond burr or 77°C with a steel burr.

The thinner the residual drilled bone was, the higher the temperature at the drilled site was.


Previous study <2> Takenaka et al. J Neurosurg Spine 2013

Hypothesis

Cooled irrigation water could prevent post-operative upper limb palsy by reducing the friction heat. Total 159 patients

RT group (n=79) Room temperature irrigation vs. LT group (n=80) Chilled irrigation
Although the incidence of muscle weakness was significantly reduced when muscle strength was assessed by a hand-held dynamometer after introduction of chilled saline, the incidence of clinical upper limb palsy, defined as a reduction of one grade or more on manual muscle testing (MMT), was not reduced.

5/79 (Room temperature irrigation) vs 3/80 (Chilled irrigation)
Because the results of the previous study may have been due to insufficient statistical power, we enrolled 800 patients in the present study to determine whether chilled irrigation saline could reduce the incidence of upper limb palsy.

**Purpose**

Exclusion criteria:
- MMT grade of <3 for the deltoid, biceps and triceps and/or articular disorder (n = 69)
- Postoperative disorder (n = 11)
- Intraoperative dural tear (n = 9)
- Mental disorder (n = 7)
- Morbid conditions within 2 weeks postoperatively (n = 3)

99 pts excluded out of 899 pts from Feb 2006 to Nov 2014

June 2010 Introduction of chilled saline irrigation

RT group (n = 400) Room temperature irrigation

LT group (n = 400) Chilled irrigation
800 patients (1600 arms; 531 men and 249 women; mean age, 64.8 [30–91] years)

Disease
- cervical spondylotic myelopathy (CSM) n = 594
- ossification of the posterior longitudinal ligament (OPLL) n = 178
- cervical disc herniation (CDH) n = 20
- calcification of the ligamentum flavum (CLF) n = 5
- destructive spondyloarthropathy caused by hemodialysis (DSA) n = 3

Clinical parameter
- Operating time per 1 level
- Blood loss per 1 level
- No. of decompression levels
- Concomitant foraminotomy
- Deltoid, biceps, and triceps brachii muscle strength by MMT
- Japanese Orthopaedic Association (JOA) score (full score, 17)
- 10-second test
- Upper limb palsy onset
- Presence or absence of concomitant sensory disturbance
- Time needed for full ULP recovery.
<table>
<thead>
<tr>
<th></th>
<th>RT group (N=400)</th>
<th>LT group (N=400)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male : female</td>
<td>272:128</td>
<td>271:129</td>
<td>1.000</td>
</tr>
<tr>
<td>Age</td>
<td>63.0</td>
<td>&lt; 66.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Operative time per lamina, min</td>
<td>22</td>
<td>&gt; 20</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Blood loss per lamina, g</td>
<td>37</td>
<td>&gt; 28</td>
<td>0.001</td>
</tr>
<tr>
<td>No. of opened laminae</td>
<td>4.5</td>
<td>&gt; 4.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Concomitant foraminotomy</td>
<td>28</td>
<td>29</td>
<td>1.000</td>
</tr>
<tr>
<td>Preoperative JOA score</td>
<td>11.2</td>
<td>11.5</td>
<td>0.081</td>
</tr>
<tr>
<td>Postoperative JOA score</td>
<td>13.5</td>
<td>13.6</td>
<td>0.987</td>
</tr>
<tr>
<td>Recovery rate (%)</td>
<td>42</td>
<td>40</td>
<td>0.145</td>
</tr>
<tr>
<td>Preoperative 10-second test</td>
<td>20.0</td>
<td>19.2</td>
<td>0.088</td>
</tr>
<tr>
<td>Postoperative 10-second test</td>
<td>26.2</td>
<td>26.0</td>
<td>0.499</td>
</tr>
<tr>
<td>Operative gain in 10-second test</td>
<td>6.2</td>
<td>6.7</td>
<td>0.116</td>
</tr>
<tr>
<td>Upper limb palsy</td>
<td>38(9.5%)</td>
<td>&gt; 16(4.0%)</td>
<td>0.001</td>
</tr>
</tbody>
</table>
### Multivariate analysis

<table>
<thead>
<tr>
<th>Model</th>
<th>Dependent variable</th>
<th>Independent variable</th>
<th>P-value</th>
<th>OR</th>
<th>95%CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1</td>
<td>ULP per patient</td>
<td>Room temperature</td>
<td>0.003</td>
<td>2.52</td>
<td>1.38-4.60</td>
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<tr>
<td>Model 2</td>
<td>ULP per arm</td>
<td>Room temperature</td>
<td>0.007</td>
<td>2.19</td>
<td>1.24-3.90</td>
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<tr>
<td></td>
<td></td>
<td>Concomitant foraminotomy</td>
<td>0.010</td>
<td>3.17</td>
<td>1.32-7.59</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Open gutter side</td>
<td>0.017</td>
<td>2.08</td>
<td>1.14-3.78</td>
</tr>
</tbody>
</table>

ULP = upper limb palsy

### Cox proportional hazard analysis for extending recovery periods

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Independent variable</th>
<th>P-value</th>
<th>HR</th>
<th>95%CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>ULP per patient</td>
<td>non-OPLL</td>
<td>&lt;0.001</td>
<td>3.44</td>
<td>1.72-6.89</td>
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<tr>
<td></td>
<td>Room temperature</td>
<td>0.018</td>
<td>2.25</td>
<td>1.15-4.40</td>
</tr>
</tbody>
</table>

ULP = upper limb palsy
Distribution of the onset of upper limb palsy

- **Early onset**
  - p < 0.001
  - 82% reduced

- **Late onset**
  - p = 0.565

Number of patients vs. Time after operation (days) for RT and LT groups.
All the three risk factors (the use of RT saline, concomitant foraminotomy and the opened side) are consistent with the thermal damage theory.

Other risk factors which were previously reported such as OPLL, drilling lateraly, multilevel anterior fusion, and wide distribution of affected nerves are also in agreement with the thermal damage theory.  

Nakashima et al. J Neurosurg 2012  
Xia et al. J Spinal Disord Tech 2011  
Hashimoto et al. Eur Spine J 2010  
Kaneyama et al. Spine 2010

Why wasn’t upper limb palsy completely prevented with chilled saline?

There are two possible explanations for this.  
First, the drilling sites may not have been sufficiently cooled.  
Second, upper limb palsy might be caused by a mechanism other than thermal damage to the nerve roots.
Given that the early-onset palsy was more severe and longer lasting than late-onset palsy, the causes of upper limb palsy might differ between early- and late-onset palsy. Most of the early-onset upper limb palsy was in the RT group, whereas no difference was found in the incidence of late-onset upper limb palsy between the LT and RT groups, suggesting that early-onset palsy was caused by thermal nerve damage, whereas late-onset palsy might result from other etiologies.

Some surgeons advocate prophylactic foraminotomy to prevent upper limb palsy, which does not contradict our conclusion that foraminotomy is a risk factor. We performed foraminotomy only for cases of nerve root impingement; i.e., the nerve roots were susceptible to friction heat because they were close to the bone. In contrast, prophylactic foraminotomy is performed for all patients who undergo laminoplasty. Because most have no root impingement, thermal injury to the nerve roots during foraminotomy is unlikely. The possibility remains that prophylactic foraminotomy can prevent upper limb palsy caused by an as yet unknown reason.
Conclusion

✓ The incidence of clinical upper limb palsy (a reduction of one grade or more on MMT) was compared between before and after the introduction of chilled saline during laminoplasty.

✓ The use of chilled irrigation saline during drilling in laminoplasty significantly decreased the incidence of upper limb palsy, especially in the early period (within two days of surgery), and shortened the recovery period for upper limb palsy.

✓ Early-onset palsy might be caused by thermal nerve damage, whereas late-onset palsy might result from other etiologies.

✓ The use of chilled irrigation saline is recommended as a simple method to prevent upper limb palsy.

EUROSPINE 2015 COI Disclosure

Name of First Author: Shota Takenaka

The authors have no financial conflicts of interest to disclose concerning the presentation.