Original Article

Global Spine Journal
2022, Vol. 12(8) 1715–1722
© The Author(s) 2021
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/2192568220987535
journals.sagepub.com/home/gsj

Combined Anterior-Posterior Fusion Versus Posterior Alone Fusion for Cervical Myelopathy in Athetoid-Cerebral Palsy

Gang-Un Kim, MD[1], Myun-Whan Ahn, MD[2], and Gun Woo Lee, MD[2]

Abstract

Study Design: Retrospective comparative study.

Objectives: Although some studies have discussed the use of lateral mass screws (LMSs) in patients with cerebral palsy (CP), it is unclear whether posterior LMS fixation alone is a suitable method. We aimed to compare the clinical, radiological, and surgical outcomes of 2 surgical modalities, namely, combined anterior-posterior (A-P) instrumented fusion and posterior fusion alone, in athetoid-type CP patients with cervical myelopathy (CM).

Methods: We analyzed 63 patients with athetoid-CP and CM who underwent posterior fusion only with LMS (group A, 35 patients) and A-P fusion (group B, 28 patients). The primary outcome was the 1- and 3-year fusion rates for the surgical segments. The secondary outcomes included the clinical outcomes based on pain intensity determined using the visual analog scale score, neck disability index, and 17-point Japanese Orthopedic Association score, radiological, and surgical outcomes.

Results: Fusion was achieved at 3 years postoperatively in 22 of 35 patients (63%) in group A and in 26 of 28 patients (93%) in group B ($P = 0.02$). The posterior neck pain intensity was also significantly lower in group B than in group A 2 and 3 years postoperatively ($P = 0.02$ and 0.01, respectively). The incidence of screw loosening and implant-related problems was higher in group A (60%) than in group B (21%) ($P = 0.01$). The other clinical and radiological parameters were similar between the groups.

Conclusions: For athetoid CP-induced CM, combined A-P fusion would result in superior clinical and radiological outcomes compared to posterior fusion alone.

Keywords
cerebral palsy, athetoid type, cervical myelopathy, instrumented fusion, anterior-posterior, posterior alone, outcomes

Introduction

Patients with cerebral palsy (CP), especially those affected by athetoid type-CP, usually present with involuntary movements of the head and neck, with severe degenerative cervical spondylosis.[1-3] When an unexplained change or deterioration of neurological function is noted in patients with CP, cervical myelopathy (CM) should be suspected even at a relatively young age.[4,5] For CP patients with CM, surgical treatment is necessary for adequate decompression of the mechanically compressed spinal neural element.[6,7]

To date, instrumented fusion with sufficient decompression has been considered the gold standard for the surgical treatment of patients with CP-induced CM (CP-CM).[8-12] However, in these patients, the risk of postoperative complications, including nonunion, progression of deformity, bone graft dislodgement, and neurological deterioration, is higher owing to the inherent characteristics of the disease, such as involuntary neck movements, poor bone strength, and insufficient biomechanical stability.[7,13] Consequently, most surgeons agree that strong fixation is essential for the surgical treatment of CP-CM. However, there is no consensus regarding the appropriate surgical modality.[6,14]

[1] Department of Orthopaedic Surgery, Hanil General Hospital, Seoul, Korea
[2] Department of Orthopaedic Surgery, Yeungnam University Medical Center, Yeungnam University College of Medicine, Daegu, South Korea

Corresponding Author:
Gun Woo Lee, Department of Orthopaedic Surgery, Yeungnam University Hospital, Yeungnam University College of Medicine, 170 Hyeonchung-ro, Nam-gu, Daegu 42415, South Korea.
Email: gwlee1871@gmail.com

In this study, we aimed to compare the clinical, radiological, and surgical outcomes of 2 surgical modalities, namely, combined anterior-posterior (A-P) instrumented fusion and posterior fusion alone, in CP-CM patients. To the best of our knowledge, this is the first study comparing the choice of surgical modalities for patients with CP-CM. We hypothesized that the postoperative outcomes following combined anterior-posterior (A-P) instrumented fusion would be superior to those of posterior fusion alone.

Methods

Patients

This retrospective comparative study evaluated the postoperative outcomes among CP-CM patients, following either combined A-P instrumented fusion or posterior lateral mass screw (LMS) fixation and fusion. The study protocol was approved by the institutional review board of the corresponding author's hospital. Between January 2005 and August 2017, 67 patients underwent surgical decompression and fixation for CP-CM. Until July 2013, the preferred treatment for CP-CM was posterior decompression and fusion (group A). However, after July 2013, the preferred treatment was A-P fixation and decompression (group B). According to this timeline, all patients who received surgical treatment for CP-CM between January 2005 and August 2017 were classified into the following 2 groups: combined A-P instrumented fusion and posterior fusion only groups.

Inclusion and Exclusion Criteria

The inclusion criteria were, as follows: (1) CP diagnosed by a pediatric neurologist during infancy; (2) obvious findings of CM on cervical radiographs, corresponding to the myelopathic symptoms and signs detected in the computed tomography (CT) and magnetic resonance imaging (MRI) scans; (3) surgical procedures involving combined A-P instrumented fusion or posterior fusion alone; and (4) follow-up period of $\geq$3 years postoperatively. We excluded patients with (1) history of infection, trauma, or tumors in the cervical spine, (2) concurrent occipito-cervical or C1–2 decompression and fusion procedures for high cervical spine pathologies (above C2 segment), (3) symptomatic disorders of the thoracic or lumbar spine, and (4) follow-up $<$3 years postoperatively.

Surgical Technique and Postoperative Protocol

Two senior spine surgeons determined the surgical segments based on the symptoms and radiologic findings of the patient. For posterior instrumentation and fusion in group A, total laminectomies with LMS fixations (Vertex system, Medtronic Sofamor Danek, Memphis, TN) were performed simultaneously on the affected segments, using matchstick-shaped surgical burrs and a Kerrison punch. For the combined A-P surgery in group B, additional anterior cervical discectomy and fusion with posterior fusion surgery was performed using polyetheretherketone (PEEK) cages (Cornerstone PSR, Medtronic Sofamor Danek) packed with autologous cancelous bone. This procedure was performed as a second stages operation, following posterior instrumentation and fusion.

Following the surgery, the patients could ambulate from the first to the third postoperative days. All patients had to wear a Philadelphia cervical collar for 3 months. At 2 months postoperatively, the patients could gradually resume normal preoperative activities.

Outcome Measures

The primary outcome measure was the rate of fusion for the surgical segments at 1- and 3-year postoperatively. Verification of fusion or nonunion was performed strictly per the following guideline: (1) a difference $<2^\circ$ in the Cobb angles on lateral dynamic flexion and extension radiographs; and (2) the presence of a definitely continuous fusion mass on CT scan imaging. Nonunion of the surgical segment was determined when the difference in Cobb angle was greater than 2°, or when the fusion mass on CT scans was discontinuous.

The secondary outcome measures were the clinical, radiologic, and surgical outcomes for each surgical modality. The intensity of posterior neck pain was measured using a 10-point visual analog scale (VAS) score. The Neck Disability Index (NDI) score was used to measure the functional status. According to Hirabayashi's method, a 17-point Japanese Orthopedic Association (JOA) score was used to measure a severity of CM.[15] Using the JOA score, the recovery rate was calculated as follows: (postoperative score $-$ preoperative score) $\times$ 100 / (17 $-$ preoperative score). The enrolled patients visited the outpatient clinic at 1 month, 6 months, 1 year, 2 years, and 3 years post-surgery. With the aid of a research coordinator, the patients themselves filled the questionnaires. Mechanical complications, such as screw loosening and metal failure, were evaluated via serial cervical spine radiographs and CT images obtained at 1 and 3 years postoperatively. The surgical outcomes, including the duration of the hospital stay, estimated blood loss, and operation time, were also assessed. The questionnaires, chart data, clinical records, and radiographs were analyzed by a surgeon who was not involved in this study.

Statistical Analysis

The paired or Student's *t*-test, Wilcoxon rank test, and analysis of variance (ANOVA) were used for the continuous variables. The Fisher's exact test was used for proportional variables. The GraphPad Prism software (version 7.01 Graph Pad Software, Inc., San Diego, CA) was used for all statistical analyses, and a 2-sided P-value < 0.05 was considered statistically significant. The numerical values were expressed as mean $\pm$ standard deviation (SD).

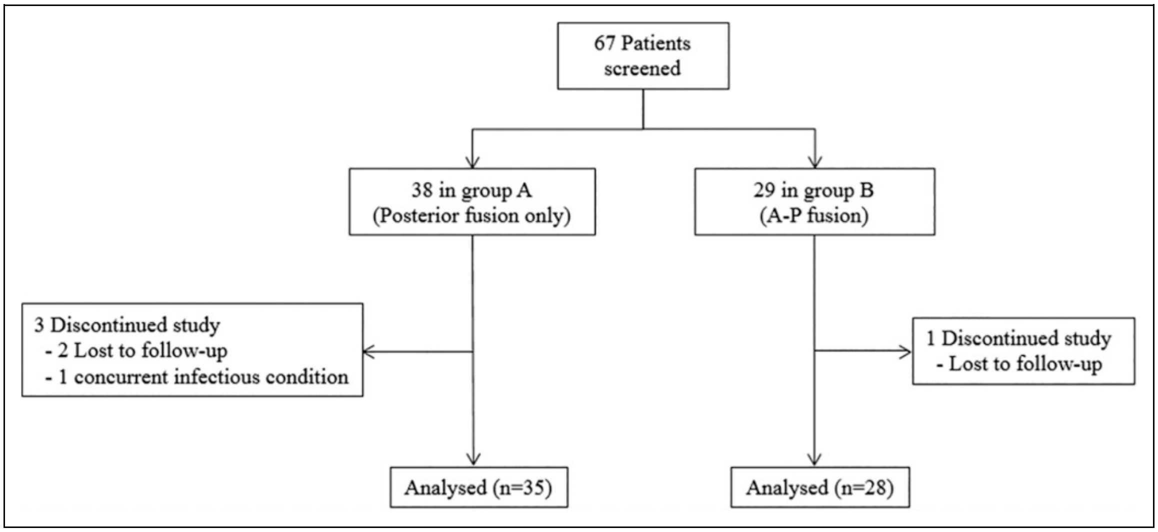

Figure 1. Flow chart showing patient enrollment.

Results

Patient Characteristics

Of the 67 consecutive patients, 63 were enrolled in this study. Of these, 35 patients received only posterior fusion (group A) and 28 patients received the combined A-P instrumented fusion (group B; Figure 1). The demographic characteristics of patients, including age, gender, smoking status, body mass index, preoperative pathology, type of CP, and surgical segments, were similar in both groups. (Table 1).

Primary Outcome Measures

According to the dynamic radiographs and CT images obtained at 1-year postoperatively, fusion was achieved in 19 of 35 (54%) and in 24 of 28 (86%) in groups A and B, respectively. A significant difference was observed in the fusion rates (at 1 year postoperatively) between the 2 groups ($P = 0.01$; Table 2). At 3 years postoperatively, fusion was achieved in 22 of 35 (63%) and 26 of 28 (93%) in groups A and B, respectively. A significant difference was also noted in the fusion rate at 3 years postoperatively between the 2 groups ($P = 0.02$; Table 2)

Secondary Outcome Measures

The preoperative VAS scores for posterior neck pain were 8.1 and 8.6 in groups A and B, respectively ($P = 0.84$). In group A, the mean VAS scores improved to 4.8 4.8, 3.0, 3.5, 4.3, and 5.7 at 1 month, 6 months, 1 year, 2 years, and 3 years postoperatively, respectively. In group B, the mean VAS scores improved to 4.2, 2.9, 3.0, 3.0, and 2.8 at 1 month, 6 months, 1 year, 2 years, and 3 years postoperatively, respectively. At 2 and 3 years postoperatively, significant differences were observed between the 2 groups [$P = 0.02$ (at 2 years), $P = 0.01$ (3 years); Figure 2].

The mean NDI score improved from 45.3 ± 12.6 preoperatively to 18.0 ± 9.8 to 1 year postoperatively in group A and from 44.1 ± 10.7 to 14.2 ± 10.1 at 1 year postoperatively in group B. A significant difference between the 2 groups was observed at only 1 year postoperatively ($P = 0.03$; Figure 3).

The mean JOA score improved from 4.9 ± 3.7 preoperatively to 10.1 ± 3.9 at 3 years postoperatively in group A and from 4.4 ± 4.2 preoperatively to 11.3 ± 4.8 at 3 years

Table 1. Demographic Data.

	Group A (n = 35)	Group B (n = 28)	P
Age (year)	53.7 ± 9.6	51.9 ± 8.3	0.86
Sex (male/female)	14 / 21	11 / 17	0.73
Height (cm)	164.6 ± 13.2	162.1 ± 18.7	0.91
Weight (kg)	53.2 ± 8.1	56.9 ± 9.2	0.72
BMI (kg/m^2)	19.5 ± 4.6	21.2 ± 7.3	0.56
Smoking			0.97
Smoker (%)	4 (11)	5 (18)	
Non-smoker (%)	31 (89)	23 (82)	
Surgical level			0.47
C3-5 (%)	18 (51)	12 (43)	
C3-6 (%)	9	4	
C2-7 (%)	2	3	
C2-T1 or below (%)	6	9	

Values in data cells represent mean ± SD (standard deviation) or number (%).
BMI, Body mass index.

Table 2. Fusion Rate.

Time-point	Fusion outcome	Group A (n = 35)	Group B (n = 28)	P-value
1 year	Fusion	19	24	0.01
	Nonunion	16	4	
	Fusion rate	54%	86%	
3 year	Fusion	22	26	0.02
	Nonunion	13	2	
	Fusion rate	63%	93%	

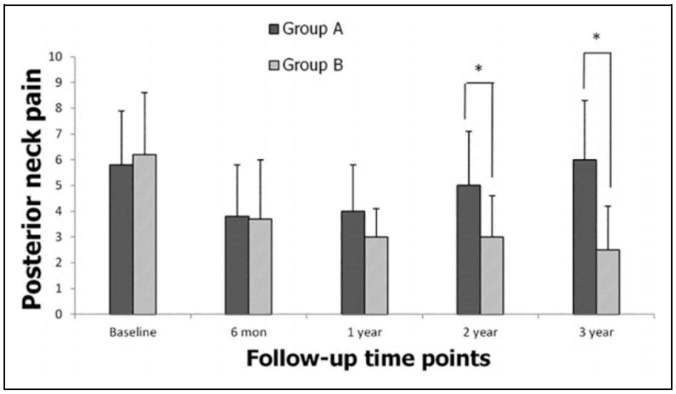

Figure 2. Mean VAS score for posterior neck pain according to the study time-points. The error bars present the standard deviations. * A statistically significant difference was observed between the groups at the follow-up time ($P < 0.05$). VAS, visual analog scale.

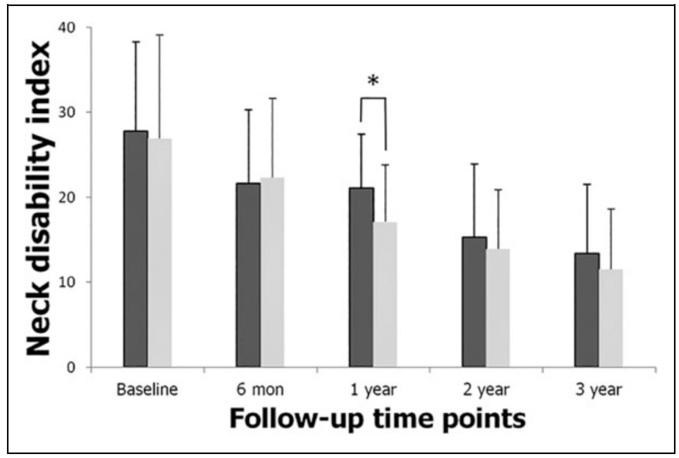

Figure 3. Mean NDI score according to the time points. The error bars present the standard deviations. * A statistically significant difference was observed between the groups at the follow-up time ($P < 0.05$). NDI, neck disability index.

postoperatively in group B. The mean recovery rates of the JOA score at the final follow-up were 41.3 $\pm$ 9.7% and 48.4 $\pm$ 11.3% in groups A and B, respectively. No significant differences were noted in the mean recovery rate of the JOA score between the groups ($P = 0.47$).

For radiologic outcomes, the authors focused on the incidence of metal-related complications, such as screw loosening, rod fracture, and other failures. A significant difference was observed between the 2 groups ($P = 0.01$), with screw loosening observed in 60% of the patients (21/35) in group A and in 21% of the patients (6/28) in group B (Figures 4 and 5). Complications associated with other failure did not develop in the patients.

Improvements in the surgical outcomes, including the estimated operative time, estimated blood loss, and duration of hospital stay, were observed in group A. However, group B showed longer surgical time, higher blood loss, and longer duration of hospital stay because the additional anterior surgical procedure was performed. However, no significant difference with respect to the postoperative complications associated with the surgical procedures was observed between the groups. The overall complication rates during surgery or follow-up were similar between the groups. Nevertheless, 1 patient in group A developed a superficial infection that was treated with debridement and additional medication.

Discussion

We investigated and compared the 3-year postoperative outcomes of 2 surgical methods, namely, combined A-P fusion and posterior only fusion, for patients with CP-CM. To the best of our knowledge, this is the first study to compare the postoperative 3-year surgical outcomes of CP-CM (A-P fusion vs. posterior fusion alone). The results of this study indicate that improved clinical and radiological outcomes for CP-CM, may be achieved via combined A-P fusion surgery. The clinical and radiological outcomes achieved via posterior fusion alone for athetoid CP were inferior to those achieved via combined A-P surgery. Statistically significant differences were observed in fusion rates, posterior neck pain intensity, and radiologic outcomes between patients who underwent combined A-P fusion surgery and those who underwent posterior fusion alone. Furthermore, patients with posterior-only constructs displayed a higher risk of clinical and radiological deterioration and subsequent revision surgery.

Cervical disorders such as myelopathy or radiculopathy in patients with CP are caused by an accelerated degenerative process resulting from the excessive involuntary movement that occurs due to an imbalance in the cervical muscle tone. This accelerated degeneration further contributes to early deformation in the structure and alignment of the cervical spine, and the compression of neural elements via severe spondylosis-related changes. Consequently, these conditions, including involuntary neck movements, severe cervical spinal deformity, and intervertebral instability, may negatively affect postoperative outcomes. Therefore, to stabilize the cervical spine in patients with CP, an extremely rigid fixation is necessary.

Dahdaleh et al., in their cadaveric biomechanical load study, observed no significant difference in posterior instrumentation (C3-C7 LMS) versus posterior and anterior instrumentation.[16] Moreover, Hua et al. reported that posterior LMS fixation with laminoplasty was effective for patients with athetoid CP with cervical spinal canal stenosis.[17] However, in our study, posterior-only fixation for patients with athetoid CP resulted in inferior postoperative outcomes. In addition, a gradual deterioration of the outcomes was observed during the follow-up period of postoperative 3 years. It has been well established that LMS fixation for the cervical spine provide rigid fixation, high fusion rates, and fewer complications.[18] More so, several modifications of the LMS technique have improved its safety and biomechanical stability.[19,20] Despite reports that describe the application of LMS in CP patients,[17] and considering their

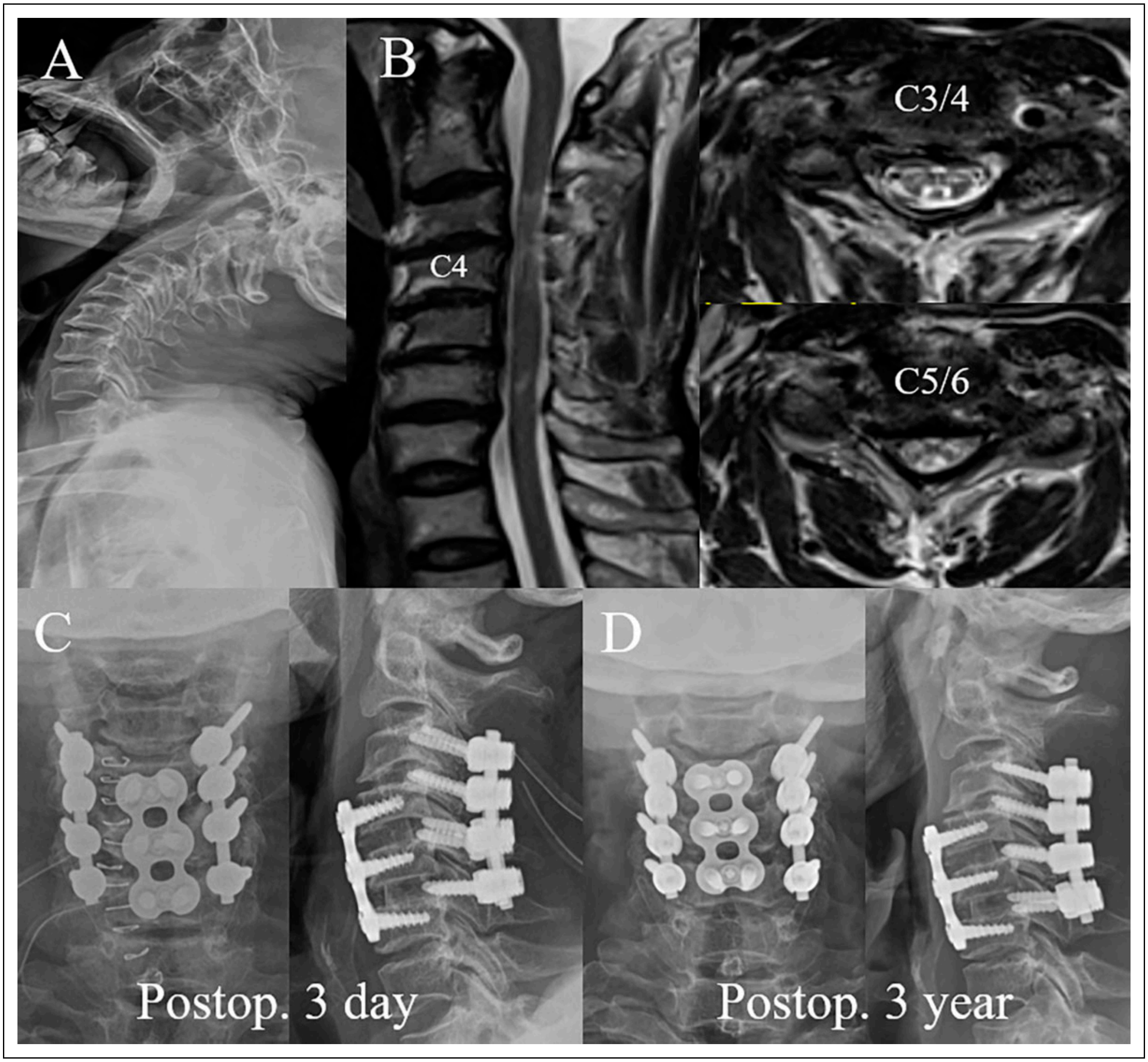

Figure 4. A case of solid union in group B (combined A-P fusion). (A and B) A 53-year-old man with athetoid-type CP presented with severe hand clumsiness with arm pain. Simple radiographs and MRI scans of the cervical spine show spinal canal stenosis with signal change of the spinal cord at C3-6 levels. (C) Cervical spine radiographs obtained at 3 days postoperatively show that combined A-P fusion was performed. (D) Cervical spine radiographs obtained at 3 years postoperatively show that complete fusion is achieved. A-P, anterior-posterior; CP, cerebral palsy; MRI, magnetic resonance imaging.

involuntary neck movements, it is uncertain whether solitary LMS fixation is a suitable method. Alternatively, some researchers have used cervical pedicle screw constructs as a strong anchor.[14,21] Cervical pedicle screw constructs are regarded as the most secure fixation method,[21] and posterior fixation with pedicle screw methods has been reported to be effective for CP-CM. However, due to a higher risk of critical screw breach associated with frequent pedicle sclerosis, a wide transverse angle, and lateral mass deformity.[13,22] caution must be exercised while performing cervical pedicle screw placement for CP-CM patients. Several reports indicate that the pedicle perforation rate ranges between 6.7% and 30%.[23-26] Additionally, Uehara et al. reported that the rate of cervical pedicle screw perforation among CP patients, was higher than that of other conditions such as rheumatoid arthritis or degenerative spondyloarthropathy.[27] For CP-CM patients, the A-P construct could correct kypho-scoliotic deformities effectively and safely via proper restoration of the intervertebral height. Kim et al.[7] mentioned that if a patient suffers from a preexisting kyphotic deformity, or

Figure 5. A case of nonunion and metal failure in group A (posterior fusion only). (A) A 41-year-old woman with athetoid-type CP presented with gradually progressive hand clumsiness and arm weakness. Based on the radiograph and MRI findings of the cervical spine, she was diagnosed with CM in athetoid-type CP. (B) C3-5 laminectomy and posterior fusion surgery was performed; however, she complained of aggravated posterior neck pain. Radiographs and CT scans obtained at 1.5 years postoperatively show nonunion and metal failure with progressive kyphosis. (C) Revision A-P fusion surgery was performed 2 years after the initial surgery. At 2 years after the revision surgery, solid fusion was achieved. A-P, anterior-posterior; CM, cervical myelopathy, CP, cerebral palsy; CT, computed tomography; MRI, magnetic resonance imaging.

requires multiple-level surgery, combined A-P rigid fixation and fusion is the preferred surgical technique for stability.

There are several limitations of the present study. First, this was a retrospective and single-center study. In addition, the 2 groups were classified with a reference of the specific time-point for changing the surgical techniques, from posterior only fusion to A-P fusion. Although the 2 groups did not differ significantly in baseline date, the point can be associated with sampling bias. Second, for patients in group A, the laminectomy defect was associated with a relatively insufficient fusion bed for the bone graft. This may have influenced the relatively lower fusion rates and poorer outcomes for patients who underwent posterior fusion alone. Finally, this study had a relatively short follow-up period of 3 years postoperatively.

Conclusions

This 3-year follow-up study revealed that combined A-P fusion for patients with athetoid CP-CM resulted in superior clinical and radiological outcomes compared to posterior fusion alone. However, in order to establish the long-term benefits of combined A-P surgery for CP-CM patients, further research is required with a larger sample size, an extended follow-up period, and a prospective randomized study design.

Acknowledgments

This retrospective study was approved by the Institutional Review Board of the Yeungnam University Medical Center (IRB file no. YUMC 2019-06-055), and informed written consent from each patient was exempted in accordance with study protocol approved by the research ethics board.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This study is supported by AO Spine Research Grant 2019 (AOSKR(R)2019-02).

ORCID iD

Gang-Un Kim, MD https://orcid.org/0000-0001-9772-4977
Gun Woo Lee, MD https://orcid.org/0000-0002-8441-0802

References

1. Duruflé A, Pétrilli S, Le Guiet JL, et al. Cervical spondylotic myelopathy in athetoid cerebral palsy patients: about five cases. *Joint Bone Spine*. 2005;72(3):270-274.
2. Singh K, Samartzis D, Somera AL, An HS. Cervical kyphosis and thoracic lordoscoliosis in a patient with cerebral palsy. *Orthopedics*. 2008;31(3):276.
3. Harada T, Ebara S, Anwar MM, et al. The cervical spine in athetoid cerebral palsy. A radiological study of 180 patients. *J Bone Joint Surg Br*. 1996;78(4):613-619.
4. Lee YJ, Chung DS, Kim JT, Bong HJ, Han YM, Park YS. Surgical treatments for cervical spondylotic myelopathy associated with athetoid cerebral palsy. *J Korean Neurosurg Soc*. 2008;43(6): 294-299.
5. Wong AS, Massicotte EM, Fehlings MG. Surgical treatment of cervical myeloradiculopathy associated with movement disorders: indications, technique, and clinical outcome. *J Spinal Disord Tech*. 2005;18(Suppl):S107-114.
6. Jameson R, Rech C, Garreau de Loubresse C. Cervical myelopathy in athetoid and dystonic cerebral palsy: retrospective study and literature review. *Eur Spine J*. 2010;19(5): 706-712.
7. Kim KN, Ahn PG, Ryu MJ, et al. Long-term surgical outcomes of cervical myelopathy with athetoid cerebral palsy. *Eur Spine J*. 2014;23(7):1464-1471.
8. Epstein NE. Circumferential cervical surgery for spondylostenosis with kyphosis in two patients with athetoid cerebral palsy. *Surg Neurol*. 1999;52(4):339-344.
9. Haro H, Komori H, Okawa A, Shinomiya K. Surgical treatment of cervical spondylotic myelopathy associated with athetoid cerebral palsy. *J Orthop Sci*. 2002;7(6):629-636.
10. Cheung JPY, Cheung PWH, Chiu CK, Chan CYW, Kwan MK. Variations in practice among Asia-Pacific surgeons and recommendations for managing cervical myelopathy: the first Asia-Pacific Spine Society Collaborative study. *Asian Spine J*. 2019; 13(1):45-55.
11. Onari K. Surgical treatment for cervical spondylotic myelopathy associated with athetoid cerebral palsy. *J Orthop Sci*. 2000;5(5): 439-448.
12. Onari K, Kondo S, Mihara H, Iwamura Y. Combined anterior-posterior fusion for cervical spondylotic myelopathy in patients with athetoid cerebral palsy. *J Neurosurg*. 2002;97(1 suppl): 13-19.
13. Watanabe K, Hirano T, Katsumi K, et al. Surgical outcomes of posterior spinal fusion alone using cervical pedicle screw constructs for cervical disorders associated with athetoid cerebral palsy. *Spine*. 2017;42(24):1835-1843.
14. Watanabe K, Otani K, Nikaido T, et al. Surgical outcomes of cervical myelopathy in patients with athetoid cerebral palsy: a 5-year follow-up. *Asian Spine J*. 2017;11(6): 928-934.
15. Hirabayashi K, Miyakawa J, Satomi K, Maruyama T, Wakano K. Operative results and postoperative progression of ossification among patients with ossification of cervical posterior longitudinal ligament. *Spine*. 1981;6(4):354-364.
16. Dahdaleh NS, Nakamura S, Torner JC, Lim TH, Hitchon PW. Biomechanical rigidity of cadaveric cervical spine with posterior versus combined posterior and anterior instrumentation. *J Neurosurg Spine*. 2009;10(2):133-138.
17. Zhou H, Liu ZJ, Wang SB, et al. Laminoplasty with lateral mass screw fixation for cervical spondylotic myelopathy in patients with athetoid cerebral palsy: a retrospective study. *Medicine (Baltimore)*. 2016;95(39):e5033.
18. Aydogan M, Enercan M, Hamzaoglu A, Alanay A. Reconstruction of the subaxial cervical spine using lateral mass and facet screw instrumentation. *Spine*. 2012;37(5):E335-341.
19. Heller JG, Carlson GD, Abitbol JJ, Garfin SR. Anatomic comparison of the Roy-Camille and Magerl techniques for screw placement in the lower cervical spine. *Spine*. 1991;16(10 suppl): S552-557.
20. Seybold EA, Baker JA, Criscitiello AA, Ordway NR, PArk CK, Connolly PJ. Characteristics of unicortical and bicortical lateral mass screws in the cervical spine. *Spine*. 1999;24(22): 2397-2403.

21. Demura S, Murakami H, Kawahara N, Kato S, Yoshioka K, Tsuchiya H. Laminoplasty and pedicle screw fixation for cervical myelopathy associated with athetoid cerebral palsy: minimum 5-year follow-up. *Spine*. 2013;38(20):1764-1769.
22. Kato S, Shoda N, Chikuda H, Seichi A, Takeshita K. Morphological characteristics of cervical spine in patients with athetoid cerebral palsy and the accuracy of pedicle screw placement. *Spine*. 2014;39(8):E508-513.
23. Abumi K, Shono Y, Ito M, Taneichi H, Kotani Y, Kaneda K. Complications of pedicle screw fixation in reconstructive surgery of the cervical spine. *Spine*. 2000;25(8):962-969.
24. Kast E, Mohr K, Richter HP, Börm W. Complications of transpedicular screw fixation in the cervical spine. *Eur Spine J*. 2006;15(3):327-334.
25. Sonone S, Dahapute AA, Waghchoure C, et al. Anatomic consideration of anterior transartiular screw fixation for atlantoaxial instability. *Asian Spine J*. 2019;13(11):890-894.
26. Gadia A, Shah J, Nene A. Cervical kyphosis. *Asian Spine J*. 2019;13(1):163-172.
27. Uehara M, Takahashi J, Hirabayashi H, et al. Perforation rates of cervical pedicle screw insertion by disease and vertebral level. *Open Orthop J*. 2010;4:142-146.