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Cervical spine injuries in spinal ankylosing disorders: results of single-stage posterior stabilization without posterolateral fusion

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Patients with long-segment cervical spinal fusion resulting from spinal ankylosing disorders (SADs) are at high risk for highly unstable cervical spine fractures necessitating surgery as the treatment of choice; however, without an existing gold standard. Specifically, patients without concomitant myelopathy, representing a rare entity, may benefit from a minimized surgical approach of a single-stage posterior stabilization without bone grafting for posterolateral fusion. This retrospective monocenter study in a Level I trauma center included all patients treated with navigated posterior stabilization without posterolateral bone grafting between January 2013 and January 2019 for cervical spine fractures in preexisting SADs without myelopathy. The outcomes were analyzed based on complication rates, revision frequency, neurologic deficits, and fusion times and rates. Fusion was evaluated by X-ray and computed tomography. 14 patients (11 male, 3 female) with a mean age of 72.7 ± 17.6 years were included. Five fractures were at the upper and nine at the subaxial cervical spine (predominantly C5-7). There was one surgery-specific complication of postoperative paresthesia. There was no infection, implant loosening, or dislocation, and no revision surgery necessary. All fractures healed after a median time of 4 months and 12 months being the latest time of fusion in one patient. Single-stage posterior stabilization without posterolateral fusion is an alternative for patients with SADs and cervical spine fractures without myelopathy. They can benefit from a minimization of surgical trauma while having equal times of fusion and no increased rate of complications.

Conflict of interests: All authors declare that they have no conflict of interests.

Keywords: Spinal ankylosing disorders; cervical spine; injury; posterior stabilization; bone grafting; myelopathy.

INTRODUCTION

Cervical spine fractures are a challenge in patients with spinal ankylosing disorders (SADs), such as ankylosing spondylitis (AS) and diffuse idiopathic skeletal hyperostosis (DISH). As a result of ossification of the vertebral ligaments, facet joints, and intervertebral disks, the spine becomes rigid and acts as a lever arm under stress *(1)*. Besides,

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the concomitant low-quality bone plays a crucial role so that the formerly highly mobile cervical spine becomes a predetermined breaking point and, thus, susceptible to fractures under the impact of a small amount of force *(2-7)*. The incidence of spine fractures in patients with SADs is 10-30% *(6)*. Simple falls from a standing or sitting position have been reported as the most frequent trauma mechanisms. They account for as many as 46-66 % of cervical spinal injuries in patients with AS *(2,8-11)*. Specifically, levels C5-7 were the locations of 57-78% of the cervical spine injuries in patients with SADs *(3,9-13)*. The frequent disruption of all three columns predisposes patients with SADs to immediate devastating neurologic deficits or later-onset neurologic deficits resulting from secondary dislocations *(6,8)*. The diagnosis of these unstable fractures can be difficult and delayed, specifically, in patients without immediate myelopathy, because they might present with only slight symptoms and after minor trauma *(6,9)*. Plain radiographs might be insufficient, and underlying alterations could mask a fracture *(9,14)*. Computed tomography (CT) and magnetic resonance imaging (MRI) are the imaging methods of choice to proof the injury and depict a concomitant myelopathy *(6,9,15)*. Surgery with internal fixation has been increasingly preferred, and external devices, such as the halo vest, have become secondary options in cervical spine injuries with SADs *(10,12,13,16,17)*. The main goal of any surgery is to achieve high primary stability to prevent secondary neurologic deficits. However, inconsistencies exist about the diagnostics and approach of surgery; thus, no specific method has been established as a standard procedure. Because of its complexity, there is no consensus on the merits of the single anterior, posterior, or circumferential approach or the single- or two-stage procedure *(6)*. While the single anterior approach has been associated with a higher level of early implant failure *(10)*, the posterior approach has been found to not sufficiently address anteriorly located alterations, and the circumferential approach creates additional surgical trauma. Caron et al. *(13)* and Ma et al. *(16)* recommended a reposition of any fracture to the least unstable injury pattern and then choose the method based on the injury pattern in order to sufficiently stabilize the fracture. After the achievement of a stable fracture reduction and retention according to Caron et al. and Ma et al., there were no reports of implant failure leading to instability or nonunion and the solely posterior approach has become more popular *(3,7,10,13,16,18,19)*. In patients with SADs and cervical spine injuries, the posterior stabilization can be performed using pedicle or lateral mass screws combined with rods, hooks, or plates as internal devices. To promote fracture healing, additional posterolateral bone grafting can be applied. However, the benefit of augmentation using bone grafting has never been analyzed and most studies do not further describe the posterior instrumentation technique. Based on the high fusion rates and the strong tendency of idiopathic fusion because of the underlying ankylosing disorders, the following questions were asked: Is additional bone grafting for posterolateral fusion necessary in patients with cervical spine injuries and SADs as long as a stable fracture reposition and stabilization is achieved? Can patients with only slight symptoms and without signs of spinal cord injuries, specifically, benefit from a minimization of surgical intervention? Until now, no study reports on how to realize posterior stabilization for cervical spine injuries in patients with SAD and whether additional bone grafting is necessary to achieve posterolateral fusion and fracture healing.

We, therefore, hypothesized that cervical spine injuries in SADs that can sufficiently be reduced by single-stage posterior stabilization do not need additional bone grafting for posterolateral fusion while having equivalent fusion rates and outcomes. Furthermore, on the basis of this assumption, we hypothesized that specifically patients without signs of spinal cord injuries can benefit from a minimization of surgical intervention.

Thus, we present the outcomes of patients with cervical spine injuries and SADs without neurologic deficits receiving posterior stabilization without additional bone grafting for posterolateral fusion.

MATERIALS AND METHODS

This retrospective monocenter study was conducted at a Level I trauma center with maximum medical care. It included all patients admitted between January 2013 and January 2019 with cervical spine injuries and SADs without neurologic deficits. The patients were treated with navigated single-stage posterior stabilization without additional bone grafting for posterolateral fusion. The inclusion criteria were one or more injuries located in the upper or subaxial cervical spine, preexisting SADs with ankylosis of at least three cervical spine levels, the absence of preoperative neurologic deficits, and a postoperative follow-up time until fusion and at least of 1 year. SADs were defined as AS, DISH, and psoriatic spondylitis. Neurologic deficits were defined as sensory impairment, including changes in pain and temperature perception, reduced or complete loss of consciousness (Glasgow Coma Scale [GCS] <14), or loss of useful motor function (<75% muscle strength, a grade less than 4/5 in accordance with Janda). Patients who did not meet all the inclusion criteria were excluded. Furthermore, the exclusion criteria were a tumor, tumor-like lesions, osteonecrosis, and metastases in the cervical spine, an osteoporotic fracture, the absence of a traumatic event, a follow-up period of less than 1 year unless the patient died during the 1 year follow-up time, respiratory distress, intubation, and difficulties of swallowing before surgery. Myelopathy in the preoperative MRI scan was defined as a criterion for exclusion if the patient simultaneously had a sensory impairment or motor function loss.

The following patient data were collected from the clinical database and evaluated: age, sex, trauma mechanism, admission pathway, preexisting conditions, concomitant injuries, fracture morphology and classification, hospitalization duration, and complications. Before surgery, in accordance with clinical standards, each patient underwent a CT scan of the cervical spine and an MRI scan to exclude spinal hematoma, occult fractures, and asymptomatic myelopathy to prevent postoperative development of neurologic deficits. Fig. 1 displays the preoperative diagnostic workup for all patients.

The outcomes were assessed on the basis of fusion times and rates, postoperative neurologic deficits, complications, revision rates, and mortality. All patients underwent routine examinations and X-rays at 6-8 weeks and 3, 6, and 12 months after surgery. Thus, the post-surgery follow-up was at least 12 months for all patients. Each patient routinely received a CT scan upon the suggestion of fusion in X-ray images and at least 12 months after surgery to confirm fusion.

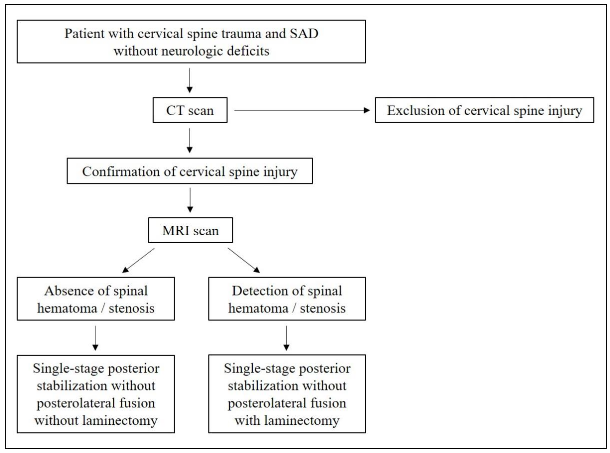

Fig. 1. — Preoperative diagnostic path and decision making.

Descriptive statistical analysis was performed with IBM SPSS Statistics, Version 25.0 (IBM Corp., Armonk, NY, USA). For the comparison of means, the Student's *t*-test was used. All tests were two-sided at the significance level of $p < 0.05$. An alpha adjustment for multiple testing was not applied.

The study was approved by the local ethics committee (ethics committee number: 250/18) and conducted in accordance with the ethical standards of the 1964 Declaration of Helsinki and its amendments.

RESULTS

In the 6-year study period, a total of 14 patients in the clinical database were identified as having met the inclusion criteria. Eleven were male (78.6%), and three were female (21.4%). The mean age was 72.7 ± 17.6 years (range 47-95 years). Table I displays patient characteristics and epidemiological data. Five patients (35.7%) exhibited intraspinal hematomas with spinal stenosis. Each of them received dorsal decompression, in addition to posterior stabilization. Four patients who received decompression each had a fracture of the subaxial,

Table I. — Patient characteristics and epidemiology

Patient	Sex	Age [y]	Spinal ankylosing disorder	Trauma mechanism	Level of fracture	AOSpine classification	Number of segments fused
1	m	81	DISH	Fall from stand	C1, C2	C1: A (Gehweiler III), N0, M2 C2: A (Anderson III), N0, M2	1
2	f	80	Psoriatic spondylitis	Fall from stand	C2	C (Effendi II), N0, M3	2
3	m	90	AS	Fall from stand	C2	A (Anderson II), N0, M2	1
4	f	91	DISH	Fall out of bed (<1 m)	C2	A (Anderson II), N0, M2	1
5	f	87	Psoriatic spondylitis	Fall from stand	C2	A (Anderson III), N0, M3	2
6	m	49	AS	High-velocity car accident	C5/6	B2, F2 BL, N0, M3	6
7	m	47	AS	Fall from stand	C5/6	B3, F2 BL, N0, M3	5
8	m	95	AS	Fall from stand	C5/6	B3, F2 BL, N2, M3	4
9	m	58	DISH	High-velocity car accident	C5/6	B3, F2 BL, N0, M3	3
10	m	77	DISH	Fall from stand	C6	B3, F2 BL, N0, M3	6
11	m	70	AS	Fall from stand	C6/7	B2, F2 BL, N0, M3	6
12	m	52	AS	Fall from >3 m	C6/7	B3, F2 BL, N0, M3	4
13	m	52	AS	Fall from stand	C7	B3, F2 BL, N0, M3	7
14	m	89	Psoriatic spondylitis	Fall from stand	C7	B3, F2 BL, N0, M2	4

AS: ankylosing spondylitis, DISH: diffuse idiopathic skeletal hyperostosis, PRBCs: packed red blood cells, FFP: fresh frozen plasma,

and one had a fracture of the upper cervical spine. There was no finding of an additional occult fracture in the MRI besides the fractures which had already been diagnosed in the CT scans.

In 11 patients (78.6%), the fractures resulted from low-energy trauma, and in 10 (71.4%), the cause was a fall from a standing position. In only three patients, the fractures resulted from high-energy trauma, such as a fall from more than 3 m and a high-velocity traffic accident. At admission, 13 patients had GCS scores of 15, and one had a score of 14.

Seven patients suffered from preexisting AS, four from DISH, and three from axial psoriatic arthritis. The medical histories are presented in Table II. Two patients were under the influence of alcohol when the accidents occurred. The related injuries are shown in Table III.

Five patients suffered from fractures of the upper cervical spine, and nine had fractures of the subaxial cervical spine. Hyperextension fractures were present in 12 cases (85.7%), and flexion fractures were present in two patients (14.3%). All the upper cervical spine fractures were located in the second

Table I. — Patient characteristics and epidemiology

Surgery	Preoperative special findings, postoperative complications	Time of fusion [months]
Posterior stabilization C1/2 (Goel-Harms)	Perioperative blood loss: 800 ml, transfusion of 2 PRBCs	12
Reposition and posterior stabilization C1-3		6
Posterior stabilization C1/2 (Goel-Harms)	Patient died 12 months after surgery (unrelated event)	9
Posterior stabilization C1/2 (Goel-Harms)		4
Posterior stabilization C1-3	Preoperative short segment dissection of right vertebral artery at C2	6
Reposition C5/6, posterior stabilization C2-Th1, laminectomy C4/5	Postoperative bilateral paresthesia according to dermatome C6	4
Posterior stabilization C4-Th2	Perioperative blood loss: 2.5 l, transfusion of 4 PRBCs, 6 FFP	7
Posterior stabilization C3/4 to C6/7, laminectomy C4-6	Preoperative epidural hematoma C5/6 with myelopathy and beginning weakness of the left triceps muscle (4/5), postoperative complete restoration, postoperative UTI; patient died 8 months after surgery (unrelated event)	4
Posterior stabilization C3-6, laminectomy C3/4	Preoperative spinal stenosis C5/6 with myelopathy due to injury and intraspinal osteophytes	5
Posterior stabilization C2/3/4 to C7/Th1, laminectomy C5/6	Preoperative spinal stenosis C5/6 due to injury and intraspinal osteophytes	3
Posterior stabilization C4/5/6 to Th1/2/3, laminectomy C6-Th2	Preoperative epidural hematoma C5/6 to Th3, perioperative blood loss: 1.2 l, transfusion of 5 PRBCs, 6 FFP, 2 PCs	3
Posterior stabilization C5/6 to Th1/2		4
Posterior stabilization C4/5/6 to Th2/3/4		6
Posterior stabilization C5-Th2	Failure of conservative treatment with cervical orthosis for 12 weeks prior to surgery	3

PCs: platelet concentrates, UTI: urinary tract infection.

vertebral body. Specifically, four were found in the odontoid, and one was in the vertebral body. One patient with an odontoid fracture suffered from an accompanying fracture of the atlas.

All nine fractures in the subaxial cervical spine were located in C5-7, the lower part of the subaxial cervical spine. C5/6, which was affected in five cases, was the most frequently affected site. Table I presents the fractures and soft tissue injuries on the basis of the AOSpine injury classification system for the upper and subaxial cervical spine (AO Foundation, Davos, Switzerland, *(20)*).

The admission pathways were as follows: Six patients (42.9%) presented to the hospital via emergency medical services, and eight (57.1%) had been transferred from a regional hospital. The length of hospital stay in our department was 14.6 ± 7.9 days (range 4-36 days). On the basis of fracture localization, the hospitalization duration was 18.4 ± 10.5 days (range 10-36 days) for patients with upper cervical spine injuries and 12.4 ± 5.5 days (range 4-22 days) for those with subaxial cervical spine fractures. There was no significant difference in hospitalization duration ($p = 0.18$).

Table II. — Medical history

Medical history	Number of patients (n)
None	8
Arterial hypertension	7
Hypothyroidism	4
Coronary heart disease	4
Benign prostatic hyperplasia	4
Asthma/emphysema/chronic obstructive pulmonary disease	3
Atrial fibrillation	2
Cardiac valve stenosis/replacement	2
Dementia	2
Stroke	1
Peripheral artery disease	1
Diabetes mellitus	1
Restless legs syndrome	1
Osteoporosis	1
Alcohol abuse	1
Liver disease	1
Anemia	1

Table III. — Related injuries

Related injuries	Number of patients (n)
None	8
Brain concussion	5
Thoracic spine fracture	2
Lumbar spine fracture	1
Fracture of the pelvis	1
Fracture of extremities	1

Each procedure was performed by a senior orthopedic trauma surgeon with expertise in spine surgery. Each patient received posterior stabilization surgery in which pedicle screws were used alone or in combination with lateral mass screws (neon³™, ulrich medical, Ulm, Germany). In spinal cord compression or myelopathy as identified by MRI, a laminectomy was also performed. Five patients underwent this additional decompression to the posterior stabilization. All screws were inserted using navigation (Brainlab Spine Navigation, Brainlab AG, Munich, Germany). No patient received bone grafting in addition to stabilization. None had a hyperkyphotic deformity; thus, the field of view was not impaired.

One segment was fused three times in the upper cervical spine (C1-2) and 2 segments were fused twice (C1-3). C3 lateral mass screws were inserted in the absence of an adequate C2 pedicle. The craniocervical segment (C0/1) was not included in the fusion in any of the 5 patients. In the subaxial cervical spine, 3 to 7 segments (mean, 5 segments) were fused.

No patient presented with peripheral neurologic deficits, such as paresthesia or paralysis, at admission. Before surgery, one patient developed partial weakness of the left triceps (muscle strength of 4/5) which regressed after surgery. There was one surgery-specific postoperative complication. One patient suffered from paresthesia relating to the impaired dermatome; however, it resolved after 3 months. No implant revision was necessary. One patient suffered a urinary tract infection and received antibiotic treatment. Three patients suffered from perioperative blood loss, which required transfusion.

Six weeks after surgery, 13 patients did not report any complaints, and none of the 14 patients reported any subjective reduction in the range of motion. One patient complained of discomfort related to the implant in the cervicothoracic junction caused by a low body mass index. At 3 months after surgery, X-rays and CT scans identified fusion in five patients (35.7%). Six months after surgery, six more patients exhibited fusion. Thus, 78.6% of the patients showed fusion. At 9 months after surgery, two more patients achieved fusion (altogether 92.9%), and after 12 months, all 14 patients exhibited fusion. Fig. 2 shows the imaging during the course of treatment from injury until fusion. The median was 4 months after surgery. Two patients died of unrelated events within 1 year of surgery. No implant failure or loosening was detected 12 months after surgery in the 12 surviving patients.

DISCUSSION

In this retrospective study, 14 patients with preexisting SADs who had received single-stage

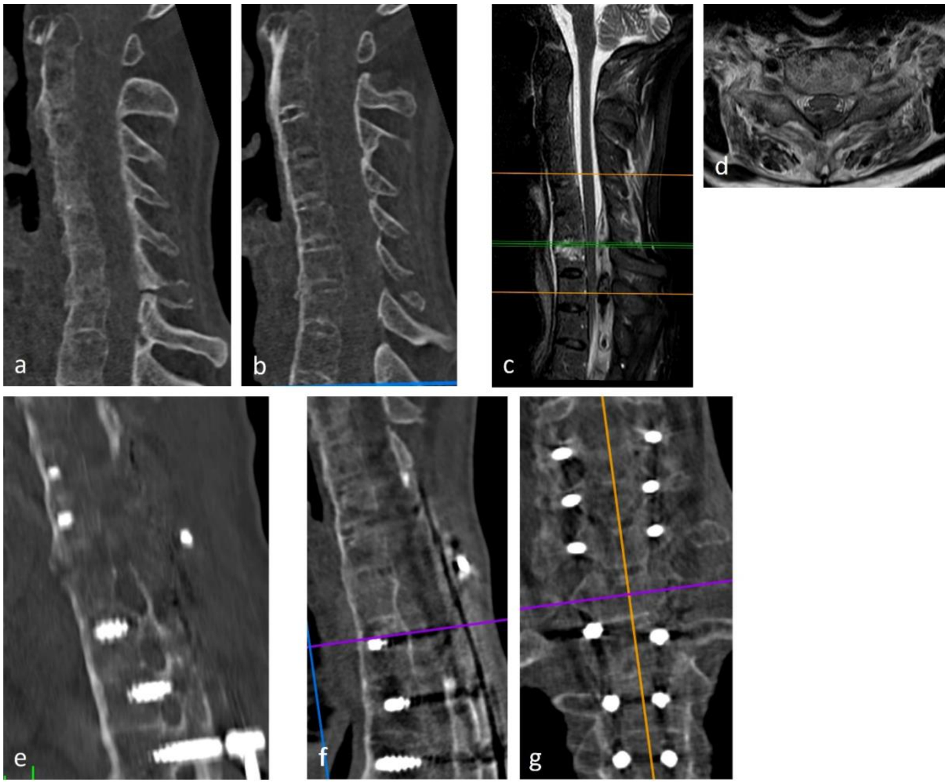

Fig. 2. — Imaging during the course of treatment from injury until fusion: Preoperative CT scans (a-b) and MRI scans (c-d) of a patient with a C6/7 fracture and AS with epidural hematoma C5/6 to Th3; postoperative CT scan after reduction, posterior stabilization C4/5/6 to Th1/2/3, and laminectomy C6-Th2 (e); and CT scans showing fusion after 3 months (f-g).

posterior stabilization without bone grafting for cervical spine injuries were reviewed. It was therefore assumed that this treatment option would result in equal fusion rates and fewer complications than conventional posterior spondylodesis techniques, including bone grafting. All the patients achieved fusion no later than 1 year after surgery. The mean time was 4 months, and the complication rate was 14.3% (n=2). Only one minor surgery-specific complication with intermittent paresthesia was registered. Besides, no surgical revision was necessary. The mortality rate for the surgery was 0%. Two patients died during the 1-year follow-up period because of unrelated events.

The fusion rates and mean times were not inferior to those for additional bone grafting. In previous studies using additional bone grafting, fusion was achieved in all patients *(16)*, and after an average of 3-4 months *(21,22)*. Compared to studies not precisely stating whether bone grafting was performed, fusion rates and time of fusion was not inferior, as well *(3,7,10,13,18,19,23)*.

The complication rate in surgical interventions in cervical spine fractures and SADs is 0-52% and remains inhomogeneous *(2,5,12,16,23)*. However, the complication rates are not affected by the approach *(12)*. With only one minor surgery-specific transient complication, the complication rate in the present study can be rated as low. More importantly, in the 1-year follow-up period, there were no major complications, such as infection, paralysis, or implant loosening or dislocation.

Despite the absence of neurologic deficits, the patient characteristics and epidemiology were similar to those of previous studies with low-energy trauma (especially falls from the standing position) accounting for most injuries *(7,12,16)* and a predominance of the male gender

(2,3,7,10,12,13,16,18,23) and elderly patients (mean age 55-74 years) *(2,3,7,10,12,13,16,18,23)*. Similarly, of the patients in the presented study, 64.3% suffered from subaxial fractures located at the lower cervical spine in the C5-7 segment and 35.7% from a fracture in the upper cervical spine, predominantly in the C2 segment. In previous studies, the C5-7 segments account for 63.2-84.2% of all cervical spine fractures in SADs, followed by the upper cervical spine *(2,3,7,9,13,19,24)*.

Thus far, the presented surgical technique, applying posterior stabilization without bone grafting in SADs, has been performed only in patients without preoperative neurologic deficits. Adequate fracture reduction without a remaining fracture gap in the anterior part of the injury was a requirement for performing this procedure. However, this technique was applied independent of the fracture line passing through the vertebra or disk, a simultaneously performed laminectomy for spinal cord decompression, and injuries at the upper and subaxial cervical spine. At this time, this procedure can be recommended only for patients without preoperative neurologic deficits but could likely be extended for use in patients with neurologic deficits after the injuries have been sufficiently reduced to stable fractures. However, further studies are needed.

Cervical spine fractures in patients with SADs and specifically without myelopathy are rare. The small number of patients remains a limitation in studies on this patient population. Further limitations in the present study are the retrospective design without controls, and the mono-center setting. Fusion was achieved in all patients within the 1-year study period; however, the long-term outcomes could not be assessed.

A review of the literature indicates that this is the first study to question the need for bone grafting in a specific patient population and to emphasize the importance of adequate fracture reduction.

CONCLUSION

Navigated posterior stabilization surgery without bone grafting for posterolateral fusion in patients with cervical spine fractures and preexisting SADs is a safe treatment option in the absence of preoperative neurologic deficits. In selected patients, it is not inferior to the posterior or circumferential approaches with bone grafting. It achieves similar fusion rates with low complication rates. This procedure was performed for the first time in patients with cervical spine injuries and SADs. It was used independent of the location of the injury at the upper or subaxial cervical spine and the fracture line passing through the vertebra or disk. The only requirement for this method is adequate fracture reduction without a remaining fracture gap in the anterior spinal column.

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