Outcomes following Laminoplasty or Laminectomy and Fusion in Patients with Myelopathy Caused by Ossification of the Posterior Longitudinal Ligament: A Systematic Review

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Keywords► cervical spine► myelopathy► ossification of the posterior longitudinal ligament► surgical treatment► laminoplasty► laminectomy and fusion► outcome

Abstract

Study Design Systematic review.

Objective To compare laminoplasty versus laminectomy and fusion in patients with cervical myelopathy caused by OPLL.

Methods A systematic review was conducted using PubMed/Medline, Cochrane database, and Google scholar of articles. Only comparative studies in humans were included. Studies involving cervical trauma/fracture, infection, and tumor were excluded.

Results Of 157 citations initially analyzed, 4 studies ultimately met our inclusion criteria: one class of evidence (CoE) II prospective cohort study and three CoE III retrospective cohort studies. The prospective cohort study found no significant difference between laminoplasty and laminectomy and fusion in the recovery rate from myelopathy. One CoE III retrospective cohort study reported a significantly higher recovery rate following laminoplasty. Another CoE III retrospective cohort study reported a significantly higher recovery rate in the laminectomy and fusion group. One CoE II prospective cohort study and one CoE III retrospective cohort study found no significant difference in pain improvement between patients treated with laminoplasty versus patients treated with laminectomy and fusion. All four studies reported a higher incidence of C5 palsy following laminectomy and fusion than laminoplasty. One CoE II prospective cohort and one CoE III retrospective cohort reported that there was no significant difference in axial neck pain between the two procedures. One CoE III retrospective cohort study suggested that there was no significant difference between groups in OPLL progression.

Conclusion Data from four comparative studies was not sufficient to support the superiority of laminoplasty or laminectomy and fusion in treating cervical myelopathy caused by OPLL.

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Introduction

Currently there is no standard surgical algorithm for treating cervical myelopathy caused by ossification of the posterior longitudinal ligament (OPLL). Surgical options include anterior corpectomy and fusion, laminoplasty, and laminectomy and fusion. The literature has demonstrated a significant complication rate associated with anterior corpectomy and fusion, which has led to the investigation of posterior-based procedures, including both laminoplasty and laminectomy and fusion. Laminoplasty has been advocated because of its preservation of neck range of motion (ROM) compared with laminectomy and fusion. However, OPLL is unique when compared with other inciting etiologies of myelopathy, in that neck ROM may incite further progression of OPLL.

The current literature is laden with studies of laminoplasty and laminectomy and fusion, with the majority of studies lacking comparative groups or long-term follow-up. In this study, we performed a systematic review to assess the clinical results and complications of laminoplasty compared with that of laminectomy and fusion for the treatment of cervical myelopathy caused by OPLL.

To compare laminoplasty to laminectomy and fusion, three key questions were devised: (1) In patients with cervical myelopathy caused by OPLL, what is the effectiveness of laminoplasty compared with laminectomy and fusion? (2) In patients with cervical myelopathy caused by OPLL, what is the safety of laminoplasty compared with laminectomy and fusion? (3) In patients with cervical myelopathy caused by OPLL, does OPLL progress after laminoplasty more than laminectomy and fusion?

Materials and Methods

Study design: Systematic review.

Search: A systematic search was conducted of PubMed/Medline, Cochrane, and Google scholar. The search included the use of Medical Subject Heading (MeSH) terms and key words. The terms specific to OPLL were: ossification of posterior longitudinal ligament OR ossified posterior longitudinal ligament OR ossification of the posterior longitudinal ligament OR calcification of posterior longitudinal ligament OR calcification of the posterior longitudinal ligament OR ligament calcification OR ossification of posterior longitudinal ligament [Mesh]. These terms were combined with terms specific to the surgical procedure: (Laminoplasty OR Laminoplast OR Laminaplast) AND (Laminectomy OR Laminectomy [MeSH]).

Date searched: The data was searched through July 17, 2015.

Inclusion criteria: Studies were included that directly compared laminoplasty with laminectomy and fusion for the treatment of cervical myelopathy caused by OPLL.

Exclusion criteria: Studies including patients with cervical trauma/fracture, infection, or tumor were excluded, as were noncomparative studies (case series and case reports), comparative studies with fewer than five patients per group, and animal, in vitro, and biomechanical studies.

Outcome: The outcome parameters included myelopathy improvement (Japanese Orthopedics Association [JOA]), pain (visual analog scale [VAS]), cervical alignment, cervical ROM, OPLL progression, and complications.

Analysis: Descriptive statistics, means, standard deviations, and ranges were collected from the original reports. The data was not pooled because of the heterogeneity of the studies.

Overall strength of evidence: The risk of bias was determined by the class of evidence (CoE) rating system. The overall body of the evidence and recommendation was determined using the Grade of Recommendation Assessment, Development and Evaluation (GRADE) system.

No approval from the Institutional Review Board was needed.

Results

One hundred fifty-seven citations were initially reviewed. After application of the inclusion criteria, seven studies were evaluated for review. Three studies were excluded because they had fewer than five patients per group or they did not directly compare laminoplasty to laminectomy and fusion.

Four studies were included in the final analysis in this study (►Fig. 1, ►Table 1). Yuan et al, the single prospective cohort study reviewed (CoE II), compared laminoplasty with laminectomy and fusion. Lee et al, a retrospective cohort study (CoE II), compared laminoplasty, laminectomy alone, and laminectomy and fusion. The final two articles, each retrospective cohort studies (CoE III), were authored by Chen et al and compared laminoplasty, corpectomy, and fusion with laminectomy and fusion. Each study included a mixture of continuous, segmental, and mixed types of OPLL. The populations in the studies were predominantly middle-aged men, and the follow-up was greater than 12 months in each study (range 12 to 72 months).

Fig. 1 Flowchart showing result of literature search.
| Study, study design, CoE, and enrollment | Intervention | Demographic | Treatment allocation | OPPL type | Follow-up | Reported outcome |
|------------------------------------------|-------------|-------------|---------------------|-----------|-----------|-----------------|
| Yuan et al (2015),⁹ prospective cohort (n = 38), CoE: II (December 2010–December 2012) | Laminoplasty  
- C3–C7 open door laminoplasty  
- Maintain opened laminar by sutured with contralateral facet capsule  
- Laminectomy and fusion  
- Lateral mass screw (C3, C5, C7) and rod fixation  
- Autograft  
- Postoperative collar for 4 wk | Laminoplasty  
- \( n = 20 \)  
- Male = 30%  
- Mean age = 59 y (SD 11.6)  
- Mean disease duration = 22 mo (SD 12.4)  
- Laminectomy and fusion  
- \( n = 18 \)  
- Male = 67%  
- Mean age = 62 y (SD 11.3)  
- Mean disease duration = 18 mo (SD 9.3) | Laminoplasty  
- Transverse diameter of OPPL less than 50% (CT scan)  
- Laminectomy and fusion  
- Transverse diameter of OPPL more than 50% (CT scan) | Laminoplasty  
- 10 continuous (50%)  
- 7 mixed (35%)  
- 3 segmental (15%)  
- Laminectomy and fusion  
- 10 continuous (55.6%)  
- 6 mixed (33.3%)  
- 2 segmental (11.1%) | At least 12 mo | JOA score  
Recovery rate  
VAS  
ROM  
CROM device (three-dimensional measurement)  
Complications |
| Lee et al (2014),¹⁰ retrospective cohort (n = 57), CoE: III (October 2003–June 2011) | Laminoplasty  
- 16 open door laminoplasty  
- Maintain opened laminar by miniplate and screw  
- 5 double door laminoplasty  
- Laminectomy alone  
- Laminectomy and fusion  
- Lateral mass screw and rod fixation  
- Local autograft | Laminoplasty  
- \( n = 21 \)  
- Male = 71.4%  
- Mean age = 54.2 y (SD 10.3)  
- Laminectomy alone  
- \( n = 15 \)  
- Male = 86.7%  
- Mean age = 61.3 y (SD 6.6)  
- Laminectomy and fusion  
- \( n = 21 \)  
- Male = 90.5%  
- Mean age = 63.7 y (SD 7.7) | Surgeons’ decision based on  
- Cervical alignment  
- Severity of OPLL  
- Surgeons’ preference | Laminoplasty  
- 14 continuous (66.7%)  
- 7 mixed (33.3%)  
- Laminectomy alone  
- 9 continuous (60%)  
- 6 mixed (40%)  
- Laminectomy and fusion  
- 15 continuous (71.4%)  
- 6 mixed (28.6%) | At least 24 mo | JOA score  
VAS  
NDI  
Cervical alignment  
C2–C7 SVA  
C2–C7 Cobb angle  
OPPL progression |
| Chen et al (2012),¹¹ retrospective cohort (n = 164), CoE: III (January 2004–December 2007) | Corpectomy and fusion  
- Laminoplasty  
- Laminectomy and fusion | Corpectomy and fusion  
- \( n = 91 \)  
- Laminoplasty  
- \( n = 41 \)  
- Male = 80%  
- Mean age = 46.3 y (SD 2.5)  
- Laminectomy and fusion  
- \( n = 32 \)  
- Male = 61.3%  
- Mean age = 52.6 y (SD 1.7) | Corpectomy and fusion  
- Short segment pathology  
(≤3 vertebral bodies)  
- Laminoplasty  
- Long segment pathology  
- Cervical lordosis  
- Laminectomy and fusion  
- Long segment pathology  
- Cervical kyphosis | No significant difference in OPPL occupying ratio  
- Laminoplasty  
- 41.2% (SD 1.4)  
- Laminectomy and fusion  
- 47.1% (SD 1.1) | At least 48 mo (range 48–72 mo) | JOA score  
Recovery rate  
Complications |

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### Table 1 (Continued)

| Study, study design, CoE, and enrollment | Intervention | Demographic | Treatment allocation | OPLL type | Follow-up | Reported outcome |
|------------------------------------------|--------------|-------------|----------------------|-----------|-----------|-------------------|
| Chen et al (2011), retrospective cohort (n = 75), CoE: III | Corpectomy and fusion | Corpectomy and fusion  
- n = 22  
- Male: 64.0%  
- Mean age: 54.2 y (range 32–66) | Laminoplasty  
- Economic reason (could not pay for instrumentation) | No significant difference in OPLL occupying ratio.  
- Laminoplasty  
- 54.3% (SD 4.6)  
- Laminectomy and fusion  
- 58.2% (SD 6.4) | At least 48 mo | JOA score  
- Recovery rate  
- Cervical lordosis  
- Complications |
| Corpectomy and fusion  
- Laminoplasty  
- 15 open door laminoplasty  
- 10 double door laminoplasty  
- Philadelphia collar for 3 mo  
- Laminctomy and fusion  
- Screw and rod fixation  
- Local autograft  
- No postoperative immobilization | Corpectomy and fusion | Corpectomy and fusion  
- n = 22  
- Male: 64.0%  
- Mean age: 54.2 y (range 32–66) | Laminoplasty  
- Economic reason (could not pay for instrumentation) | No significant difference in OPLL occupying ratio.  
- Laminoplasty  
- 54.3% (SD 4.6)  
- Laminectomy and fusion  
- 58.2% (SD 6.4) | At least 48 mo | JOA score  
- Recovery rate  
- Cervical lordosis  
- Complications |

Abbreviations: CoE, class of evidence; CROM, cervical range of motion; CT, computed tomography; JOA score, Japanese Orthopedic Association Score; NDI, Neck Disability Index; OPLL, ossification of posterior longitudinal ligament; ROM, range of motion; SD, standard deviation; SVA, sagittal vertical axis; VAS, visual analog scale.

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Comparision of Clinical Results

**Myelopathy**

- The recovery rate as defined by Hirabayashi et al is based on the equation: 
  \[
  \text{Recovery rate} = \frac{100\% \times (\text{postoperative JOA score} - \text{preoperative JOA score})}{17 - \text{preoperative JOA score}}
  \]

- The mean recovery rate after laminoplasty (65.2 versus 50.8%) was significantly higher than after laminectomy and fusion (61.9 versus 43.5%).

- Lee et al did not find any significant difference in the mean recovery rate after treatments groups at 1-year follow-up.

- The mean recovery rate was 43.7% in the laminectomy group and 50.0% in the laminoplasty group. In agreement, Chen et al assessed the neurologic improvement using the JOA score and recovered the neurological improvement with laminoplasty.

- Therefore, after laminoplasty was assessed the neurologic improvement using the JOA score and recovered the neurological improvement with laminoplasty.

- This study reported a significantly higher recovery rate in the laminoplasty compared with laminectomy group.

- Lee et al additionally assessed the neurologic improvement using the JOA score and evaluated neurologic improvement.

- The mean recovery rate was 43.7% in the laminectomy group and 50.0% in the laminoplasty group. In agreement, Chen et al assessed the neurologic improvement using the JOA score and recovered the neurological improvement with laminoplasty.

- Therefore, after laminoplasty was assessed the neurologic improvement using the JOA score and recovered the neurological improvement with laminoplasty.

- This study reported a significantly higher recovery rate in the laminoplasty compared with laminectomy group.

- Lee et al additionally assessed the neurologic improvement using the JOA score.
seen following laminoplasty and 80% following laminectomy and fusion.

Cervical Alignment
Lee et al found a significant loss of cervical lordosis over time following both laminoplasty and laminectomy and fusion: laminoplasty, change from 14.2 degrees to 8.0 degrees; laminectomy and fusion, change from 10.0 degrees to 5.1 degrees (Table 2). Additionally, this study showed that the mean C2–C7 sagittal vertical axis of patients in the laminoplasty group increased gradually from preoperative to 24 months (change from 22.0 to 28.2 mm). In contrast, there

Table 2 Studies comparing laminoplasty with laminectomy and fusion: comparison of clinical results

| Study and study design | Outcomes | Laminoplasty | Laminectomy and fusion | p Value |
|------------------------|----------|--------------|------------------------|---------|
| **Yuan et al (2015),**<sup>9</sup> prospective cohort | JOA score/mJOA score | 10.6 | 11.1 | NR |
| Preoperative | 13.4 | 14.1 | NR |
| Postoperative (12 mo) | 43.7 | 50.8 | NS |
| Recovery rate (%) | | | | |
| Pain improvement (VAS) | 4.8 | 4.5 | NR |
| Preoperative | 1.7 | 2.5 | NR |
| Postoperative (12 mo) | 3.1 | 2.0 | NS |
| VAS change | | | | |
| ROM preservation (%) | Flexion 75.1 | Extension 59.8 | | |
| | Left flexion 80.9 | Right flexion 76.1 | | |
| | Left rotation 89.4 | Right rotation 90.8 | | |
| **Lee et al (2014),**<sup>10</sup> retrospective cohort | JOA score/mJOA score | 14.0 (2.8) | 12.4 (2.9) | NR |
| Preoperative, mean (SD) | 13.6 (3.4) | 13.1 (1.2) | NR |
| Postoperative, mean SD | −13.3 | 15.2 | NR |
| Recovery rate (%) | | | | |
| Pain improvement (VAS) | 3.4 (3.5) | 2.9 (2.8) | NS |
| Preoperative, mean (SD) | 3.0 (2.8) | 1.3 (1.7) | NS |
| Postoperative, mean (SD) | 0.4 | 1.6 | NS |
| VAS scale change | | | | |
| NDI | | | | |
| Preoperative, mean (SD) | 12.3 | 17.9 | NR |
| Postoperative, mean (SD) | 8.8 | 13.8 | NR |
| NDI change | 3.5 | 4.1 | NS |
| ROM preservation (%) | NR | NR | NR |
| C2–C7 SVA | 22.0 (12.1) | 29.5 (10.7) | NR |
| Preoperative, mean (SD) | 28.2 (15.5) | 29.2 (10.9) | NR |
| Postoperative, mean (SD) | 6.2 | −0.3 | NS |
| SVA change (mm) | | | | |
| Cervical lordosis | | | | |
| Preoperative, degree (SD) | 14.2 (5.8) | 10.0 (11.6) | NR |
| Postoperative, degree (SD) | 8.0 (7.9) | 5.1 (12.0) | NR |
| Lordosis change (degree) | 6.2 (decrease lordosis) | 4.9 (decrease lordosis) | NS |
| OPLL progression (%) | 45.5 (no clinical) | 30.0 (no clinical) | NS |
| **Chen et al (2012),**<sup>11</sup> retrospective cohort | JOA score/mJOA score | 10.2 (0.3) | 9.1 (0.4) | Significant |
| Preoperative, mean (SD) | 14.6 (0.2) | 13.0 (0.2) | Significant |
| Postoperative, mean (SD) | 65.2 (5.8) | 50.8 (6.4) | Significant |
| Recovery rate, % (SD) | NR | NR | NR |
| Pain improvement (VAS scale) | NR | NR | NR |
| ROM preservation (%) | NR | NR | NR |
| Cervical lordosis | | | | |
| Preoperative, degree (SD) | 8.5 (0.7) | 8.7 (1.6) | NS |
| Postoperative, degree (SD) | 10.9 (0.4) | 12.4 (1.2) | NS |
| Recovery rate, % (SD) | 25.1 (8.5) | 43.5 (12.7) | Significant |
| Pain improvement (VAS scale) | NR | NR | NR |
| ROM preservation (%) | NR | NR | NR |
| Cervical lordosis | | | | |
| Preoperative, degree (SD) | 4.9 (0.7) | 6.5 (1.8) | NS |
| Postoperative, degree (SD) | 6.1 (0.6) | 11.7 (1.2) | Significant |
| Lordosis change (degree) | 1.2 (increase lordosis) | 5.2 (increase lordosis) | Significant |

Abbreviations: JOA score, Japanese Orthopedic Association Score; mJOA score, modified Japanese Orthopedic Association Score; NDI, Neck Disability Index; NR, not reported; NS, not significant; ROM, range of motion; SD, standard deviation; SVA, sagittal vertical axis; VAS, visual analog scale.
was no change in the laminectomy and fusion group for 24 months (change from 29.5 to 29.2 mm). Subgroup analysis showed that a high sagittal vertical axis (>40 mm) was correlated with significant neck pain in the laminoplasty group. Chen et al reported significantly greater lordosis following laminectomy and fusion than laminoplasty.12

Complications

Fifth Cervical Nerve Root Palsy
All four studies reported that the incidence of cervical nerve root five (C5) palsy was higher following laminectomy and fusion (range, 9.6 to 25%) than laminoplasty (range, 0 to 8%). The majority of C5 palsy fully recovered at 12 months’ follow-up (► Table 3).

Other Complications
Miscellaneous complications were reported following laminoplasty including hematoma (4%),12 progressive kyphosis (20%),12 and incomplete decompression (9.6%).10 Lee et al reported a 4.8% rate of screw malposition following laminectomy and fusion.10

OPLL Progression
Lee et al reported that the progression rate of OPLL was 45.5, 52.5, and 30.0% in laminoplasty, laminectomy alone, and laminectomy and fusion groups, respectively (► Table 2).10 This study found no significant difference following laminoplasty compared with laminectomy and fusion. Additionally, no neurologic deterioration was found as a result of OPLL progression in any of the groups.

Evidence Summary
The evidence presented does not establish the superiority of laminoplasty or laminectomy and fusion (► Table 4). The evidence regarding improvements in myelopathy and NDI following laminoplasty or laminectomy and fusion is insufficient. The strength of evidence regarding pain and ROM following either procedure is low. Additionally, the strength of evidence evaluating the safety of either procedure is insufficient. Finally, the overall strength of evidence evaluating the incidence of OPLL progression following laminoplasty or laminectomy and fusion does not establish the beneficence of one procedure over the other.

Discussion
The gold standard surgical treatment for cervical myelopathy caused by OPLL remains controversial. Anterior corpectomy and fusion surgery, which directly decompresses the spinal cord, is technically demanding and associated with high complication rates, causing surgeons to opt for the posterior approach to address this cervical pathology. In this study, we evaluated the evidence regarding laminoplasty or laminectomy and fusion by analyzing data obtained from PubMed/Medline, Cochrane, and Google scholar. Despite many studies on the surgical treatment of OPLL, few had comparative groups. After application of inclusion criteria, four studies were included for analysis: one prospective cohort and three retrospective cohort studies. Due to the heterogeneity of these studies, we were unable to perform a meta-analysis of the data. Therefore, we performed a systematic review regarding the surgical effectiveness, safety, and risk of OPLL progression comparing laminoplasty and laminectomy and fusion.

Each of the studies reported a JOA score and an individual recovery rate; however, the results diverged. Yuan et al suggested no significant difference in recovery rate between the treatment groups.9 Insignificance between the two groups was similarly seen in the study by Lee et al.10 In contrast, Chen et al reported that laminoplasty was superior. However, all patients who underwent laminectomy and fusion had preoperative cervical kyphosis and more severe neurologic deficits.11 In another study, Chen et al reported conflicting conclusions that favored laminectomy and fusion.12 Although each study was comparative, each also has significant limitations. All four studies were nonrandomized controlled studies. Additionally, the
Overall, data from two CoE III prospective cohorts suggested that incidence of hematoma, progressive kyphosis, and incomplete decompression appears to be higher in laminoplasty group. However, data from the CoE II prospective cohort and three CoE III retrospective cohort studies suggested that incidence of C5 palsy and screw malposition appear to be higher in laminoplasty group. However, data from the CoE II prospective cohort study found no significant difference in axial pain between groups.

Data from two CoE III retrospective cohorts suggested that incidence of hematoma, progressive kyphosis, and incomplete decompression appears to be higher in laminoplasty group. However, data from the CoE II prospective cohort and three CoE III retrospective cohort suggested that incidence of C5 palsy and screw malposition appear to be higher in laminoplasty and fusion group. However, there was no neurologic deterioration found as a result of OPLL progression.

One CoE III prospective cohort study suggested that there was no significant difference between groups in OPLL progression. There was no neurologic deterioration found as a result of OPLL progression. The greatest limitation to this current study is that few comparative studies are available, and there were no randomized controlled studies for evaluation. Additionally, the NDI score and ROM preservation were reported in only one study. Data from these four comparative studies is not sufficient to establish the superiority of laminoplasty or laminectomy and fusion in treating cervical myelopathy caused by OPLL. The overall strength of evidence to support any conclusion is low or insufficient. Often, the value of a systematic review is to identify the absence of clear-cut evidence. For example, some surgeons believe that one procedure is superior to the other and cite the few articles on the topic. Our analysis suggests that the evidence for superiority of one over the other is not strong. However, because outcomes of both procedures appear to be equivalent, one might consider the less-invasive nature and lower cost of laminoplasty. Although there is insufficient evidence to make the recommendation

| Outcome                                      | Strength of evidence | Conclusions/comments                                                                 |
|----------------------------------------------|----------------------|--------------------------------------------------------------------------------------|
| Improvement of myelopathy                    | Insufficient         | The CoE II prospective cohort study suggested that there was no significant difference between groups in recovery rate of myelopathy. One CoE III retrospective cohort study reported that the recovery rate was significant higher in laminoplasty group. One CoE III retrospective cohort study reported that the recovery rate was significant higher in laminectomy and fusion group. |
| Pain (VAS)                                   | Low                  | The CoE II prospective cohort and one CoE III retrospective cohort studies found no significant difference in pain outcomes between treatment groups. |
| NDI                                          | Insufficient         | One CoE III retrospective cohort study found no significant difference in NDI score improvement between treatment groups. |
| ROM preservation                             | Low                  | The CoE II prospective cohort study found significant better ROMs (flexion, extension, and lateral flexion) preservation in laminoplasty group compared with laminectomy and fusion group. |
| Cervical sagittal alignment                   | Insufficient         | One CoE III retrospective cohort study found that there was significant increase in C2–C7 SVA in laminoplasty group. One CoE III retrospective cohort study showed that the postoperative lordosis after laminectomy and fusion was significant larger than laminoplasty. |

Abbreviations: CoE, class of evidence; NDI, Neck Disability Index; OPLL, ossification of posterior longitudinal ligament; ROM, range of motion; SVA, sagittal vertical axis; VAS, visual analog scale.
based upon the available literature, surgeons and patients might consider cost and invasiveness when choosing between the two options. Nonetheless, it is a reflection of the state of the literature, and at minimum, this review can be a springboard for future research to fill in the gaps. Well-designed randomized studies are required to answer this question.

**Conclusion**

The data from four comparative studies is not sufficient to support the superiority of laminoplasty or laminectomy and fusion in treating cervical myelopathy caused by OPLL. The overall strength of evidence to support any conclusion is low or insufficient.

**Disclosures**

Weerasak Singhatanadgige: none
Worawat Limthongkul: none
Frank Valone III: none
Wicharn Yingsakmongkol: none
K. Daniel Riew: Board member (AOSpine International); Editorial board (Global Spine Journal, Spine Journal, Neurosurgery); Grant (AOSpine, Cerapedics, Medtronic); Honorarium (AOSpine, NASS); Royalties (Medtronic, Biomet); Travel expenses (Broadwater)

**Funding**

None

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