Accepted Manuscript

Submission Date: 2023-12-05
Accepted Date: 2024-03-27
Accepted Manuscript online: 2024-05-22

Journal of Neurological Surgery Part A: Central European Neurosurgery

Radiological Outcomes after Operative Management of Traumatic Spine Fractures: Stand-Alone Posterior Stabilization vs Combined AnteroposteriorApproach

Ali Mulhem, Ziad Omran, Stefanie Hammersen, Sven R Kantelhardt.

Affiliations below.

DOI: 10.1055/a-2331-2466

Please cite this article as: Mulhem A, Omran Z, Hammersen S et al. Radiological Outcomes after Operative Management of Traumatic Spine Fractures: Stand-Alone Posterior Stabilization vs Combined AnteroposteriorApproach. Journal of Neurological Surgery Part A: Central European Neurosurgery 2024. doi: 10.1055/a-2331-2466

Conflict of Interest: The authors declare that they have no conflict of interest.

Abstract:
Objective. Previous research emphasises correcting deformities resulting from spine fractures by restoring sagittal alignment and vertebral height. This study aims to compare radiological outcomes, including sagittal index (SI) and loss of vertebral body height (LVBH), between stand-alone posterior stabilisation (Group I) and the posteroanterior/combined approach (Group II) in the operative management of traumatic thoracic or lumbar spine fractures.
Methods. In this retrospective single-centre study, all patients with traumatic spine fractures (T1 to L5) undergoing surgical stabilisation between January 1, 2015, and May 31, 2021, were included. Two spine surgeons independently assessed imaging, recording SI and LVBH values at baseline, after each surgical intervention, and during follow-up (at least three months post-treatment). The mean values of SI and LVBH between the assessing surgeons were utilised. Linear mixed-effects regression models, adjusted to baseline values, compared SI and LVBH between the two groups.
Results. 71 patients (42 men), median age 38 years (IQR 28 to 54), with a median follow-up of 4 months (IQR 3 to 17), were included. 32 were in Group I and 39 in Group II. 40 fractures included the thoracolumbar junction (T12 or L1), 15 affected the thoracic- and 14 the lumbar spine. The regression model revealed superior sagittal alignment in Group II, with an adjusted mean difference for SI of -4.24 (95% CI -7.13 to -1.36; p-value=0.004), and enhanced restoration of vertebral body height with an adjusted mean difference for LVBH of 0.11 in the combined approach (95% CI 0.02 to 0.20; p-value=0.02). Nine postoperative complications occurred in the entire cohort (4 in Group I and 5 in Group II).
Conclusions. Combined posteroanterior stabilisation for spine fractures improves deformities by enhancing sagittal alignment and increasing vertebral body height, with acceptable morbidity compared to the stand-alone posterior approach.

Corresponding Author:
M.Sc. Ali Mulhem, University of Oxford, Department for Continuing Education, Oxford, United Kingdom of Great Britain and Northern Ireland, ali.mulhem@kellogg.ox.ac.uk

Affiliations:
Ali Mulhem, University of Oxford, Department for Continuing Education, Oxford, United Kingdom of Great Britain and Northern Ireland
Ali Mulhem, Vivantes Klinikum im Friedrichshain, Department of Neurosurgery, Berlin, Germany
Ziad Omran, Vivantes Klinikum im Friedrichshain, Department of Neurosurgery, Berlin, Germany

Stefanie Hammersen, Vivantes Klinikum im Friedrichshain, Department of Neurosurgery, Berlin, Germany
Sven R Kantelhardt, Vivantes Klinikum im Friedrichshain, Department of Neurosurgery, Berlin, Germany

Introduction

Severe spinal fractures impose substantial medical, social, and economic burdens, particularly given their predilection for adolescents and young adults, affecting their crucial productive years [1]. These fractures predominantly manifest in the thoracic and thoracolumbar regions, often stemming from motor vehicle accidents, falls from heights, and, notably, instances of suicidal jumping [2].

The management of such fractures typically involves two primary surgical approaches: the stand-alone dorsal approach employing transpedicular screw rod fixation with or without implant removal after consolidation of fractures, and the posteroanterior combined approach, wherein dorsal stabilization is reinforced by anterior fixation through vertebral body replacement [3]. Controversy surrounds the determination of the optimal surgical treatment [3].

To comprehensively assess surgical outcomes, numerous authors advocate evaluating short-term clinical results and scrutinizing the correction of deformities arising from the fractures, specifically sagittal alignment and reduction in vertebral height. Previous studies have underscored a positive correlation between sagittal index (SI) and loss of vertebral height (LVH) with long-term clinical outcomes [3, 4, 5]. Patients with an increased SI (indicative of malalignment) and heightened LVH (suggesting increased compression) are more prone to experiencing or developing severe neurological injuries compared to those with less deformity [3, 6].

Therefore, this study aims to compare radiological outcomes and complications following surgical treatment of traumatic spine fractures between stand-alone posterior stabilization versus anteroposterior stabilization (combined approach).

Methods and Materials

Patients Selection

We conducted a retrospective review of patient records and imaging studies for all patients treated at our supra-regional maximal care trauma centre for traumatic spine fractures between January 1, 2015, and May 31, 2021. Patients were identified using ICD-10 codes S22.0 and S32.0.

Patients were included based on the following eligibility criteria:

1. Patients with a spine fracture at any vertebrae from the first thoracic (T1) to the last lumbar (L5).
2. Fractures diagnosed after a specified date of trauma, including traffic accidents, falls from a height (suicidal or non-suicidal), or other acute traumatic insults.
3. No age restriction.
4. Only patients treated surgically by either a posterior or combined approach were included. The surgical approach was chosen based on the preference of the attending neurosurgeon.
5. Patients with cervical, pathological fractures (due to tumour or metastasis) or patients with a previous history of osteoporosis were excluded.

Patients groups

The cohort was divided into two groups based on the surgical approach: Group I underwent stand-alone posterior dorsal stabilization using transpedicular screws and rods (as exemplified in Figure 1), while Group II underwent dorsal stabilization as in Group I, followed by a second surgical session within less than two weeks, involving anterior replacement of the fractured vertebra through a titanium intervertebral cage (as exemplified in Figure 2).

Surgical techniques

After initial clinical and radiological assessment and cardiopulmonary stabilization of patients in the emergency department, patients were prepared to undertake the surgery. The posterior approach was done in the prone position with a midline incision over the fractured vertebra to undertake decompression, if necessary. Pedicle screw implantation was performed either through open technique by expanding the midline incision to involve two segments over and two segments under the fracture or through percutaneous technique by small paravertebral incisions. No screws were inserted in the fractured segment. The anterior approach was made in a lateral left-sided position through the transthoracic corridor when fractures were in the thoracic or thoracolumbar regions (i.e. from T1 till L1) or through retroperitoneal corridor when the fractures were in the lumbar region (i.e. from L2 till L4), patients with L5 fractures were operated on through a supine position with a midline incision infra umbilical with the aid of a vascular surgeon. The anterior approach entailed the partial resection of the fractured vertebra and the implantation of an intervertebral cage filled with autogenous bone.

Outcomes measurement

Two spine surgeons independently assessed radiological outcomes. Measurements included the sagittal index (SI) using the Farcy method [4] and the loss of vertebral height index (LVH) estimated through the Keene method [5]. Surgeons independently entered measurements into the dataset based on CT or X-rays to avoid mutual interference.

The calculation of SI involved determining the kyphotic angle at the fractured motion segment level minus the normal contour. Baseline values of 5° in the thoracic region, 0° at the thoracolumbar junction, and -10° in the lumbar region were applied. An SI of zero indicated normal perfect alignment, and any deviation, whether smaller or greater than zero, was recorded as the absolute value. This approach allowed for a standardized scale across all spine regions, indicating malalignment [4]. Figure 3a illustrates an example of the SI measurement.

LVH was defined as the ratio of the anterior height of the injured vertebra and the mean anterior height of the two adjacent intact vertebrae. An LVH of 1 represented the standard perfect height, and any value smaller than that indicated a loss of height, with zero being the lower limit of LVH [5]. Figure 3b provides an example of the LVH measurement.

Both SI and LVH were measured at four time points: baseline (at presentation in groups I and II), after posterior approach (in groups I and II), after combined approach (in group II) using CT-scans in the supine position, and at a follow-up of a minimum of 3 months (in groups I and II) using mostly X-rays in the standing position, if possible, or using CT-scans. The number of patients with follow-up X-rays was comparable between both groups (19 in group I vs 22 in group II).

Postoperative complications were recorded in both groups. Complications were defined as any postoperative condition related to surgical treatment requiring specific treatment or readmission to the hospital.

Statistical Analysis

Continuous variables were presented as mean ± standard deviation (SD) or median and interquartile range (IQR). SI and LVH comparisons between groups employed mixed-effects regression modelling, adjusted for baseline values. The mean values of the independent measurements of spine surgeons were used for SI and LVH. Statistical significance was set at a p-value of 0.05. All analyses were performed using StataCorp. 2020. Stata Statistical Software: Release 17. College Station, TX: StataCorp LLC.

Results

Baseline Characteristics

Using the ICD-10 codes S22.0 and S32.0, we identified 135 patients. Among them, 64 were deemed ineligible due to non-traumatic fractures or non-surgical treatment. Consequently, 71 patients (29 females, 42 males) with a median age of 38 (IQR 16-72) were included in the study. 32 were assigned to Group I (stand-alone posterior stabilization) and 39 to Group II (combined approach). The median follow-up was four months (IQR 3-17) with a minimum of 3 months. Complete follow-up data was available for 31 patients. Table 1 presents the baseline characteristics of the two groups. Notably, no statistically significant differences in demographic and clinical parameters were observed between the two groups.

Outcomes

The baseline sagittal index showed a remarkable improvement (reduction) after dorsal stabilization in both groups (see Figure 4). Group II exhibited a slight additional improvement after the anterior replacement of the fractured vertebra. However, there was a deterioration (increased SI) at the follow-up, which was more pronounced in group I, indicating a regression in sagittal alignment (see Figure 4).

A similar pattern of improvement after each surgical intervention, followed by a subsequent deterioration at follow-up, was observed for the loss of vertebral height (LVH increased initially after each intervention and then reduced at the follow-up) in both groups (see Figure 5).

Comparison of these outcomes (SI and LVH) through the mixed-effects regression model (see Table 2) revealed statistically significant differences between the groups. Group II showed a slight improvement in both indices at the follow-up compared to Group I, indicating a better sagittal alignment and slightly more effective and significantly more lasting restoration of vertebral height through the combined approach.

Regarding complications, there were four cases in group I and five in group II. A detailed breakdown of all complications in both groups is provided in Table 3. The complications in group II were mainly pulmonary related because of the transthoracic corridor when undertaking anterior approach in patients with fractures in the thoracic or thoracolumbar junction regions. In contrast, the main complications in group I were related specifically to the insufficiency of fixation materials in patients with fractures in the thoracolumbar or lumbar regions.

Discussion

In 1959, Boucher HH reported the pioneering use of pedicle screws for treating spine fractures. This technique marked the inception of a treatment approach that has since evolved in technique and material [7, 8]. The replacement of the vertebral body with foreign material to treat spine fractures was first described in 1967 by Scoville and others, and since then, it has undergone further development[9]. The optimal approach for managing unstable spine fractures remains a point of contention for spine surgeons [8, 10]. Our study comparing stand-alone posterior and combined anteroposterior approaches showed significant differences in radiological outcomes. Specifically, this concerned the sagittal index and loss of vertebral height. Intriguingly, postoperative complications did not exhibit a statistically significant difference during follow-up. The effect of less efficient restoration of alignment and vertebral height may cause apparent clinical problems later.

Singh et al. previously suggested that adding an anterior reconstruction to the stand-alone posterior approach could enhance the correction of sagittal alignment and loss of vertebral height [11]. However, their study focused on a small subgroup of patients (n = 4), limiting generalizability. Another case series, albeit without a control group, echoed positive results for posterior/anterior combined surgery [10]. Our analysis, incorporating a control group and a relatively large cohort (n= 39 in the combined approach and n= 32 in the dorsal approach), substantiates these prior findings statistically and methodologically.

On the contrary, a randomized controlled trial (RCT) that compared the combined approach with the stand-alone posterior stabilization in 40 patients concluded no difference in radiological deformity correction and clinical outcomes [12]. Although this study is an RCT, there are two points of criticism to be mentioned here: First, the authors included only patients with L2, L3, or L4 fractures, which limits the generalizability of their results on other spinal regions. Second, statistically, they compared the radiological outcomes between preoperative and postoperative in the same group, not between the groups. At the final observation in this RCT, the sagittal deformity correction was better in the combined group [12], which matched our findings at the final follow-up.

In a recent systematic review comparing the two groups, authors found no statistically significant difference in the radiological outcomes; however, they included only patients with thoracolumbar junction fractures and measured only the Cobb angle to assess the deformity [13]. To the best of our knowledge, this is the first study that compared SI and LVH in traumatic thoracic or lumbar fractures between these two groups of patients.

Our results, aligning with biomechanical principles, demonstrate that sagittal alignment and vertebral height improvement were comparable in both groups in the early postoperative period when patients were less mobile. However, after discharge and a minimum 3-month follow-up, a decline in radiological outcomes was noted, particularly in the stand-alone posterior stabilization group. This suggests that increased loading forces postoperatively compromised the stability of the weakest fractured region, with the combined approach exhibiting superior outcomes through increasing the load-carrying capacity of the spine. Consistent with the biomechanical properties of the thoracolumbar spine, our recommendation emphasizes reconstructing all three columns for severe spine fractures in the thoracic or lumbar regions [14].

Acknowledging limitations, our study faced challenges with follow-up measurements for about half the patients. However, using a mixed-effects model helped address this limitation through multiple imputations[15]. Another limitation considers the follow-up period, which was short in most patients, so the effect of the constructs in both approaches under long-term loading could have been differential. The construct in the combined approach is more rigid, which can lead to more adjacent segment problems with resulting deformity. On the other hand, less restored SI and LVH in the stand-alone posterior stabilization can also increase the adjacent segment problem with resulting kyphosis. In light of this limitation, another follow-up study with longer follow-up is warranted. Moreover, the extended follow-up period, ranging from 3 months to over three years, contributed to outcome variability.

While we found statistically significant differences, we acknowledge that these primarily pertained to radiological outcomes, serving as surrogates for clinical significance. Nevertheless, examination of postoperative complications revealed that stand-alone posterior stabilization was more susceptible to implant failure, which might carry a risk for clinical deterioration at a later time point. Expanding our study by involving a larger sample size and longer follow-up with registration of additional clinical outcomes will address these limitations in future research.

Conclusions

In addressing severe spine fractures within the thoracic and lumbar regions, optimal surgical treatment should prioritize the restoration of alignment and height. Our findings support the consideration of an anterior replacement of the vertebra in conjunction with posterior stabilization using pedicle screws, commonly known as a combined anteroposterior approach. Compared to stand-alone posterior stabilization, this combined approach demonstrates superiority in maintaining a more favourable sagittal alignment and vertebral height at follow-up. These conclusions emphasize the potential benefits of a comprehensive three-column reconstruction strategy for better outcomes in managing severe thoracic and lumbar spine fractures.

Declarations

Funding: no funding was obtained for this research

Conflicts of interest: The authors declare no conflict of interest.

Availability of data and material: all data and material used in this study are available for sharing with researchers

Code availability: not applicable

Ethics approval: ethical approval was waived in this retrospective cohort study with anonymous data

References

1. Katsuura Y, Osborn JM, Cason GW. The epidemiology of thoracolumbar trauma: A meta-analysis. J Orthop [Internet]. 2016;13(4):383–8. Available from: http://dx.doi.org/10.1016/j.jor.2016.06.019

2. Whitney E, Alastra AJ. Vertebral Fracture. StatPearls Publishing; 2023.

3. Yüksel MO, Gürbüz MS, Gök Ş, Karaarslan N, İş M, Berkman MZ. The association between sagittal index, canal compromise, loss of vertebral body height, and severity of spinal cord injury in thoracolumbar burst fractures. J Neurosci Rural Pract [Internet]. 2016;7(Suppl 1):S57–61. Available from: http://dx.doi.org/10.4103/0976-3147.196466

4. Farcy JP, Weidenbaum M, Glassman SD. Sagittal index in management of

thoracolumbar burst fractures. Spine (Phila Pa 1976) [Internet]. 1990;15(9):958–65. Available from: http://dx.doi.org/10.1097/00007632-199009000-00022

5. Keene JS. Radiographic evaluation of thoracolumbar fractures. Clin Orthop Relat Res [Internet]. 1984;189(189):58–64. Available from: http://dx.doi.org/10.1097/00003086-198410000-00007

6. Singh R, Kumar RR, Setia N, Magu S. A prospective study of neurological outcome in relation to findings of imaging modalities in acute spinal cord injury. Asian J Neurosurg [Internet]. 2015;10(3):181–9. Available from: http://dx.doi.org/10.4103/1793-5482.161166

7. Boucher HH. A method of spinal fusion. J Bone Joint Surg Br [Internet]. 1959;41-B(2):248–59. Available from: http://dx.doi.org/10.1302/0301-620X.41B2.248

8. Aly TA. Short segment versus long segment pedicle screws fixation in management of thoracolumbar burst fractures: Meta-analysis. Asian Spine J [Internet]. 2017;11(1):150–60. Available from: http://dx.doi.org/10.4184/asj.2017.11.1.150

9. Tarhan T, Froemel D, Rickert M, Rauschmann M, Fleege C. Geschichte des Wirbelkörperersatzes. Unfallchirurg [Internet]. 2015;118 Suppl 1(S1):73–9. Available from: http://dx.doi.org/10.1007/s00113-015-0084-x

10. Machino M, Yukawa Y, Ito K, Nakashima H, Kato F. Posterior/anterior combined surgery for thoracolumbar burst fractures--posterior instrumentation with pedicle screws and laminar hooks, anterior decompression and strut grafting. Spinal Cord [Internet]. 2011;49(4):573–9. Available from: http://dx.doi.org/10.1038/sc.2010.159

11. Singh A, Bali SK, Maji S, Ahuja K, Moger NM, Mittal S, et al. Short segment versus long segment posterior pedicle screws fixation for treatment of thoracolumbar burst fracture: A comparative prospective study. Asian J Med Res [Internet]. 2020;9(2):1–6. Available from: http://dx.doi.org/10.47009/ajmr.2020.9.2.or1

12. Korovessis P, Baikousis A, Zacharatos S, Petsinis G, Koureas G, Iliopoulos P. Combined anterior plus posterior stabilization versus posterior short-segment instrumentation and fusion for mid-lumbar (L2-L4) burst fractures. Spine (Phila Pa 1976) [Internet]. 2006;31(8):859–68. Available from: http://dx.doi.org/10.1097/01.brs.0000209251.65417.16

13. Tan T, Donohoe TJ, Huang MS-J, Rutges J, Marion T, Mathew J, et al. Does combined anterior-posterior approach improve outcomes compared with posterioronly approach in traumatic thoracolumbar burst fractures?: A systematic review. Asian Spine J [Internet]. 2020;14(3):388–98. Available from: http://dx.doi.org/10.31616/asj.2019.0203

14. Haher TR, Tozzi JM, Lospinuso MF, Devlin V, O'Brien M, Tenant R, et al. The contribution of the three columns of the spine to spinal stability: a biomechanical model. Paraplegia [Internet]. 1989;27(6):432–9. Available from: http://dx.doi.org/10.1038/sc.1989.69

15. Huque MH, Carlin JB, Simpson JA, Lee KJ. A comparison of multiple imputation methods for missing data in longitudinal studies. BMC Med Res Methodol [Internet]. 2018;18(1):168. Available from: http://dx.doi.org/10.1186/s12874-018-0615-6

Figure 1 a. Example of surgical treatment in group I (stand-alone posterior stabilization).
Figure 1 b. Example of surgical treatment in group I (stand-alone posterior stabilization).

Figure 2 a. Example of surgical treatment in group II (combined approach).
Figure 2 b. Example of surgical treatment in group II (combined approach).

Figure 3: Measurement of the sagittal index (SI) and loss of vertebral height (LVH) in a patient, 28 years old, with a T10 fracture after falling from a height (no suicide).a. The measurement of SI(left image at the presentation= 18.3° + 5°= 23.5°, middle image after dorsal stabilization= 9.1° + 5°= 14.1°, and right image after combined approach= 6.2° + 5°= 11.2°). **b.** The measurement of LVH(left image at the presentation= 12.3/0.5(20.6+26.2)= 0.526, middle image after dorsal stabilization= 15.7/0.5(21.1+26.5)= 0.660, and right image after combined approach=21/0.5(22.5+25.5)= 0.875).

Figure 4: The two groups' sagittal index (SI) at different time points. Time 0= at baseline, Time 1: after dorsal approach, Time 2: after adding anterior vertebral replacement (in the combined approach group), Time 3: at follow-up (a minimum of 3 months).

Figure 5: The two groups' loss of vertebral height (LVH) at different time points. Time 0= at baseline, Time 1: after dorsal approach, Time 2: after adding anterior vertebral replacement (in the combined approach group), Time 3: at follow-up (a minimum of 3 months).

Table 1: Baseline Characteristics in patients with spine injuries

Table 2: Radiological outcomes (SI and LVH) at follow-up per mixed regression analysis with adjustment to baseline values of SI and LVH between the two approaches

Table 3: Postoperative complications in two groups

Table 1: Baseline Characteristics in patients with spine injuries

Variable	Group I (Stand-alone stabilisation) N=32	Group II (Combined approach) N= 39
Age (mean±SD) in year	41 ± 16	42 ± 19
Sex (female/male)	10/22	19/20
Cause of injury Suicide-jumper Falling Traffic Other Trauma	 8 12 10 2	 9 14 11 5
Region of injury Thoracic (n) Thoracolumbar (n) Lumbar (n)	 5 19 8	 7 23 9
AO Classification A (n) B (n) C (n)	 30 2 0	 33 4 2
Initial Hemoglobin (mean±SD) in g/dl	12.50 ± 2.53	13.12 ± 1.62
Baseline SI (mean±SD) in °	11.58 ± 5.85	10.24 ± 6.44
Baseline LVH (mean±SD) in °	0.76± 0.17	0.71± 0.20
Follow-up (median, IQR) in months	4 (3-13)	6 (3-18)

Table 2: Radiological outcomes (SI and LVH) at follow-up per mixed regression analysis with adjustment to baseline values of SI and LVH between the two approaches

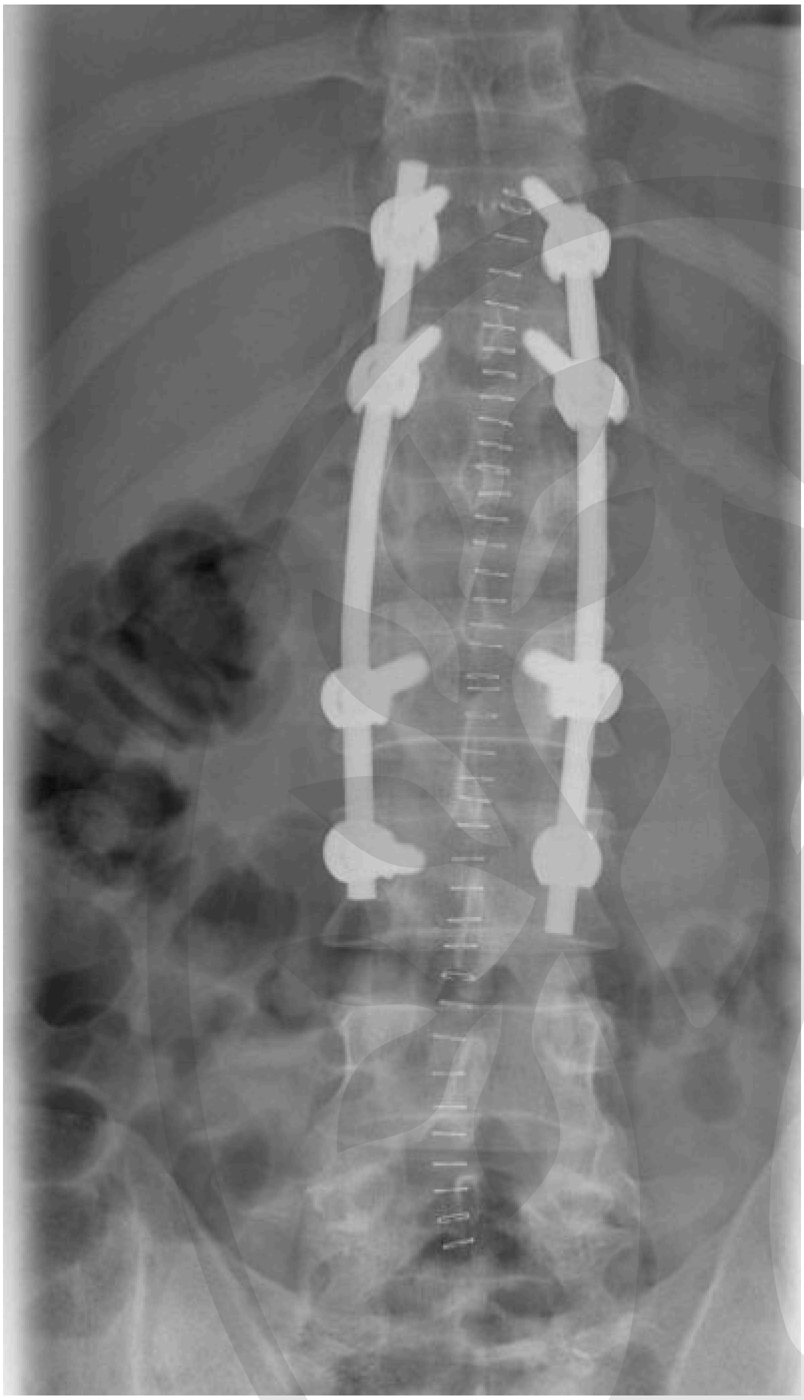
Outcome	Adjusted mean difference (Group II – Group I)*	95% CI	P-value
SI	-4.24§	-7.13 to -1.36	0.004
LVH	0.11§	0.02 to 0.20	0.02

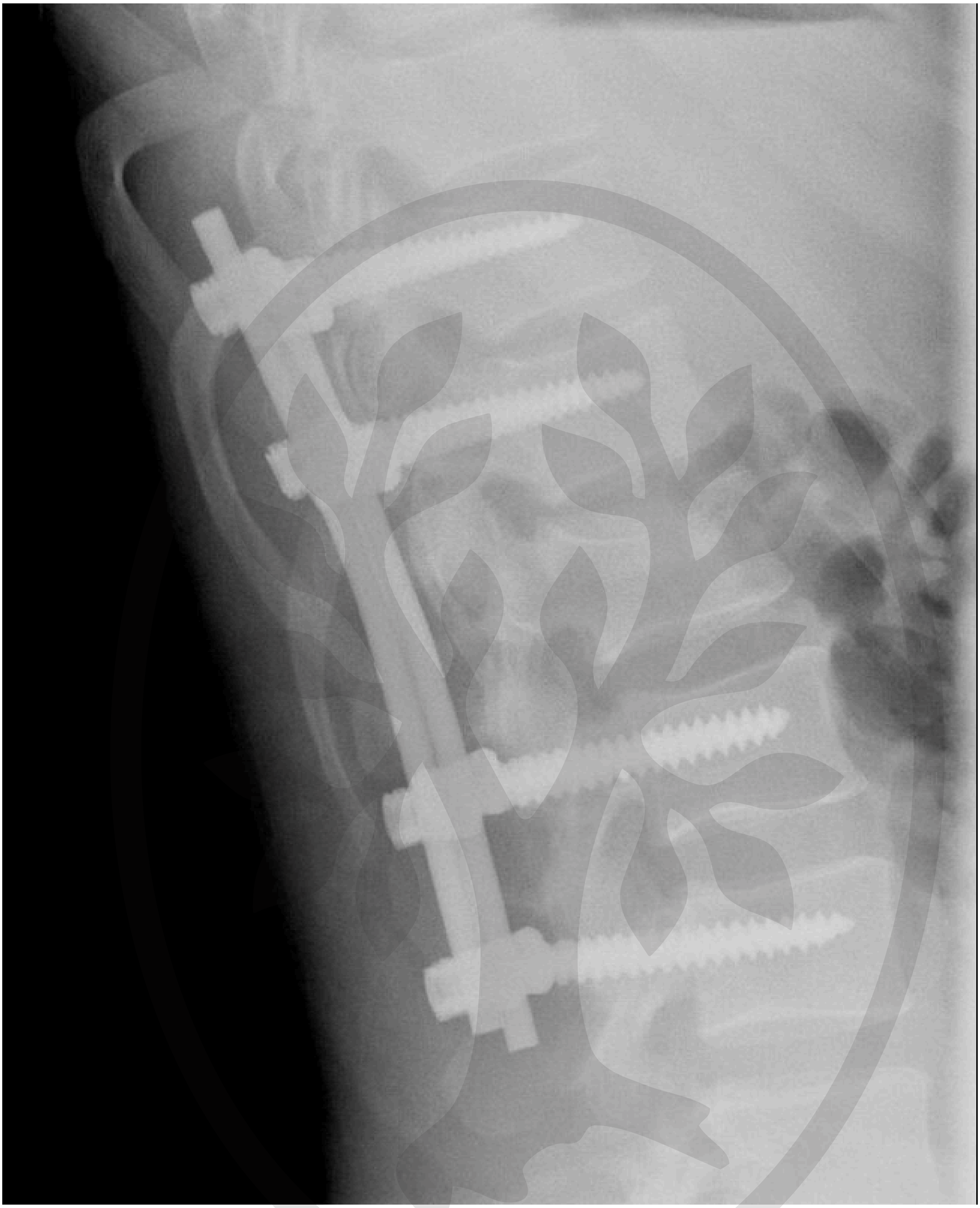
*: mean difference (SI in group II minus SI in group I) at follow-up calculated through a mixed regression model taking all outcomes measurements at different time points in the model with adjustment to the baseline values.

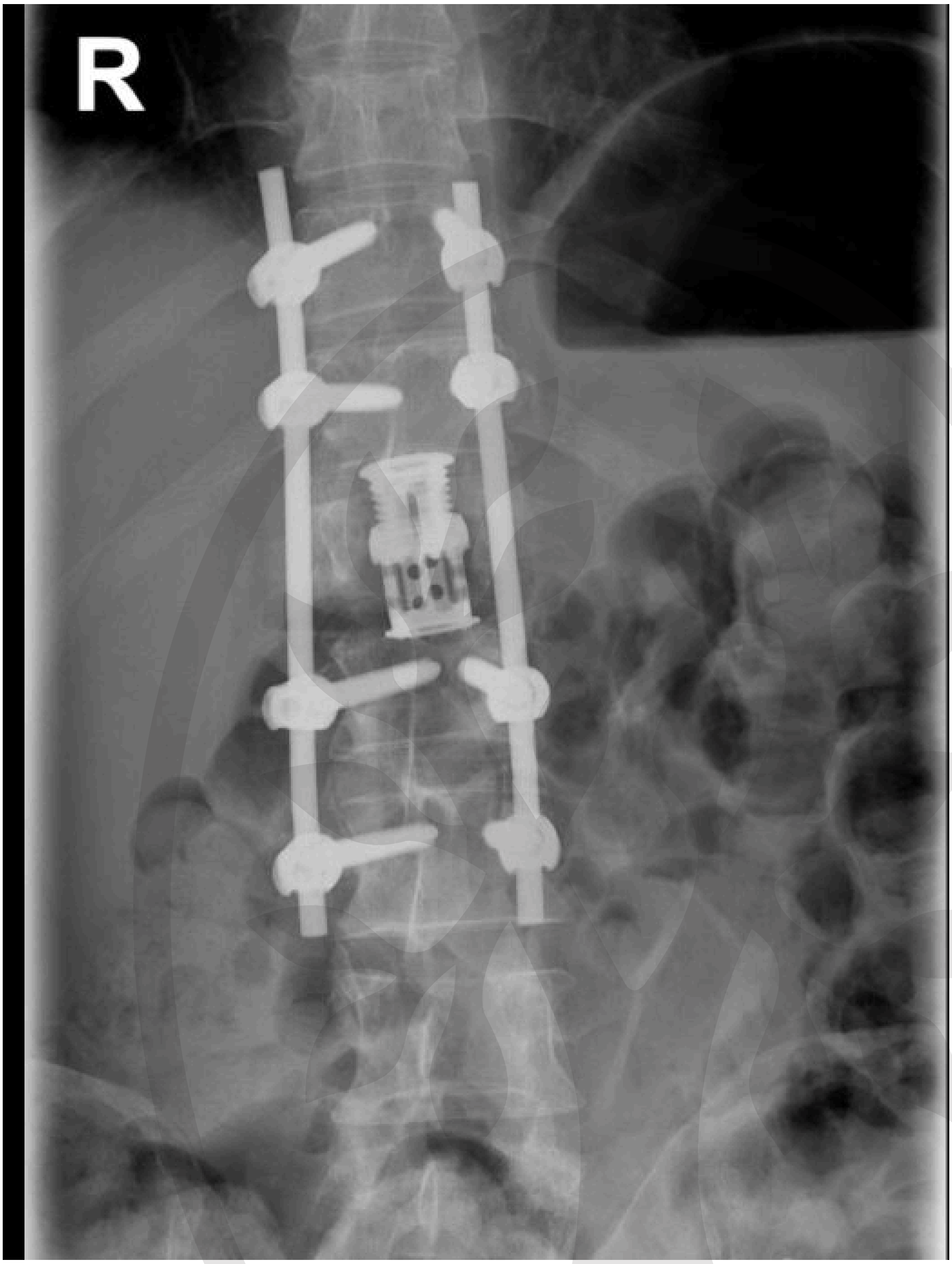
§: SI difference is negative, indicating that group II has less malalignment since the best SI should be zero. On the other hand, LVH is positive, indicating that group II has a better vertebral height since the best LVH is 1 (i.e. no loss of vertebral height).

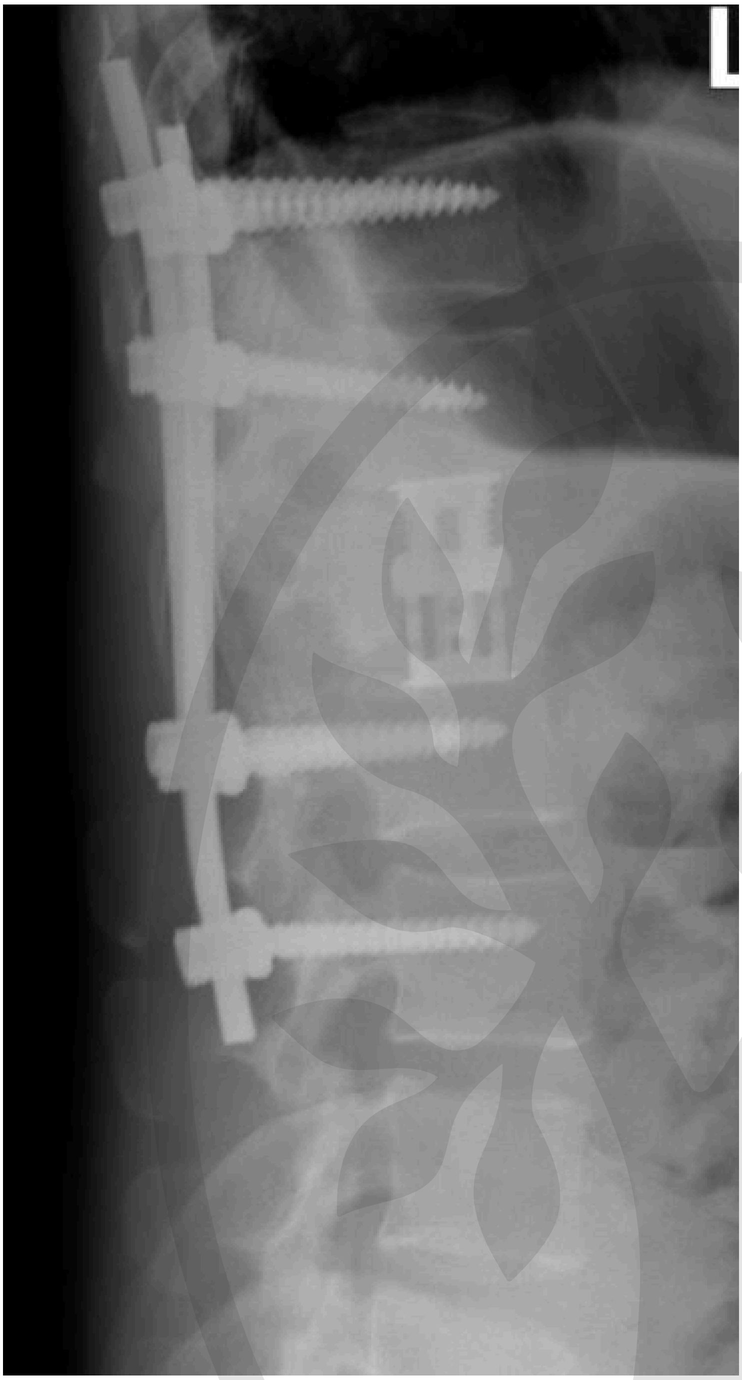
Table 3: Postoperative complications in two groups

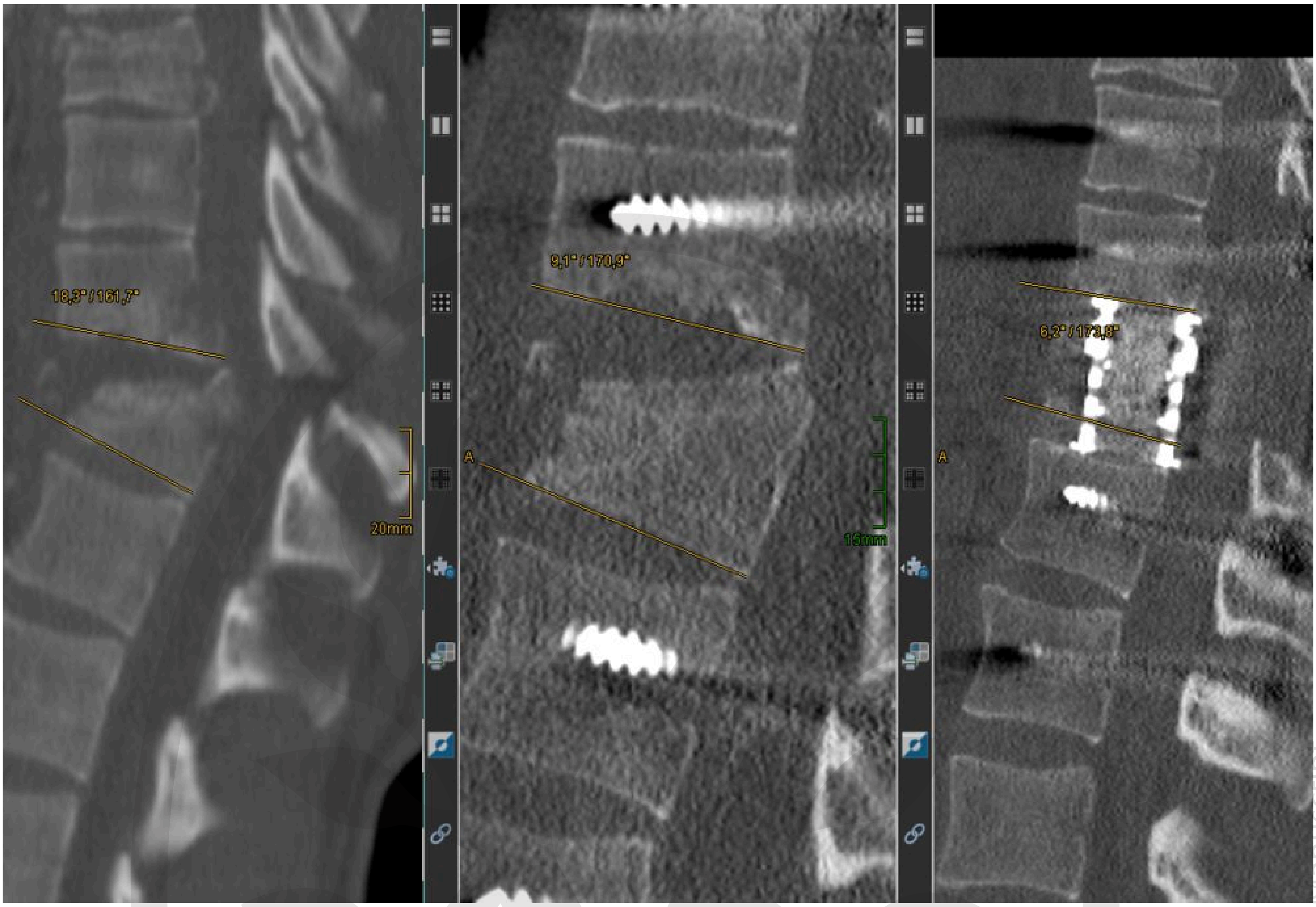
Group I (stand-alone posterior stabilisation)	Vertebra	Group II (combined approach)	Vertebra
1. Chronic back pain	L1	1. Pneumothorax	T9
2. Reoperation because of pedicle screw insufficiency	T11	2. Pneumonia.	L1
		3. Wound infection	L2
3. Reoperation because of the shortage of the fixation system	L1	4. Reoperation because of insufficiency of fixation system.	L4
4. Reoperation because of fixation system insufficiency	L2	5. Lung embolism.	T12

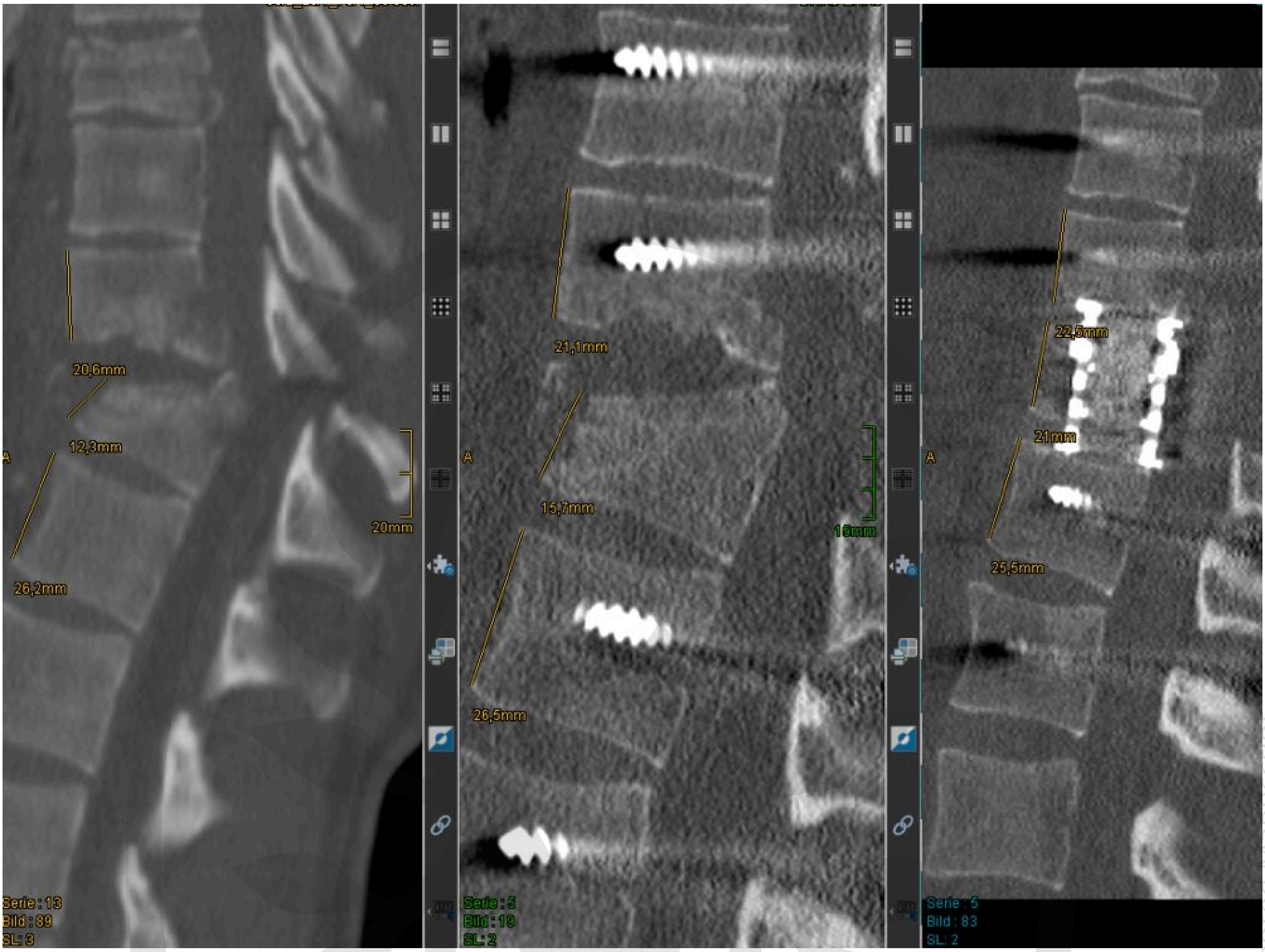


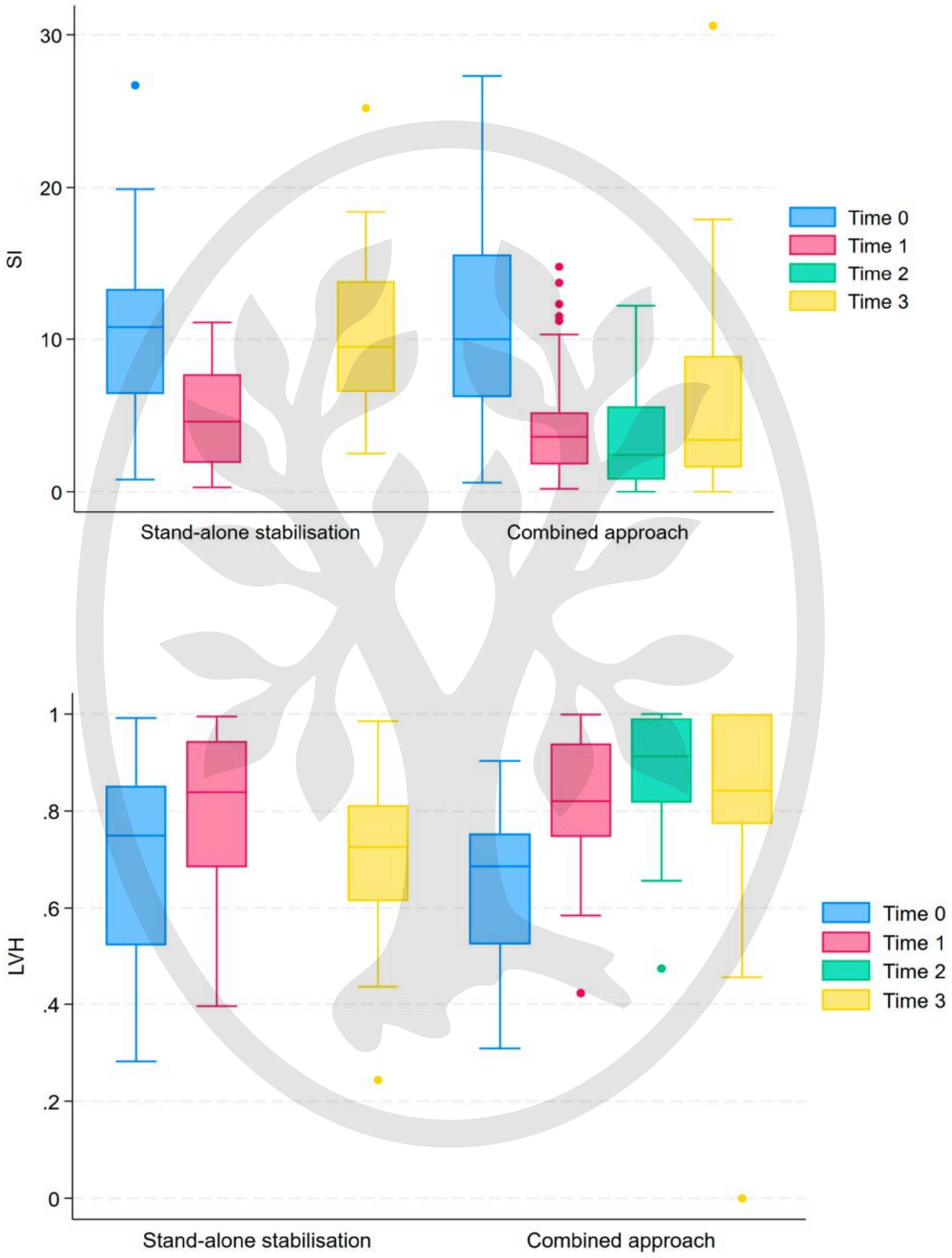



R




18,3° / 161,7°
20mm
9,1° / 170,9°
A
15mm
6,2° / 173,8°
A


20,6mm
12,3mm
26,2mm
20mm
Serie : 13
Bild : 89
SL: 3
21,1mm
15,7mm
26,5mm
Serie : 5
Bild : 19
SL: 2
22,5mm
21mm
25,5mm
Serie : 5
Bild : 83
SL: 2



30
20
10
0
SI
Time 0
Time 1
Time 2
Time 3
Stand-alone stabilisation
Combined approach
1
.8
.6
.4
.2
0
LVH
Time 0
Time 1
Time 2
Time 3
Stand-alone stabilisation
Combined approach