Surgical Outcomes and Complications Following All Posterior Approach for Spinal Deformity Associated with Neurofibromatosis Type-1

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Objectives: The purpose of this study was to evaluate surgical outcomes and complications of spinal deformity associated with neurofibromatosis type-1 (NF-1).

Methods: From 2012 to 2018, patients suffering from spinal deformity associated with NF-1 who underwent surgical correction were identified. Demographic data and radiographic measures were retrospectively reviewed. Pre- and postoperative whole spine radiograph images were used to determine both coronal and sagittal Cobb angles. All of patients underwent 3-dimentional computed tomographic scan and magnetic resonance imaging scan to confirm dystrophic features. For evaluation of clinical outcomes, we surveyed the pre- and postoperative scoliosis research society-22r (SRS-22r) score.

Results: Seven patients with spinal deformity associated with NF-1 were enrolled in this study. The mean age of patients was 29.5±1.2 years old. The mean follow-up period was 2.8±1.4 years. The apex of the deformity was located in cervicothoracic (n=1), thoracic (n=4), and lumbar region (n=2). Most patients have poor bone quality and decreased bone mineral density with average T-score of -3.5±1.0. All patients underwent surgical correction via posterior approach. The pre- and postoperative mean coronal and sagittal Cobb angle was 61.6±22.6° and 34.6±38.1°, 56.8±18.5° and 40.2±9.1°, respectively. Mean correction rate of coronal and sagittal angle was 44.7% and 23.1%. Ultimate follow-up SRS-22r score (average score, 3.9±0.4) improved comparing to preoperative score (average score, 3.3±0.9). Only one patient received revision surgery due to rod fracture. No serious complication occurred, such as neurological deficit, and viscerovascular injury.

Conclusion: The surgical correction of patients having spinal deformity associated with NF-1 is challenging, however the radiographic and clinical outcomes are satisfactory. The all posterior approach can be a safe and effective surgical option for patients having dystrophic curves associated with NF-1.

Key Words: Neurofibromatosis 1 · Scoliosis · Kyphosis · Surgical procedures · Complication · Instrumentation.

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INTRODUCTION

Neurofibromatosis type-1 (NF-1), von Recklinghausen disease, peripheral neurofibromatosis is a rare autosomal dominant hereditary disorder. This disease is characterized by multiple cutaneous neurofibromas, multiple café-au-lait macules, axillary and inguinal freckle, iris Lisch, and choroidal freckling. About 50% of patients with NF-1 have orthopedic disorders. Orthopedic complications appear as either focal or generalized features. Focal orthopedic complications include long bone or sphenoid wing dysplasia, chest wall deformity and short segmented scoliosis. Generalized feature include short stature, larger head circumference, and decreased bone mineral density (BMD). Most common skeletal manifestation is spinal deformity. Scoliosis of NF-1 patients is accounted about 3% of all scoliosis cases. Usually, Scoliosis associated with NF-1 is classified into nondystrophic and dystrophic type.

Clinical radiographic findings and treatment of nondystrophic type are very similar to those of idiopathic scoliosis. Furthermore, NF-1 patients with nondystrophic type scoliosis appear earlier in life than idiopathic scoliosis. And they have a worse prognosis and more complications after correction surgery such as pseudarthrosis or fusion failure. Typical features of Dystrophic type scoliosis include wedging of vertebral body, vertebral scalloping, spindling of transverse process, rib penciling, paraspinal or intraspinal soft tissue mass, dural ectasia and sharp angular curves. Previous researcher reported that 3 or more dystrophic features is highly predictive of curve progression and the need for surgery.

Occasionally deformity correction surgery is required due to curve progression or severe spinal deformation in NF-1 patients with spinal deformity. The surgical correction of patients having spinal deformity associated with NF-1 is challenging. The purpose of this study was to evaluate surgical outcomes and complications of spinal deformity associated with NF-1.

MATERIALS AND METHODS

This study was obtained approval of the Ethics Committee and Institutional Review Board of Seoul National University Bundang Hospital before initiation of the study (IRB No. B-1910-572-105). We reviewed scoliosis patients who meet diagnostic criteria of NF-1 from 2012 to 2018. A diagnosis of NF-1 was based on the criteria showed in Table 1. Among them, patients who underwent surgical correction were identified. Demographic data and radiographic measures were retrospectively reviewed. In addition, the demographic characteristic of patients including age, sex, follow-up period, history of previous surgeries was collected and recorded.

| Table 1. Diagnostic criteria defined by the 1987 Consensus Development Conference of National Institutes of Health for the diagnosis of neurofibromatosis. Two or more criteria present confirm the diagnosis of NF-1 |
| --- |
| Diagnostic criteria for NF-1 |
| Six or more café-au-lait macules >5 mm in greatest diameter in pre-pubertal individuals and >15 mm in greatest diameter in post-pubertal individuals |
| Two or more neurofibromas of any or more than one plexiform neurofibroma |
| Freckling in the axillary or inguinal regions |
| Optic glioma |
| Two or more Lisch nodules (iris hamartomas) by slit lamp examination |
| A distinctive osseous lesion, such as sphenoid dysplasia or thinning of a long bone cortex, with or without pseudarthrosis |
| A first-degree relative (parent, sibling, or offspring) |
| NF-1 : neurofibromatosis type-1 |

| Table 2. Typical dysplastic change evident on plain radiographs in patients with NF-1 |
| --- |
| Dysplastic change |
| Vertebral scalloping (considered to be present when the depth of scalloping is more than three millimeters in the thoracic spine or more than four millimeters in the lumbar spine)- this is either associated with dural ectasia or neural tumour |
| Rib pencilling (considered to be present when the width of the rib was smaller than that of the narrowest portion of the second rib) |
| Transverse process spindling |
| Vertebral wedging |
| Paravertebral soft tissue mass |
| Short curve with severe apical rotation |
| Intervertebral foraminal enlargement |
| Widened interpedicular distances |
| Dysplastic pedicles |
| NF-1 : neurofibromatosis type-1 |
Whole spine radiograph images were reviewed pre-, postoperatively and at 1 year. Those were used to determine coronal and sagittal Cobb angles. The radiographic review for all patients was performed by a spine surgeon who did not involve in this surgical series. All of patients underwent 3-dimensional (3D) computed tomographic (CT) scan to investigate fusion segment, to assess pedicle deformity and bony fusion after surgery. 3D CT was used to confirm bony dystrophic features. The fusion rates were confirmed on CT image at 1 year postoperatively. We also consider loss of correction of 10° or more as nonunion or pseudarthrosis.

Magnetic resonance imaging also was performed in all patients to confirm dystrophic features such as paraspinal or intraspinal soft tissue mass, dural ectasia and spinal cord compromise (Table 2). To assess preoperative bone quality, BMD by dual-energy X-ray absorptiometry (DEXA) was taken.

For evaluation of clinical outcome, we surveyed the pre- and postoperative scoliosis research society-22r (SRS-22r) score to evaluate pain, function, body image, mental health and satisfaction of patients underwent correction surgery. Surgical details, including approach, levels of the procedure and osteotomy type were examined.

**RESULTS**

Seven patients with spinal deformity associated with NF-1 were enrolled in this study. The surgeries were performed via all posterior approach by a single spine neurosurgeon under intraoperative neurophysiologic monitoring. Patients having prior spinal fusion surgeries were excluded. There were four female and three male patients. The mean age at surgery was 27.7±1.2 years old (range, 16–56). The mean follow-up period was 2.8±1.4 years with a minimum 1.5-year follow-up (Table 3).

| Case | Sex | Age (years) | F/U years | Fusion level | BMD T-score | Osteotomy type |
|------|-----|-------------|-----------|--------------|-------------|----------------|
| 1    | F   | 54          | 2         | T9-pelvis    | -5.4        | PCO            |
| 2    | M   | 16          | 5         | T3-L1        | -2.8        | PCO            |
| 3    | F   | 17          | 5         | T4-L3        | -3.3        | PCO            |
| 4    | M   | 35          | 2         | T10-pelvis   | -4.0        | PCO            |
| 5    | M   | 24          | 2         | T10-pelvis   | -2.5        | PCO            |
| 6    | F   | 31          | 2         | T8-L1        | -4.0        | -              |
| 7    | F   | 17          | 1.5       | C2-pelvis    | -4.0        | PCO            |
| Average | | 27.7±1.2 | 2.8±1.4 | 11.1±5.9 | -3.5±1.0 |

F/U : follow-up, BMD : bone mineral density, F : female, PCO : posterior column osteotomy, M : male

| Case | Penciling of ribs | Scallopine of vertebrae | Spindling of the transverse processes | Foraminal enlargement | Severe rotation of vertebrae | Adjacent soft tissue tumor |
|------|-------------------|-------------------------|--------------------------------------|-----------------------|-----------------------------|---------------------------|
| 1    | 0                 | 3                       | 3                                    | 3                     | 0                           | No                        |
| 2    | 3                 | 2                       | 3                                    | 0                     | 3                           | Yes                       |
| 3    | 4                 | 3                       | 4                                    | 3                     | 3                           | Yes                       |
| 4    | 0                 | 4                       | 4                                    | 3                     | 0                           | No                        |
| 5    | 0                 | 3                       | 3                                    | 0                     | 0                           | No                        |
| 6    | 4                 | 4                       | 4                                    | 4                     | 4                           | No                        |
| 7    | 0                 | 8                       | 8                                    | 6                     | 4                           | No                        |
| Average | 1.5             | 3.8                     | 3.7                                  | 2.7                   | 2.0                         | -                         |

The numbers indicate the prevalence of signs in each case.
All patients presented with two or more dystrophic features showed in Table 4 including scalloping of vertebrae and wedging of apical vertebrae. Seven dystrophic curvatures consisted of three thoracic scoliosis, two lumbar scoliosis, one thoracic kyphoscoliosis, one cervicothoracic scoliosis. The kyphoscoliosis means that the degree of kyphosis exceeds 50°. Six patients had one staged procedure by all posterior correction and instrumentation. One patient underwent two staged procedures by anterior release followed by posterior correction and instrumentation.

The preoperative mean coronal Cobb angle and sagittal Cobb angle was 61.6±22.6° and 56.8±18.5°. The postoperative mean coronal Cobb angle and sagittal Cobb angle was 34.6±38.1° and 40.2±9.1°. Mean coronal and sagittal correction rate was 44.7±26.9% and 23.1±20.0% (Table 5). Most patients have poor bone quality with average T-score of -3.5±1.0. At 1 year after surgery, 85.7% (six of seven) of patients had achieved solid bone fusion. Ultimate follow-up SRS-22r scores (average score, 3.9±0.4) improved comparing to preoperative SRS-22r score (average score, 3.3±0.9) (Fig. 1).

In our series, there were one case of pseudarthrosis (rod fracture) and one case of radiographic loss of correction without clinical symptoms. Only one patient required revision surgery due to symptomatic rod breakage at the lumbosacral area. No serious complication occurred, such as neurologic deficit, viscerovascular injury and deep wound infection.

### Table 5. Pre- and postoperative radiologic data

| Case | Preop. coronal Cobb angle (°) | Postop. coronal Cobb angle (°) | Correction rate (%) | Preop. sagittal Cobb angle (°) | Postop. sagittal Cobb angle (°) | Correction rate (%) |
|------|-----------------------------|------------------------------|---------------------|-------------------------------|-------------------------------|---------------------|
| 1    | 54.9                        | 28.6                         | 47.9                | 14.0                          | 11.1                          | 21.0                |
| 2    | 74.5                        | 26.9                         | 63.8                | 23.2                          | 13.9                          | 40.0                |
| 3    | 51.8                        | 13.8                         | 73.3                | 63.7                          | 26.6                          | 58.2                |
| 4    | 90.3                        | 68.5                         | 24.1                | 40.0                          | 37.8                          | 5.0                 |
| 5    | 24.0                        | 13.4                         | 44.1                | 63.6                          | 37.8                          | 0.7                 |
| 6    | 51.2                        | 43.2                         | 16.2                | 187.7                         | 147.7                         | 21.3                |
| 7    | 85.0                        | 48.0                         | 43.5                | 6.0                           | 7.0                           | 16.0                |
| Mean | 61.6±22.6                   | 34.6±38.1                    | 44.7±26.9           | 56.8±18.5                     | 40.2±9.1                      | 23.1±20.0           |

Preop. : preoperative, Postop. : postoperative

![Fig. 1. Pre- and postoperative mean SRS-22r-score of all patients. Preop. : preoperative, Postop. : postoperative, SRS-22r : scoliosis research society-22r.](image-url)
DISCUSSION

In this study, total seven patients with spinal deformity associated with NF-1 were surgically treated by all posterior approach (Fig. 2). The clinical and operative details from previous studies are shown in Table 6. Previous researchers recommended corpectomy and combined circumferential fusion to treat or correct dystrophic scoliosis in NF-1 patients. Halmai et al. reported a series of 12 patients who underwent 3-week preoperative traction and then anterior release, posterior instrumentation and fusion were performed. In these patients, the mean scoliosis correction rate was 66%. There were one neurologic deficit and one pseudarthrosis. Koptan and ElMiligui reported a series of 32 patients who underwent anterior release followed by posterior hybrid instrumentation augmented by sublaminar wires. The correction rate was 61.8% and 61% for scoliotic and kyphotic curves, respectively. Two patients had superficial infection and two patients had a definite pseudarthrosis. Furthermore, one patient experienced a transient weakness in the left lower limb for 3 months. Another investigator reported a series of 16 patients who had undergone anterior and posterior combined fusion. Surgery improved the mean preoperative scoliosis of 87° (range, 60°–110°) and local kyphosis of 69.3° (range, 50°–100°) to 49° (range, 15°–85°) and 49° (range, 35°–70°), respectively. There were no neurological or wound complications. However, one individual died in the recovery room because of sudden cardiorespiratory arrest apparently from a transfusion. Intraoperative blood loss of 20–25% of the

Fig. 2. Preoperative (A) and postoperative (B) plain radiographs of a 17-year old female patient (case No. 7).

Table 6. Clinical and operative details in the literatures of NF-1 deformity or scoliosis

| Study                        | Country       | No. of cases | Age in years | F/U years | Complications          | Surgical approach                        |
|------------------------------|---------------|--------------|--------------|-----------|------------------------|------------------------------------------|
| Halmai et al. (2002)         | Hungary       | 12           | 17.5         | 4.4       | One neurologic deficit | Anterior release and posterior            |
| Shahcheraghi and Tavakoli (2010) | Iran        | 9            | 11.8         | 6.7       | Two surgical site infection | Instrumentation and fusion               |
| Koptan and ElMiligui (2010)  | Egypt         | 32           | 14           | 6.5       | One death              | Anterior release and posterior            |
| Wang et al. (2015)           | China         | 16           | 13           | 3.4       | One neurologic deficit | Posterior instrumentation and fusion      |
| Deng et al. (2017)           | China         | 31           | 13.5         | 4.4       | One pseudarthrosis      | Posterior instrumentation and fusion      |

NF-1: neurofibromatosis type-1, F/U: follow-up
Correction for Spinal Deformity in NF-1 | Park BJ, et al.

Correction for Spinal Deformity in NF-1 | Park BJ, et al.

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Total blood volume (including one mortality case) was observed, mainly during the anterior approach.

In recent studies, there are several reports regarding posterior approach to correct spinal deformity associated with NF-1. The authors suggested that posterior approach is safe and effective method. Wang et al.31 reported a series of 16 patients who underwent one-stage posterior surgery with pedicle screw system. Mean scoliosis and kyphosis improved from 83.2° to 27.6° and 58.5° to 26.8°, respectively. They found no pseudarthrosis or nonunion during follow-up. However, one patient exhibited lower extremity weakness defined as grade 1 muscle strength after surgery. After revision decompression surgery and regular rehabilitation exercises, the patient eventually recovered grade 4 lower extremity muscle strength within 3 months. Another investigator reported a series of 31 patients who underwent posterior only surgical correction using a multiple anchor point method30. The mean postoperative correction rate was 58.7% (range, 46.3–74.1%). Only one patient presented with hook dislodgments because of pseudarthrosis, which required revision surgery. In these two series, the focus is primarily on surgical correction rather than complications that can be caused by the posterior approach. However, in our series, we discussed on how to prevent surgery-related complications how to achieve solid bony fusion and how to satisfy the patients’ needs. Recently, national trends in spinal fusion surgery for neurofibromatosis in the United States were reported15. The authors analysed 548 patients with a diagnosis of NF-1 who had received spinal fusion surgery between 2003 and 2014. The rate of posterior spinal fusion (PSF) surgeries increased 2.9-fold, whereas the rate of anterior-posterior spinal fusion (APSF) surgeries decreased 2.2-fold. Compared with patients undergoing PSF and anterior spinal fusion, patients undergoing APSF were significantly younger and had significantly higher hospitalization lengths and costs. It is in line with the fact that APSF is an extensive multistage procedure.

For these reasons such as the insufficient anterior bony structure due to dystrophic changes, a high grade of risk of dura injury, and vessel injury, we performed only posterior approach in this series with an acceptable outcome. Moreover, there were no serious complications occurred in the current cohort.

The instrumentation and correction of the deformed curves is not easy due to dystrophic vertebral deformity, pedicle dysplasia and osteoporosis. In addition, in dystrophic scoliosis, very careful exposure is required during surgery due to very thin lamina, and very careful decortication for fusion is needed due to spinal canal injury.

In our series, the preoperative mean coronal Cobb angle and sagittal Cobb angle was 61.6±22.6° and 56.8±18.5°. The postoperative mean coronal Cobb angle and sagittal Cobb angle was 34.6±38.1° and 40.2±9.1°. Mean coronal and sagittal correction rate was 44.7±26.9% and 23.1±20.0%. At 1-year follow-up evaluation, the mean loss of coronal and sagittal correction rate was 2.3% and 2.4%, respectively.

In our series, a patient underwent revision surgery due to

Fig. 3. A and B : Follow-up plain radiographs after initial surgery showing rod fracture (red arrow) above side connector of iliac screw on the right side. C : Postoperative plain radiograph after revision surgery using multiple rod construct by 4-Cobalt Chrome rods. D : Two-year follow-up plain radiograph of a 24-year old male patient (case No. 5).
Symptomatic pseudarthrosis with rod fracture (Fig. 3). We revised him using multiple rod construct (multi-RC) and additional posterolateral fusion. Previous broken rod on the right side was replaced by multi-RC using cobalt chrome (CoCr) rod. Patients with conventional 2-rod constructs (2-RC) had a statistically greater incidence of lumbosacral pseudarthrosis than those with multi-rod constructs in adult spinal deformity surgery. In addition, in another study, there were significant differences in the occurrence of rod breakage and revision surgery for pseudarthrosis at the 3-column osteotomy site (rod breakage, 2-RC: 11 vs. multi-RC: 2, p=0.002; and revision, 2-RC: 6 vs. multi-RC: 0, p=0.011). Thus, the use of a multi-RC is an effective method to provide increased stability to prevent implant failure and symptomatic pseudarthrosis versus a standard 2-RC. It is known to be important that biomechanical properties are dependent on the material of rod. CoCr rod has in recent years been introduced for major spinal deformity surgery, which is characterized by a very high mechanical stiffness.

In several previous studies, a major difficulty encountered in NF-1 patients is the poor bone stock and remarkable osteoporosis which can result in metal failure, hook dislodgement and consequent loss of correction. Furthermore, previous researchers reported that dural ectasia can cause vertebral scalloping and weaken the fixation of the implants which makes loosening of the hooks and loss of correction. In the case No. 1 patient, there were no occurrence of proximal junctional kyphosis or proximal junctional failure after surgery (Fig. 4). However, the trunk shift to the left side progressed on the 2-year follow-up radiograph due to loss of correction comparing to the immediate postoperative radiographs. Her pre-/postoperative and 2-year follow-up difference between the vertical trunk reference line (VTRL) and the center sacral vertical line (CSVL) was 50.1 mm, 16.6 mm, and 26.3 mm, respectively. According to a previous study, trunk shift was defined as a greater than 2 cm difference between VTRL and CSVL. They insisted that coronal imbalance does not correlate with trunk shift and undercorrection of the lumbar curve predisposing to the development of postoperative trunk shift.

In previous studies, most NF-1 patients have significant low BMD because of defect of bone metabolism. In our series, average T-score of BMD was -3.5±1.0. Five of seven patients had osteoporosis and two patients had osteopenia. Because of the osteoporotic condition in NF-1 patient, the pseudarthrosis rates of patients undergoing surgery have been reported to rise to 60%. Thus, we used several strategies to increase fusion rates in these patients. During surgery, adequate autologous and allogenic bone mixture were used for fusion with meticulously preparing the fusion bed to be decorticated and free.
from soft tissue. Furthermore, multiple iliac screws, Wisconsin wires, and multiple-RC technique were utilized to achieve solid bony fusion. These surgical methods may overcome the poor bone quality and compensate for the lack of fixation points caused by pedicle dysplasia. As a result, in our series, 85.7% (six of seven) of patients had achieved solid bony fusion on the 1-year follow-up radiographic images.

Finally, we surveyed the pre- and postoperative SRS-22r score to evaluate a satisfaction of all patients underwent correction surgery. Final average SRS-22r score of the patients shows significantly improved than preoperative average score. Considering dystrophic scoliosis in NF-1 patients, we did not focus on the degree of correction in this series. The main purpose of surgery was to prevent progression of deformity, to stabilize the deformed spine and to satisfy the patients’ needs.

The limitation of the study is the small number of cases. However, severe spinal deformity associated with NF-1 is a very rare disease entity and the surgical strategy was quite complicated, which is hard to be compared to adolescent idiopathic scoliosis.

CONCLUSION

The surgical correction of patients having spinal deformity associated with NF-1 is challenging, however, the radiographic and clinical outcomes are satisfactory. All posterior approach can be safe and effective surgical option for patients having dystrophic curves associated with NF-1. The main purpose of this kind of surgery should be focused on stabilizing the deformed spine and stopping the progression of the deformities rather than attempting excessive correction.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

INFORMED CONSENT

This type of study does not require informed consent.

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