Surgical Treatment of Osteoporotic Vertebral Fracture Associated with Diffuse Idiopathic Skeletal Hyperostosis along with Comparative Assessment of the Levels of Affected Vertebra or Anterior Column Reconstruction

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Abstract:

Introduction: Surgical treatment of osteoporotic vertebral fracture (OVF) often involves older patients with various comorbidities; thus, attending physicians must pay special attention to the invasiveness of surgical procedures and possible perioperative complications. In this retrospective observational study, we investigated the relationship between OVF and diffuse idiopathic skeletal hyperostosis (DISH) by examining the clinical characteristics and surgical outcomes.

Methods: Subjects comprised 26 patients (14 men, 12 women) who underwent surgical treatment for OVF complicated by DISH. Vertebral injuries affected the thoracolumbar transitional vertebrae in 18 patients and the middle and lower lumbar vertebrae in eight patients. The clinical characteristics, surgical results, radiological assessments, and outcomes were evaluated on the basis of the levels of affected vertebrae and whether anterior column reconstruction (ACR) was performed.

Results: Visual Analog Scale (VAS) measurements improved from an average of 69.7 mm before surgery to 21.3 mm after surgery. 14 patients had neurological deficits, who exhibited improvements by one or more steps on the Frankel scale after surgery. Activities of daily living (ADLs) were maintained during the six-month period following surgery in 23 patients. Comorbidity was observed in 22 patients. 14 patients had perioperative complications, and six required additional surgery. Both operating time and blood loss volume were significantly higher in patients in the middle and lower lumbar vertebrae and ACR groups. Postoperative correction loss was also significantly lower in the ACR group.

Conclusions: Favorable degrees of improvement in neurological deficits and VAS were observed following surgery in patients with OVF complicated by DISH, and postoperative ADLs were maintained in 92% of the patients. Elderly men frequently presented with comorbidities, and the frequencies of patients with perioperative complications and those requiring additional surgery were high.

Keywords:

diffuse idiopathic skeletal hyperostosis, osteoporotic vertebral fracture, comorbidity, perioperative complication, surgery

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Introduction

Osteoporotic vertebral fracture (OVF) is the most common type of osteoporosis-related fracture; the diminished capacity for activities of daily living (ADLs) that occurs following injury may shorten healthy life expectancy. Many comorbidities may be resolved through conservative treatment, but surgical intervention becomes necessary if persistent pain or neurological deficits occur due to delayed bone union. As target patients are generally older and often present with various comorbidities, it is necessary for attending physicians to select a surgical procedure, while considering the invasiveness of the proposed procedure and complications that may arise during the perioperative period. Diffuse idiopathic skeletal hyperostosis (DISH) was initially reported by Forestier et al.[1], which was accompanied more frequently by cerebrovascular disease; conversely, the mortality rate was not significantly different[2,3]. Although the comorbidity

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rate and prevalence of DISH have increased among elderly people in recent years because of improved disease awareness[4], publications reporting the comorbidities of DISH with OVF are limited. In this study, we investigated the clinical characteristics and surgical results of patients with OVF complicated by DISH and compared them with respect to the levels of affected vertebrae with and without anterior column reconstruction (ACR).

Materials and Methods

Study design, patient population, and inclusion and exclusion criteria

This retrospective observational study was conducted in compliance with the Declaration of Helsinki. The study's protocol was reviewed and approved by the Institutional Review Board for Clinical Research Ethics at our university, and written informed consent was obtained from all participants. The subjects of this study had undergone surgical treatment for OVF complicated by DISH between April 2010 and April 2017. The average subject age was 80.0 years (range: 66-93 years), the average observation period was 30.9 months (range: 4-80 months), and the levels of affected vertebrae were the thoracolumbar transitional vertebrae (TL) in 18 patients (Th12: 6 patients; L1: 8 patients; L 2: 4 patients) and the middle and lower lumbar vertebrae (ML) in eight patients (L3: 1 patient; L4: 6 patients; L5: 1 patient). DISH was diagnosed according to the criteria of Resnick[4], and ossification of the sacroiliac joint was excluded.

Surgical techniques

Surgical indications were OVF-induced neurological deficits and persistent back pain affecting ADL. The surgical procedure in all cases involved the use of spinal implants, which involve no hook system or sublaminar wires following the typical dorsal incisions. Posterior decompression was applied in cases involving neurological deficits accompanying spinal canal stenosis for fracture fragments. As a general principle regarding fixation procedures, posterior spinal fusion (PSF) was performed at two levels above and below the affected vertebra, with intraoperative limb position maintained and without corrective manipulation for the TL group. A vertebroplasty (VP) procedure was added if instability was observed at the vertebral cleft. For the ML group, PSF was performed at one level above and below the affected vertebra in cases in which ACR was performed. When instability was observed around the affected vertebrae involving disk levels, a posterior lumbar interbody fusion (PLIF) was added. For cases exhibiting favorable overall conditions, additional anterior fixation was performed for massive vertebral collapse, and posterior vertebral osteotomy was performed for marked posterior kyphosis. The fixation range was extended as appropriate in cases involving vertebral osteotomy and those complicated by an already existing vertebral fracture for the upper and lower ends in PSF.

Clinical and radiological assessment and outcomes

The items examined were clinical characteristics such as the fracture stage, injury mechanism, delayed diagnosis, Visual Analog Scale (VAS), changes in neurological deficits and ADLs, comorbidities, degenerative lumbar lesions, and osteoporotic treatments. Surgical results were examined in terms of operating time, blood loss volume, number of fixed vertebrae, perioperative complications, additional surgery required, number of DISH based on an imaging assessment, spatial relationship between DISH sites and OVFs, prior vertebral fractures, three-column injuries, intraoperative correction angle and postoperative correction loss, additional vertebral fractures, and union of affected vertebrae observed. Outcomes were examined in terms of discharge destination and survival prognosis.

The Frankel system was used to classify neurological disorders, and the quality of ADLs was divided into four categories: independent lifestyle, requiring help to go out, quasi-bedridden, and bedridden. The quality of ADLs before injury and at six months postoperatively was compared and assessed in terms of reserved or decreased quality. Additional vertebral fractures and union of affected vertebrae were assessed in all 25 patients, who were monitored for six months or longer after surgery. Surgical results and imaging findings were compared with the levels of affected vertebrae and whether ACR was performed.

Statistical analysis

Statistical analyses were performed with respect to the levels of affected vertebrae and whether ACR was performed. The continuous scale (surgical time and blood loss, fusion level, and corrective angle and loss) used the Mann-Whitney *U* test, the classification scale (perioperative complication, OVF fusion) used Fisher's exact test, and the level of statistical significance was set to $p < 0.05$. All values are expressed as the mean ± standard deviation. The analytical software used was the JMP® 12.0.1 software suite (SAS Institute Inc., Cary, NC, USA).

Results

Clinical records

There were 15 cases in which a fracture developed within three months after injury, eight cases of delayed union, two cases of nonunion, and one case of pseudarthrosis. The most common injury mechanism was low-energy trauma, such as ground-level fall (65.4%). Delayed diagnosis was seen in 42.3% of the patients. The VAS for back pain improved from a preoperative average of 69.7 mm to a postoperative average of 21.3 mm. 14 cases developed neurological disorders, and based on the Frankel classification system, one case was rated B, seven were rated C, and six were rated D, and all cases exhibited improvement by one or more steps

Table 1. Clinical Records.

Fracture stage (n)	Within 3 months: 15
	Delay-union: 8
	Non-union: 2
	Pseudo-arthrosis: 1
Mechanism of injury (n)	Low energy: 17 High energy: 5 Unknown: 4
Delayed diagnosis (n)	11 (TL: 7 ML: 4)
VAS (mm)	Before surgery: 69.7±15.9 After surgery: 21.3±11.7
Frankel score (n)	Before surgery B: 1 C: 7 D: 6 After surgery C: 1 D: 2 E: 11
ADL (n)	Reserved: 23
	Decreased: 2 (CI at 5 weeks after surgery; femoral fracture at 7 months after surgery)
Comorbidity (n)	HT: 13 GERD: 10 DM: 6 BPH: 5
Lumbar degenerative disease (n)	10 (TL: 4 ML: 6)
Osteoporosis treatment (n)	Before surgery: 6 After surgery: 22

OVF, osteoporotic vertebral fracture; VAS, visual analog scale; ADL, activity of daily living; CI, cerebral infarction; HT, hypertension; GERD, gastro esophageal reflux disease; DM, diabetes mellitus; BPH, benign prostatic hyperplasia; TL, thoraco-lumbar; ML, middle-lower lumbar

Table 2. Surgical Records.

Surgical procedure (n)	PSF: 9 (TL 8 ML 1) PSF+VP: 9 (TL 8 ML 1)
	PSF+PLIF: 5 (ML 5) APF: 2 (TL 2) PSO: 1 (ML 1)
Operating time (min)	222±98
Surgical blood loss (mL)	453±476
Fusion level	4.7±1.5
Perioperative complication (n)	delayed wound healing: 5 (TL 5)
	implant failure: 4 (TL 3 ML 1)
	wound infection: 3 (TL2 ML1)
	cerebral infarction: 1 (ML 1)
	pneumonia: 1 (TL 1)
Revision surgery (n)	implant dislocation: 3 (TL 2 ML 1)
	implant malposition: 1 (TL 1)
	wound infection: 2 (TL 1 ML 1)

PSF, posterolateral spinal fixation; VP, vertebroplasty; PLIF, posterior lumbar interbody fusion; APF, anterior and posterior fixation; PSO, pedicle subtraction osteotomy; TL, thoraco-lumbar; ML, middle-lower lumbar

following surgery. ADLs were reserved in 23 cases and in the two cases in whom the ADLs were decreased. There were 22 cases of comorbidities, and 10 cases of lumbar spinal degenerative diseases. Regarding osteoporosis treatments, bisphosphonate, teriparatide, or denosumab preparations were administered preoperatively in six cases and postoperatively in 22 cases (Table 1).

Surgical records

Regarding surgical procedures, PSF was performed in nine cases, PSF + VP in nine cases, PSF + PLIF in five cases, anterior-posterior surgery in two cases, and posterior vertebral osteotomy in one case. The average operating time was 222 min (range: 107-474 min), the average blood loss volume was 453 mL (range: 36-1,869 mL), and the average fusion level number was 4.7 (range: 2-8). There were 14 cases with perioperative complications, and six cases requiring a revision surgery (Table 2).

Radiological and outcome records

The average number of DISH vertebrae was 7.8 (range 4-14), and spatial relationships between the DISH sites and OVFs were 16 cases at the bottom end, five inside the ossified site, and five at the distal bottom end. Prior vertebral fractures were observed in 12 cases, and three-column injuries were observed in 15 cases. The average correction angle was 18° (range: 2.8°-41.9°), and the average correction loss was 6° (range: 0.2°-20.2°). Of the 25 patients who were monitored for six months or more after surgery, additional vertebral fractures were confirmed in two and union of the affected vertebrae was confirmed in 21. 15 patients were released to return home, eight were released to return home after being transferred to another hospital, two were transferred to another institution, one died after being transferred to another department, and five died during follow-up (Table 3).

Comparative assessment of cases involving thoracolumbar and middle/lower OVFs

Assessment of cases in the TL and ML groups showed that the average operating times were significantly longer ($p < 0.05$) in the ML group (280 minutes) than in the TL

Table 3. Radiological and Outcome Records.

Number of DISH	7.8±2.8
OVF level in DISH (n)	bottom-end: 16 inside: 5 distal of the bottom-end: 5
Prior vertebral fracture (n)	12
3-column injury (n)	15
Corrective angle (degree)	18.4±11
Corrective loss (degree)	6.3±5.7
Additional vertebral fracture (n)	2
OVF fusion (n)	21
Destination after discharge (n)	Home: 15
	Home after another hospital: 8
	Institution after another hospital: 2
	Mortalities after hospital transfer: 1
Mortality (n)	5
Details of deaths	An 87-year-old woman died from pneumonia after 4 months
	An 87-year-old man died from malignant lymphoma after 10 months
	A 75-year-old man died from large bowel cancer after 11 months
	An 81-year-old man died from suicide after 27 months
	A 79-year-old man died from an uncertain reason after 30 months

Table 4. Surgical and Radiological Records in Comparison with TL and ML.

	TL (*n*=18)	ML (*n*=8)	p value
Surgical time (m)	196±89	280±98	0.020*
Surgical blood loss (mL)	339±424	713±514	0.031*
Fusion level	4.8±1	4.4±2.3	0.480
Perioperative complication (n)	11	3	0.264
Corrective angle (degree)	17.8±11	19.8±11.5	0.669
Corrective loss (degree)	7.1±6.2	4.5±4	0.289
OVF fusion (n)	14	7	0.738
ACR (n)	10	7	0.095

OVF, osteoporotic vertebral fracture; ACR, anterior column reconstruction; TL, thoraco-lumbar; ML, middle-lower lumbar. *statistically significant

Table 5. Surgical and Radiological Records in Comparison with ACR and nACR.

	ACR (*n*=17)	nACR (*n*=9)	p value
Surgical time (m)	253±104	162±46	0.02*
Surgical blood loss (mL)	572±548	230±150	0.04*
Fusion level	4.5±1.7	5.1±1.1	0.306
Perioperative complication (n)	9	5	0.898
Corrective angle (degree)	19±13	17.4±6.4	0.73
Corrective loss (degree)	4.7±4.5	9.1±6.7	0.029*
OVF fusion (n)	17	4	0.001*

OVF, osteoporotic vertebral fracture; ACR, anterior column reconstruction; nACR, not anterior column reconstruction; TL, thoraco-lumbar; ML, middle-lower lumbar. *statistically significant

group (196 minutes) and that the average blood loss volume was significantly higher ($p < 0.05$) in the ML group (713 mL) than in the TL group (339 mL). The average fusion level number was 4.8 in the TL group and 4.4 in the ML group; perioperative complications occurred in 11 cases in the TL group and in three cases in the ML group. The average intraoperative correction angle was 17.8° in the TL group and 19.8° in the ML group, the average postoperative correction loss was 7.1° in the TL group and 4.5° in the ML group, and union of the affected vertebrae was confirmed in 14 cases in the TL group and in seven cases in the ML group. No significant differences were observed with respect to any of these assessment items (Table 4).

Comparative assessment of cases treated with ACR and without ACR

Assessment of cases in which ACR was performed showed that the average operating time was significantly longer ($p < 0.05$) in the ACR group (253 min) than in the non-ACR group (162 min), and that the average blood loss volume was significantly higher ($p < 0.05$) in the ACR group (572 mL) than in the non-ACR group (230 mL). The average fusion level number was 4.5 in the ACR group and 5.1 in the non-ACR group; perioperative complications occurred in nine cases in the ACR group and in five cases in the non-ACR group; the average intraoperative corrective angle was 19° in the ACR group and 17.4° in the non-ACR group. No significant differences were observed with respect to any of these assessment items. The average postoperative correction loss was 4.7° in the ACR group and 9.1° in the non-ACR group, with significantly smaller losses in the ACR group ($p < 0.05$). Union of the affected vertebra was observed significantly more frequently in the ACR group ($p < 0.05$, Table 5).

Case Presentation

A 79-year-old female presented with comorbidities of hypertension and hyperlipidemia and no symptoms of neuropathy. The number of vertebrae exhibiting DISH was seven,

Figure 1. Case presentation.
(a) Fluid accumulation at the L1 vertebra observed on the MRI T2-weighted sagittal plane. (b) DISH region spanning Th6 to Th12, L1 vertebral cleft, and a prior L2 vertebral fracture were observed. (c) X-ray lateral view of L1 OVF and kyphosis. (d) During the initial surgery, posterior fixation from Th11 to L3 and L1 vertebroplasty were performed. (e) Shortly after the initial surgery, L1 vertebral compression and displacement of the caudal pedicle screw occurred. (f) L1 anterior fixation revision surgery was performed, and sinking of the replacement vertebrae occurred, but they were subsequently fused.

and persistent pain was noted (VAS: 80 mm) at the L1 OVF located at the bottom end of the DISH site [Fig. 1(a), (b), (c)]. The surgery performed included PSF from Th11 to L3 and VP of L1 [Fig. 1(d)]. As compression of the L1 vertebra and caudal pedicle screw dislocation occurred shortly after surgery [Fig. 1(e)], revision surgery was performed with L1 anterior fixation three weeks postoperatively. After revision surgery, her condition improved, and she was subsequently discharged. She began receiving a bisphosphonate preparation after surgery; her ADLs were maintained (VAS: 5 mm) without the development of any additional vertebral fractures, and favorable union of the affected vertebra was observed 10 months after surgery [Fig. 1(f)].

Discussion

DISH causes systemic ossification of the anterior longitudinal ligaments; with a significantly higher prevalence in elderly men[5,6]. Resnick et al. proposed diagnostic criteria for pathologies exhibiting continuous ossification of four or more spinal vertebrae[4]. Diederichs et al. investigated osteoporosis in vertebral fracture cases complicated by DISH in men aged 65 and above and found that the bone mineral density was significantly lower in the group with vertebral fractures complicated by DISH than in the group without fractures[7]. The average number of DISH vertebrae in our study was 7.8 at 80 years of mean age, and over half of our patients were men within three months of their injury. These results indicated that cases involving surgical treatment for OVFs complicated by DISH tended to be more frequent among elderly men and in a relatively short time after injury.

As vertebral fractures complicated by DISH are concentrated by long lever arm compensation, some studies recommended that surgical methods should utilize broad posterior fixation[8], but there have been few reports discussing the levels of affected vertebrae and ACR.

We distinguish surgical methods and corrective procedures between the TL and ML lesions. At the ML lesion, we are especially conscious of the preference to treat complicated

lumbar degenerative conditions simultaneously. As DISH is characterized by continuous ossification of the vertebra and intervertebral discs, we believe that ACR is critical and could shorten the fusion level for PSF. As an indication for ACR, VP is performed mainly in cases involving TL lesions, whereas PLIF is performed mainly in those involving ML lesions. Postoperative correction loss was significantly smaller and the union of affected vertebrae was favorable in cases in the ACR group compared to those in the non-ACR group. Thus, performing ACR as required is the preferable course of action. Although the rate of perioperative complications did not differ significantly between groups, the degree of surgical invasiveness increased significantly, and careful attention should be paid to the management of systemic conditions.

Katsumi et al. performed thoracolumbar OVF at two levels above and one level below the affected vertebra for PSF combined with VP and achieved favorable resolution of neurological deficits and bone union; however, excessive correction for kyphosis resulted in postoperative corrective loss[9]. In our cases, PSF was performed in the TL region without corrective procedures, with the limbs in the intraoperative position. However, if the OVF cleft is large or the ACR proves inadequate, as in the presented case, there will be a danger that such conditions may give rise to early corrective loss and implant dislocation; thus, due care is necessary.

Research on spinopelvic parameters has advanced, and it is now possible to evaluate the ideal lumbar lordosis. Meanwhile, according to Nakajima et al., mismatch of parameters did not necessarily increase the rate of complications postoperatively with surgeries involving the ML lesion[10]. In addition, cases exist in which obtaining full-length radiography of the spinal column prior to surgery proved impracticable and avoiding highly invasive surgical procedures is deemed necessary. Therefore, when operations were performed in the ML lesion, we often emphasized lordosis formation to the highest extent possible and prioritized achieving the union of the affected vertebrae.

Regarding the results of surgery addressing lumbar degenerative diseases complicated by DISH, the risk of revision surgery reportedly increases when the DISH range extends to the lumbar vertebrae[11]. In addition, complication of DISH is a risk factor for revision surgery following fixation of the lumbar interbody[13]. Thus, the presence of DISH impacts the results of surgeries involving the lumbar vertebrae, and more attention is needed in monitoring the postoperative course of OVF in ML lesions complicated by DISH.

Regarding comorbidities, complications, prognosis of spine fracture cases complicated by DISH, hypertension, type II diabetes mellitus, and hyperlipidemia occur frequently[8,13]. The frequency of perioperative complications is 10.9-84%[8,14,15], and the one-year mortality rate is 24-32%[8,15-17]. In cases of cervical vertebral injuries, more than half of all severe pulmonary complications are discovered after surgery, and severe neurological deficits are common prior to surgery, which exhibit minimal improvement after surgery[18].

In our cases, the rate of improvement of neurological deficits was favorable, as there were no instances of severe neurological deficits or cervical vertebral injuries and the ADLs were maintained in 92% of the cases at six months after surgery, allowing these patients to live at home. Meanwhile, comorbidities were observed in >80% of the patients, and the postoperative mortality rate was 19.2%.

Yeoh et al. reported observing fewer complications as a result of percutaneous spinal fusion surgery in the course of treatment to address vertebral fractures associated with ankylosing spondylitis[19]. In addition, Nakajima et al. described the importance of osteoporosis treatment as an approach to prevent implant-related postoperative complications arising after OVF surgery[10]. Among our cases, 54% had perioperative complications and 23% had instances of revision surgery that are considered to be frequent; the causes are presumed to be the presence of comorbidities and osteoporosis, age of around 80 years, and the impact of invasive surgery.

For surgery to address adult spinal deformities, the allowed operating time and blood loss volume by age and comorbidity are predicted and used as indicators for the selection of the surgical procedure[20]. However, in the context of OVF surgery, physicians must examine each case without such clear indicators. In order to avoid perioperative complications, we are currently evaluating the use of a hook system and sublaminar wires or a strategy of percutaneous implant insertion as a minimally invasive surgical treatment for elderly patients and patients with poor overall condition. In addition, aggressive osteoporosis treatment is performed prior to surgery in only 23% of the cases, and we believe that administering pharmacological therapy prior to surgery may lead to a reduced frequency of complications such as implant dislocation.

This study had some limitations. First, this was a retrospective, single-center study. Second, the sample size, especially for ML lesions complicated by DISH, was small. Lastly, the rate of perioperative complications was higher than that of other outcomes for ankylosing spine fracture[14], except for elderly patients. Thus, a further prospective and multicenter study is necessary.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

Author Contributions: Shinichi Kato wrote and prepared the manuscript, and all of the authors participated in the study design and analysis of the data. All authors reviewed, and approved the manuscript.

Informed Consent: Written informed consent was obtained from all participants.

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