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EDITORIAL

Dear Colleagues,

Once again, I am honored and grateful to be the person responsible for publishing the 3rd issue of our professional journal this year. I sincerely appreciate the reviewers, assistant editors, secretaries and the Galenos Publishing House team for the efforts they put into getting this issue together. It includes seven clinical research studies. Please review it very carefully, and apply as many techniques, and as much new information as you can, into your practice.

The first is a retrospective study, "The Efficacy and Safety of Radiofrequency Neurotomy in the Treatment of Chronic Cervical Facet (zygapophyseal) Joint Pain: A Retrospective Study". The second one is entitled, "Assessment of the Medical Accuracy and Quality of Kyphosis Videos Shared on Social Media Platforms". The third is a clinical study, "Evaluation of Adolescents with Idiopathic Scoliosis Treated with Posterior Spinal Fusion". The following study is entitled "Cervical Proprioception and Vestibular Functions in Patients with Neck Pain and Cervicogenic Headache: A Comparative Study", while the fifth, is a clinical article investigating "Surgical Site Infection After Spinal Instrumentation: Review Of Pathogenesis, Diagnosis, Prevention And Treatment". The sixth is entitled, "Comparative Results in Hemivertebrectomy and Fusion Surgery Below and Above 10 Years of Age". In the seventh study, the authors evaluated "The Efficacy of *In Situ* Fusion for Low-Grade Spondylolisthesis: A retrospective Study".

I'd like to thank everyone, especially the reviewers, who worked to get this issue out to our colleagues. I hope everyone appreciates the amount of work and effort that goes into publishing these issues. Please incorporate all of the pertinent information included here into your practice. Our mission remains the same, to keep you abreast of all the latest developments in our field.

With kindest regards,

Editor in Chief
Metin Özalay, M.D.

ORIGINAL ARTICLE
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THE EFFICACY AND SAFETY OF RADIOFREQUENCY NEUROTOMY IN THE TREATMENT OF CHRONIC CERVICAL FACET (ZYGAPOPHYSEAL) JOINT PAIN: A RETROSPECTIVE STUDY

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ABSTRACT

Objective: To investigate the efficacy and safety of traditional radiofrequency ablation (TRFA) for the treatment of cervical facet-mediated pain. We evaluated 169 TRFA procedures performed on 64 patients who had clinical diagnoses of chronic cervical facet-mediated pain. TRFA was performed in patients who were refractory to conservative therapy and responded favorably to two sets of diagnostic medial branch blocks.

Materials and Methods: For patients who underwent TRFA, pain scores were recorded on a numeric rating scale (NRS) at different pre-treatment and post-treatment follow-up (FU) time points [1st (4-8 weeks), 2nd (>2-6 months) and 3rd (>6 months)]. The primary outcomes were NRS improvement and average improvement from baseline NRS (at least 50% or more) at each FU time point. The secondary outcome measure was the time to repeat treatment with subsequent cervical TRFA.

Results: The primary outcome measure was achieved in 1st FU time-point with 56.75% pain reduction. In the 2nd and 3rd FU, we found a 47.66% and 21.47% reduction in NRS, respectively. Our subgroup analysis of the age of the patients demonstrated that the younger (≤50) age groups showed superior pain relief with cervical TRFA in both the 1st and 2nd FU time points, with 58.36% and 53.46% reduction in NRS, respectively.

Conclusion: TRFA is an effective and safe procedure for the treatment of cervical facet-related pain in the early (<2 months) and intermediate terms (2-6 months). There was partial recurrence of pain in the long term (>6 months) in all age groups.

Keywords: Cervical pain, facet joint mediated cervical pain, facet radiofrequency ablation, neurotomy, zygapophyseal

INTRODUCTION

Chronic neck pain is a common and challenging health problem, leading to significant rates of disability and high economic costs[1]. The point prevalence rates of chronic neck pain vary between 6% and 22%[1-3]. The lifetime prevalence of chronic neck pain among the adult population was reported to vary from 14.2% to 71%, with an average of 48.5%[3].

Cervical spine-related pain may originate from multiple anatomical structures such as cervical zygapophyseal (facet) joints, intervertebral discs, nerve roots, dura, ligaments, fascia, and muscles. Upper neck pain and occipital headaches may originate from the upper cervical zygapophyseal joints, which are known as cervicogenic headaches[4]. Among the studies with diagnostic and controlled blocks, it has been shown that the cervical facet joints account for 50% to 60% of chronic neck pain cases[5-7].

Two important factors may serve as the reason for the high incidence of cervical facet joint pain in chronic neck pain: (a) the density of mechanoreceptors in cervical facet joints is higher compared to density in lumbar facet joints[8], and (b) cervical facet joints are susceptible to injury during trauma[9].

The success of minimally invasive pain interventions for cervical facet joint pain depends highly on the proper selection of patients based on clinical features. The level of diagnostic blocks must be planned using facet joint referral maps[10,11]. The research indicates that physical and neurologic examinations may not be effective in identifying the origins of symptomatic facet joint-related pain. Moreover, observation of facet joint arthrosis on plain radiographs, computed tomography, or magnetic resonance imaging may not be predictive of facet joint-related pain[11]. Controlled diagnostic medial branch blocks (MBB) are the main validated modality for the diagnosis of facet joint-related pain[12,13].

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Radiofrequency ablation (neurotomy) of the medial branch nerves with sensory innervation to the specific facet joints is among the best-validated treatments for facet joint-related pain[11,14]. When diagnostic blocks of the nerves with sensory innervation to the specific facet joints relieve the pain temporarily, radiofrequency ablation of the same nerves can be applied for prolonged benefits[12,15]. The evidence is level II in the management of neck pain with cervical radiofrequency neurotomy and level III to IV for cervicogenic headache[15,16]. This retrospective study aims to investigate the efficacy of traditional radiofrequency ablation (TRFA) for patients with the diagnosis of chronic neck pain originating from the cervical facet joints.

MATERIALS AND METHODS

This study was conducted at a single urban, academic pain medicine center specializing in the treatment of musculoskeletal disorders. The study was approved by the Institutional Review Board (IRB) (2023-0711), and the IRB waived the requirement for written consent. Data were collected by retrospective chart review.

We analyzed 169 consecutive cervical zygapophyseal (facet) joint radiofrequency ablation (neurotomy) procedures performed on 64 patients by a single practitioner in our institution from July 2011 to March 2023. Sixty-four patients who underwent the 169 procedures at different levels on separate occasions were treated as separate individuals in the results.

We performed TRFA procedures in eligible patients with a diagnosis of cervical facet joint pain who are refractory to conservative therapy. A written informed consent was obtained from each patient for the procedure. We evaluated the pain levels on the numeric rating scale (NRS), the duration for the requirement of repeat radiofrequency denervation at the same levels, and adverse effects from the procedure.

Pretreatment and posttreatment NRS were recorded prior to the procedure at 4 to 8 weeks (early), 2 to 6 months (intermediate-term), and 6 to 12 months (long-term) time points. Each patient's follow-up (FU) period was at least 12 months.

Patient Selection

Patients with neck pain refractory to conservative therapy for at least six months and fulfilling the inclusion criteria outlined below were recommended diagnostic MBB for the levels between C2 to T1 zygapophyseal joints, depending on the levels selected by the clinical and radiological evaluation of the patients. All patients who consented to this therapy underwent dual diagnostic MBB of the related facet joints. In eligible patients who responded to dual diagnostic medial blocks favorably (≥80% temporary pain relief consistent with the duration of the local anesthetic used) and consented to the procedure, the TRFA procedure was performed. All patients who underwent TRFA with documented FU in all predetermined time points were included in the study.

Inclusion Criteria

- Age between 18 and 85 years.
- ≥6 months history of non-specific cervical pain.
- Refractory to conservative treatment, including activity modification, home exercises, physical therapy, and medication management.
- Pretreatment pain levels of ≥5 in NRS.
- The following criteria make a preliminary clinical diagnosis of cervical facet-related pain:

a. Non-specific neck pain in the cervical spine.
b. Absence of cervical radiculopathy.
c. As indicated, X-rays, computed tomography, or magnetic resonance imaging studies were performed to exclude the possibility of pathology that was amenable to primary therapy.
d. Some of the examination findings are suggestive, but not an absolute requirement, for diagnosis of cervical facet joint mediated pain, such as reproduction of pain with palpation of the corresponding facet joints and extension maneuver of the cervical spine.

- The patients fulfilling the inclusion criteria outlined above were recommended diagnostic MBB.
- The area of pain was marked on the skin prior to MBB, and the actual spinal levels of MBB were determined under fluoroscopic counting of the corresponding levels. In each patient, diagnostic local anesthetic blocks of either 3 or 4 medial branches, corresponding to 2 or 3 facet joint levels, respectively, were performed.
- ≥80% temporary pain relief after dual diagnostic MBB with 0.5 mL of lidocaine 2% or 0.5 mL of bupivacaine 0.5% in two different sessions.

Exclusion Criteria

- Disc herniation, stenosis, myelopathy, cervical fracture, and suspected radiculitis.
- Previous history of spinal surgery at the level of intervention.
- Systemic or local infection.
- Coagulation disorder.
- Allergy to iodinated contrast.
- Rheumatic disorders.
- Malignancy.
- Pregnancy.
- An uncontrolled medical or psychiatric condition.

Statistical Analysis

The primary outcome measure was to report descriptive NRS pain score and average % improvement from baseline at each time point. A significant pain relief was determined by a decrease of at least 50% or more of mean NRS. Pain relief was also categorized as early relief at 4 to 8 weeks, intermediate-term relief at 2 to 6 months, and long-term relief at 6 to 12 months post-procedure. The secondary outcome measure, which is the duration of treatment, was quantified in terms of the time to repeat treatment with a subsequent TRFA. Adverse events were also recorded.

Sample size was determined empirically. To mitigate selection bias, all eligible patients from the hospital records were included in the cohort. Patient characteristics were summarized as count, mean, or ratio as appropriate to the context. Tables were utilized to report the changes in NRS scores and corresponding pain relief percentages, along with their mean values, standard deviations, 95% confidence interval bounds, and associated p-values observed across all patients during FU assessments. Distribution of pain scores and count levels was assessed using histograms. Analyses were conducted using SPSS 28.

MBB and TRFA Procedure

All patients underwent the procedure awake under local anesthesia. No sedatives were given before the procedures. Patients were positioned prone with a C-arm fluoroscopy with an anteroposterior view of the appropriate level of the spine. After local anesthetic was given for entry points, 22-gauge spinal needles were placed in the appropriate location described as cervical MBB in Spinal Intervention Society Guidelines[17]. All patients underwent diagnostic MBB of the related facet joints with 0.5 mL of lidocaine 2% or 0.5 mL of bupivacaine 0.5% in two different sessions. In eligible patients who responded to dual diagnostic medial blocks favorably (≥80% temporary pain relief consistent with the duration of the local anesthetic used) and consented to the procedure, the TRFA procedure was offered. In the TRFA procedure, 22-gauge, 5 or 10 cm, 5 mm active tipped TRFA electrodes were placed in the appropriate location similar to those described as cervical MBB in Spinal Intervention Society Guidelines[17]. After appropriate testing for sensory and motor components, 1 mL of Lidocaine 1% was injected through each needle prior to the TRFA procedure. Radiofrequency denervation was carried out at 70 °C for 90 seconds for each level (NeuroTherm NT2000iX RF Generator, Abbott, USA). No further medication was given at the procedure site post-procedure. All the procedures were done by the same fellowship-trained and board-certified interventional pain specialist with over 20 years of experience.

RESULTS

We evaluated the data from 169 TRFA procedures in 64 patients obtained during their pre-procedural and post-procedural FU visits. Data collected from the 1st (4-8 weeks), 2nd (>2-6 months) and 3rd (>6-12 months) FUs were used to determine the short- and long-term outcomes of cervical TRFA. The mean NRS scores were recorded and analyzed to quantify the average improvements in NRS. We also performed a subgroup analysis of the data based on age (≤50 versus >50). There were no complications reported in 169 procedures.

As shown in Figure 1 and summarized in Table 1, the majority of patients were female: 45 out of 64 patients were female with a mean age of 47.95; the remaining 19 patients were male with a mean age of 50.20. The overall age range was 24-70 years, with a mean of 48.66. As shown in Table 1, based on their symptoms, patients needed repeated TRFA procedures due to the presence of recurrent pain.

As shown in Table 2, the average NRS at baseline was 7.41 for all age groups. Improvement of pain was 56.75% (mean NRS: 3.18) in the 1st FU (4-8 weeks). In the 2nd FU (>2-6 months), there was a 47.66% improvement in the pain scores (mean NRS: 3.85). In the 3rd FU (>6-12 months), the recorded improvement of the pain scores was 21.47% (mean NRS: 5.57).

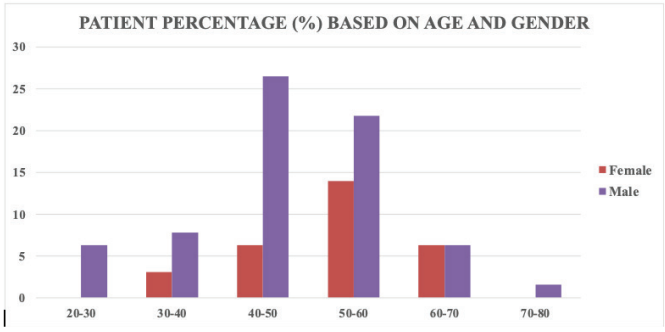

Figure 1. Patient percentage based on gender and age

Table 1. Descriptive statistics of the baseline demographic and procedural characteristics

	Number of patients	Mean age	Number of procedures	Percentage of procedures
Female	45	47.95	106	62.72
Male	19	50.20	63	32.28
All	64	48.66	169	100

Table 2. Changes in NRS scores and corresponding pain relief percentages, including mean values, SD, and 95% confidence interval bounds, observed across all patients during FU assessments

	NRS				Pain relief			
	Mean	SD	95% confidence interval		Mean	SD	95% confidence interval	
			Lower	Upper			Lower	Upper
Pre-TRFA	7.41	1.11	7.24	7.58				
1st FU	3.18	1.63	2.92	3.44	56.75%	20.55%	53.46%	60.03%
2nd FU (2-6 m.)	3.85	2.10	3.50	4.21	47.66%	29.00%	42.72%	52.59%
3rd FU (7-12 m.)	5.57	2.31	5.12	6.01	21.47%	37.79%	14.22%	28.71%

NRS: Numeric rating scale, SD: Standard deviation, FU: Follow-up, TRFA: Traditional radiofrequency ablation, m.: Month

We also performed a subgroup analysis of the data based on the age and pain scores of patients in different age categories (≤50 versus >50). Among the 169 TRFA procedures, there were 21 bilateral procedures (12.42% of the total). As shown in Table 3, distributions of bilateral procedures were similar in both age groups (10 for the ≤50 years group and 11 for the >50 years group). The remainder of the procedures were unilateral.

As we report in Tables 4 and 5, for both age groups, the pain relief was similar in the first (4-8 weeks) and 2nd FU (>2-6 months). Recurrence of pain was also similar in the 3rd FU (> 6-12 months). The average baseline NRS (pre-TRFA) level was 7.41. Baseline NRS levels were similar for both age groups (7.62 for ages ≤50 and 7.21 for ages >50).

• Our primary outcome measure was the adequate reduction of pain scores (50% or more). As shown in Table 4, our primary outcome was achieved in the first FU period in both age groups (58.36% and 55.42%, respectively). For ≤50 years-old patients', the pain reduction at the second FU (53.46%) also achieved our primary outcome, though this result is statistically weaker as observed by the p-values reported in the table. While the pain relief (43.15%) was also good for >50 years-old patients' in the second FU, our primary outcome of 50% or more pain relief was not met in this age group.

• Figure 2 and Table 4 show a partial recurrence of pain when compared to baseline NRS in the third FU period (>6-12 months) in both groups. For the ≤50 years-old patients' group, the pain level was 5.52 (indicating a 25.36% reduction), and for the >50 years-old patients' group, the pain level was 5.61 (indicating a 17.79% reduction). Note that the pain relief confidence intervals for the age groups ≤50 and >50 do intersect, indicating that the age difference does not make statistically significant difference in pain relief.

As reported in Table 5, there were 58 repeated radiofrequency neurotomy procedures: 25 (43.1%) of these were in the ≤50 age group, and 33 (56.9%) were in the >50 age group:

• Most of the repeated TRFA procedures were performed early: 25 of these procedures (10 for the ≤50 age group and 15 for the >50 age group) were performed between 6 and 12 months.

• Younger patients most frequently needed a repeated TRFA procedure between years 1 and 2 (13 procedures), while the

Table 3. Descriptive statistics of the procedural characteristics

	Unilateral	Bilateral	All
≤50 years	71	10	81
>50 years	77	11	88
All	148	21	169

Table 4. Changes in corresponding pain relief percentages, including mean values, standard deviations, 95% confidence interval bounds, and p-values observed across all patients during FU assessments

		Mean	SD	95% confidence interval		Significance	
				Lower	Upper	One-sided p	Two-sided p
1st FU	**A≤50**	58.36%	20.90%	53.34%	63.38%	<0.001	0.001
	A>50	55.42%	20.28%	51.02%	59.82%	0.008	0.016
	All	56.75%	20.55%	53.46%	60.03%	<0.001	<0.001
2nd FU (2-6 m.)	**A≤50**	53.46%	26.43%	46.57%	60.35%	0.159	0.319
	A>50	43.15%	30.26%	36.24%	50.06%	0.026	0.052
	All	47.66%	29.00%	42.72%	52.59%	0.175	0.349
3rd FU (7-12 m.)	**A≤50**	25.36%	33.60%	16.00%	34.71%	<0.001	<0.001
	A>50	17.79%	41.34%	6.61%	28.97%	<0.001	<0.001
	All	21.47%	37.79%	14.22%	28.71%	<0.001	<0.001

FU: Follow-up, SD: Standard deviation, m.: Month

Table 5. Requirement of repeated TRFA based on different age groups

	All	≤50 year	>50 year
<6 month	0	0	0
>6 month to 1 year	25	10	15
>1 year to 2 year	22	13	9
>2 year	11	2	9
Total	58	25	33

TRFA: Traditional radiofrequency ablation

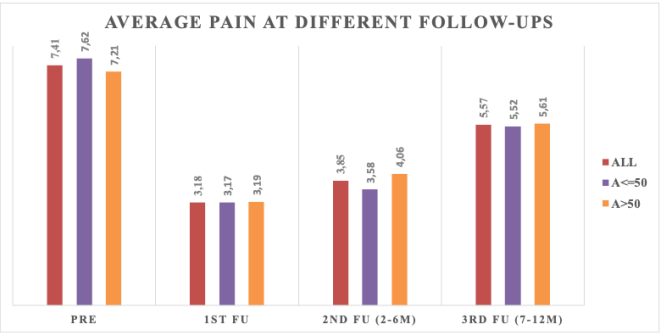

Figure 2. Average pain in different FUs based on age of patients age (≤50 vs. >50)
FU: Follow-up

older group needed repetitions earlier (6 months to 1 year, with 15 procedures).

• The longest duration of pain relief requiring repeated TRFA was 230 weeks for the age group ⩽50 and 228 weeks for the age group >50.

• The shortest duration of pain relief requiring repeated TRFA was 30 weeks for the age group ⩽50, and the longest duration was 25 weeks for the age group >50.

• No patients required a repeated procedure during the first six months.

Figure 3 presents the distribution of the levels for the TRFA applications. As we see in this chart, most TRFA applications were for the higher cervical levels (C2, C3, C4, and C5) for both the left and right sides. In particular, the C5 level received the largest number of ablations. Figure 4 shows the distribution of levels for different age groups; for all age groups, C2, C3, C4, and C5 levels received the largest numbers of ablations, with the 50-60 age group receiving the largest share of all ablations performed, followed closely by the 40-50 age group.

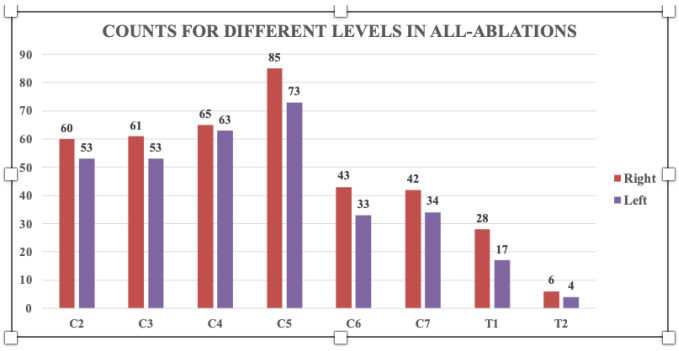

Figure 3. Distribution of the ablations performed at different cervical levels

DISCUSSION

There is strong evidence that TRFA/neurotomy of medial branches provides symptomatic relief for chronic pain originating from facet joints in the cervical and lumbar spine[18,19] (Figure 5 illustrates both the anteroposterior and lateral fluoroscopic images of cervical TRFA). However, certain limitations about the efficacy of this therapy for spine-related pain have also been reported[20-23], and long-term relief with this therapy may require repeated neurotomy[24-27]. The majority of chronic neck pain patients can experience 80%-100% pain relief for up to a year after the application of TRFA[24,28]. A major source of failure for the radiofrequency ablation (RFA) technique in cervical applications is the false-positive responses to diagnostic blocks[29,30]. False-positive rates in the case of single blocks can be up to 63%[31]. Several other factors might contribute to failures, including inadequate patient selection, inaccurate surgical anatomy, and technical errors[32].

In our retrospective study, we report the outcomes of cervical TRFA procedures that were applied to the patients who were refractory to conservative therapy and responded favorably to two sets of diagnostic MBB. Our results showed that cervical TRFA is effective in the early period, with more than a 50% reduction in NRS. Sixty-four patients included in our study have received significant short-term pain relief (56.75% decrease in NRS, pre-treatment NRS=7.41 vs. 1st FU NRS=3.14). During longer-term FUs (6-12 months), the mean NRS value was 5.57 (21.47% decrease in NRS with respect to the baseline). Younger patients (⩽50 years of age) have received the most significant pain relief in all FU time points. However, it's noteworthy that the confidence intervals for pain relief in the age groups ⩽50 and >50 overlap (Table 4), suggesting that there is no statistically significant difference in pain relief based on age.

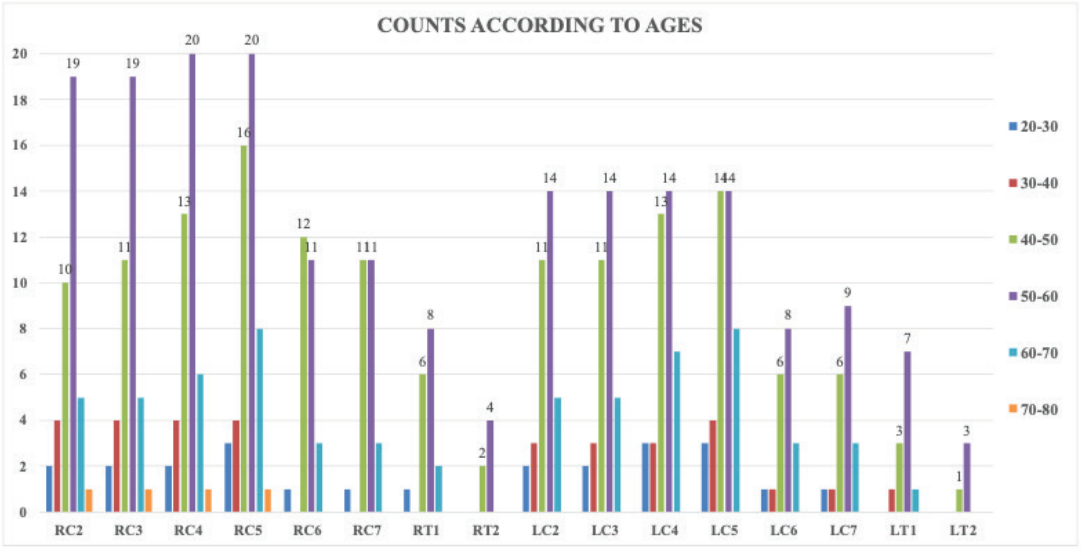

Figure 4. Distribution of the ablations performed at different cervical levels for different age groups

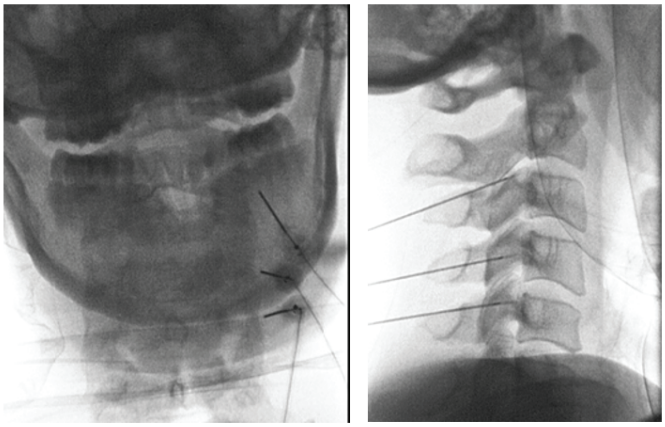

Figure 5. The anteroposterior (left) and lateral (right) fluoroscopic views of cervical TRFA are shown
TRFA: Traditional radiofrequency ablation

In a study, Burnham et al.[33] indicated that in patients who had temporary improvement with dual concordant MBB of corresponding facet joints, subsequent application of cervical TRFA was an effective treatment modality[33]. This study included 50 patients, and the results demonstrated an overall 50% pain reduction rate of 54%. While the results of this study were similar to our results, they used a different mixture of ablation techniques (80% cooled RFA and 20% TRFA).

Barnsley[34] presented the results of their study that showed that radiofrequency neurotomy was an effective treatment for chronic cervical zygapophysial joint pain. This study evaluated the outcomes of percutaneous radiofrequency neurotomy of 47 procedures performed on 35 patients with chronic neck pain[34]. In this study, 80% of the procedures achieved significant pain relief lasting a mean duration of 36 weeks. In another study, Lord et al.[34] demonstrated that radiofrequency neurotomy provided long-lasting relief (with a median time of 263 days to the return of at least 50% of the preoperative level of pain) in a moderate proportion of the patients. In our study, we observed repeated TRFA procedures were applied most frequently between 6 and 12 months, which supports both studies[33,34].

MacVicar et al.[24] reported the results of a study where 66% of cervical RF patients achieved complete pain relief, restoration of activities of daily living, and return to work[24]. The authors also reported that the patients who responded well to TRFA did not need additional therapy for neck pain for a median duration of 17-20 months. In our study, there was a recurrence of pain in all groups after six months (all patients: 21.47%; age≤50: 25.36%, age>50: 17.79%), and TRFA procedures were most frequently repeated between 6-12 months (the highest rate of repeated procedures was between 6-12 months for the younger patients (age≤50), and between 1-2 year for patients older than 50).

In the published consensus practice guidelines on interventions for cervical spine (facet) joint pain[12], cervical facet joints are indicated as the primary source of pain in 25-67% of chronic neck pain patients. Cooper et al.[10] reported cervical zygapophysial joint pain maps based on areas in which patients are relieved of pain by controlled blocks. According to their results, C2-3 (36%) and C5-6 (35%), followed by C6-7 (17%) joints are the most common sources of neck pain. According to published facet joint pain referral maps[10,11], while upper cervical pain with headache is most likely attributable to the C2-3 facet joint, lower cervical pain more likely originates from C5-6.

In our study, upper cervical facet joints (C2-3, C3-4, C4-5) were more symptomatic than the lower cervical facet joints, including the upper thoracic facet joints. Among all repeated injections, the most frequently ablated medial branches were right C5 and left C5, followed by right C4 and left C4. In our study, patients between ages 40 and 60 had the largest number of TRFA applications, and the most frequently ablated levels were the upper cervical levels, C2, C3, C4, and C5 in this age group.

Our study's primary limitation lies in its retrospective design, which prevents effective FU of each patient. Moving forward, conducting prospective studies with control groups is crucial to validate our findings. Prospective studies allow for comprehensive evaluation of all patients across all FU periods, providing invaluable insights. Therefore, we recommend conducting prospective randomized controlled studies with larger sample sizes to maximize the value of the results obtained.

CONCLUSION

This retrospective clinical study was designed to evaluate the efficacy of TRFA for facet joint-related pain in the cervical spine. Our data indicates that TRFA is a safe and effective treatment for cervical facet joint-related pain lasting for at least six months. Partial recurrence of pain between 6 and 12 months was observed in all age groups, requiring repeated TRFA procedures.

Ethics

Ethics Committee Approval: The study was approved by the Hospital for Special Surgery Institutional Review Board (approval number: #2023-0711, date: 05.08.2023) and patients provided written informed consent for the procedure from the participants involved.

Informed Consent: Retrospective study.

Authorship Contributions

Surgical and Medical Practices: S.G., Concept: B.C., S.G., Design: B.C., S.G., Data Collection or Processing: B.C., S.G., Analysis or Interpretation: B.C., S.G., Literature Search: B.C., S.G., Writing: B.C., S.G.

Conflict of Interest: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study received no financial support.

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ASSESSMENT OF THE MEDICAL ACCURACY AND QUALITY OF KYPHOSIS VIDEOS SHARED ON SOCIAL MEDIA PLATFORMS

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ABSTRACT

Objective: This study aims to evaluate the accuracy and quality of videos about kyphosis by analyzing posts about the disease on social media using a scoring system.

Materials and Methods: We searched the word "kyphosis" in the search engine of relevant social media sites. The Global Quality Score (GQS), the Journal of American Medical Association (JAMA) score, Kyphosis Specific Score, DISCERN, and Video Power Index (VPI) scales were used to analyze the quality and accuracy of the medical posts.

Results: YouTube was the most common media for video posts and had the highest GQS, JAMA, and DISCERN scores (1.87, 2.18, 41.2). YouTube videos had significantly higher correlations with JAMA, GQS, and DISCERN ($p<0.01$). Facebook videos showed a moderate correlation between JAMA criteria GQS ($p=0.724$, $p<0.001$) and DISCERN ($p=0.568$, $p<0.01$). A high correlation was observed between GQS and DISCERN ($p=0.713$, $p<0.01$). The social media outlet with the lowest scores was Instagram, with JAMA 1.4 (±0.93), DISCERN 27.4 (±15.7), GQS 2.52 (±1.15), and VPI 264.2 (±180.9).

Conclusion: Videos on YouTube and Facebook were found to have better medical quality. It is evident that there is a need to establish strategies for integrating social media into future patient education to align with the contemporary era of information exchange.

Keywords: Kyphosis, social media, accuracy of medical posts

INTRODUCTION

The use of the social media in daily life is increasing[1]. The rapid proliferation and transfer of information on social media offers new opportunities for patients or their relatives to learn about their medical conditions before visiting a specialist and to connect with others who have the same experience[2-5].

With the use of the internet and the increase in knowledge, people have access to medical information much more than in the past[4]. Orthopedic surgery, which has a wide range of patients from the neonatal period to the geriatric period, has been affected by these developments. Prior research has documented the frequency of internet and social media utilization among orthopedic patients[6-8]. Of the visual materials used to create content on social media, videos in particular are more engaging in terms of reaching communities with relevant information and interactivity. However, despite the richness of the sources, the timeliness and accuracy of the information in them can be questionable. Most of the content owners who post on social media environments may provide misleading information in their videos and often do not go through any editorial process, thus raising the important problem of credibility.

Kyphosis is a deformity of the thoracic spine that can be caused by various factors such as trauma, degeneration, inflammatory conditions, or infections. While there are studies on the quality of videos on various medical problems on social media, there are very few reports on the quality of videos related to the spine, especially kyphosis, which is distributed among different age groups[9-12]. However, it was observed that the previous study on kyphosis was evaluated only on the YouTube platform[9].

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In our study, we aimed to evaluate the medical accuracy and quality of kyphosis-related videos shared in videos uploaded on YouTube, Facebook and Instagram platforms, which contain large user groups and sharing on the internet.

MATERIALS AND METHODS

In order to obtain data independent of search algorithms, an e-mail account that had not been used before was created and accounts were opened on Facebook, YouTube, and Instagram. On October 07, 2023, an inquiry was made in the search engine of pertinent social media platforms on the term "kyphosis". Videos in languages other than English and republished videos were excluded. The first 50 videos among the search results were included in the study and characteristics such as video duration, number and rate of views (number of views/day), number and rate of likes [such as 100/(dislike)], and by which person/organization the video was uploaded were recorded. The present study also investigated the metric of daily views (total views divided by total online days), a variable that has not been previously operationalized or utilized in prior research. With this parameter, the popularity and usability among internet users independent of platforms was questioned.

The Journal of American Medical Association (JAMA) score[8], Global Quality Score (GQS)[13], Quality Criteria for Consumer Health Information (DISCERN) and Video Power Index (VPI) scales were used[14,15]. There is a scarcity of publications that employ all four scales concurrently[16-19]. However, there is no study comparing videos from three different platforms analyzed in our study in terms of kyphosis.

In addition, although the original VPI formula was (number of likes/dislikes + number of likes) x 100, the formula was changed to (number of likes/number of views) x 100 since the numbers in the number of dislikes were hidden after the policy change on YouTube. For the sake of objectivity, it was used the same way on all social media accounts[12].

Previous research has often excluded factors like view counts and the duration of related video content due to their low occurrence, or because the video source content and groups are highly fragmented. Therefore, it is conceivable that such distinctions may manipulate the data obtained in the comprehensive comparison of video algorithms. To maintain homogeneity and statistical robustness in our study's results, we applied exclusion criteria such as short video duration, a low count of likes and views, and simplified the categorization of source and content groups.

Videos were divided into five categories based on their content and source. Source-based categories were 1) academic (the uploader was affiliated with an institute/research group), 2) physician (the individual or group responsible for uploading the content lacked affiliation with any academic institution or research organization), 3) non-physician (physiotherapists, massage therapists, non-health professional trainers and alternative medicine providers), 4) patient, and 5) commercial. Content-based categories were 1) information about the disease, 2) exercise education, 3) treatment of the disease, 4) patient experiences, and 5) advertising. This study did not require ethics committee approval because it was conducted as an internet-based research and did not involve the collection of personal or sensitive data from participants.

Statistical Analysis

The data files underwent processing and analysis utilizing SPSS v.25 (IBM Corp, Armonk, NY). The correlation between date was investigated through the utilization of social media platforms (YouTube, Facebook and Instagram). The study aimed to compare values, specifically popularity and medical knowledge, across different publication sources and social media platforms. Mann-Whitney U test was used for non-normal distribution. The Spearman's correlation tests were used to examine the associations between the parameters. The chosen level of significance was established at a p-value of less than 0.05.

RESULTS

The first 200 (4x50) videos that met the criteria on the three social media platforms were included. All videos on these platforms were analyzed separately for source and content type (Tables 1-3). Cross-correlations with JAMA, GQS, VPI and DISCERN were then performed (Table 4).

A) YouTube

When 50 YouTube videos were analyzed, the mean duration was 843 seconds (±1203), the number of views per day was 1995 (±631), the number of views was 712,352 (±516,024), and the scores were JAMA 1.87 (±0.98), GQS 2.1 (±0.66), VPI 154.2 (±159.2) and DISCERN 41.2 (±20.7). The distribution by source was academic 6%, physician 31%, trainer 48%, patient 8% and commerical 7%. In terms of content, the percentages were information 33%, exercise training 37%, treatment 23%, patient experience 5% and advertising 2%.

YouTube videos showed a high correlation between JAMA criteria GQS ($p=0.812, p<0.001$) and DISCERN ($p=0.605, p<0.001$). However, a high correlation was observed between GQS and DISCERN in videos on this platform ($p=0.753$, $p<0.001$). A high correlation was observed between the number of daily views and JAMA ($p=0.691$, $p<0.001$) and a moderate correlation was observed between the VPI ($p=0.372$, $p<0.001$) score.

When compared depending on the source, a significant difference was found in JAMA ($x^2=5.84$, $p=0.046$), GQS ($x^2=6.52$, $p=0.049$), and duration ($x^2=9.57$, $p=0.023$). The academic and trainer groups were found to have higher JAMA scores than the others ($w=-3.725$, $p=0.043$, $w=-4.04$, $p=0.029$). The academic group had the highest GQS and DISCERN values ($w=3.212$, $p=0.044$) and was found to have much higher ratings than the other groups ($w=-3.5134$, $p=0.052$). However, longer videos were shared in this group than others ($w=3.69$, $p=0.013$).

JAMA scores differed significantly when content was considered (x^2=13.47, p=0.012), GQS (x^2=8.15, p=0.016), DISCERN (x^2=12.28, p=0.039). Informational videos were high in all scores compared to the other content groups [JAMA (w=-4.154, p=0.017), DISCERN (w=-3.856, p=0.029) and GQS (w=-3.988, p=0.025)]. However, for patient experience videos, JAMA (w=-4.771, p=0.004), DISCERN (w=-4.126, p=0.017) and GQS (w=-4.656, p=0.011) were significantly lower.

B) Facebook

When 50 Facebook videos were analyzed, the average duration was 325 seconds (±391), daily views were 751 (±1350), the number of views was 152,213 (±616,243), and the scores were JAMA 1.53 (±0.71), GQS 1.91 (±0.65), VPI 127.7 (±207.2) and DISCERN 31.9 (±13.9). The distribution by source was academic 4%, physician 34%, trainer 44%, patient 12%, commerical 6%. In terms of content, information was 29%, exercise training 33%, treatment 14%, patient experience 23% and advertising 1%.

Facebook videos shown a moderate correlation between JAMA criteria GQS (p=0.724, p<0.001) and DISCERN (p=0.568, p< 0.001). A strong positive association was identified between the Global Quality Scale (GQS) and the DISCERN (p = 0.713, p< 0.001). However, a high correlation was observed between daily viewing and VPI (p=0.693, p<0.001).

When analyzed by video source, a significant difference was observed between JAMA (x^2=7.90, p=0.042) and GQS (x^2=6.67, p=0.044). The posts in the Tranier group were found to have higher JAMA and GQS scores than the others (w=-3.886, p=0.046, w=-3.99, p=0.039). Likewise, this group's posts received significantly more likes than the others (w=-3.7659, p=0.039).

Table 1. Scoring table of YouTube videos

	JAMA	DISCERN	GQS	VPI
Video source				
Academic	3.5±0.8	71.2±39.4	5.2±0.5	17.83±7.51
Physican	2.17±0.83	65.3±15.6	2.23±0.9	479.5±932.3
Nonphysician	3.29±0.8	36.8±7.9	3.86±0.79	103.1±87.4
Patient	1.1±0.3	27.4±5.4	1.4±0.5	28.2±43.3
Commerical	1.3±0.1	32.2±10.3	1.2±0.41	86.7±5.32
Video content				
Information	1.86±1.36	37.1±12.7	3.11±0.89	40.4±117.2
Exercise training	1.34±0.71	26.3±7.33	1.52±0.73	97.1±178.4
Treatment	1.61±1.1	31.4±12.3	1.34±0.82	463.3±416.8
Patient experience	1.2±0.7	33.1±9.4	1.1±0.4	55.1±64.4
Advertisement	1±0.2	1.2±0.2	1.0±0	37.2±87.5
Total	1.87±0.98	41.2±20.7	2.1±0.66	195.6±207.2

JAMA: Journal of American Medical Association, DISCERN: Quality Criteria for Consumer Health Information, GQS: Global Quality Score, VPI: Video Power Index

Table 2. Scoring table of Facebook videos

	JAMA	DISCERN	GQS	VPI
Video source				
Academic	1.51±0.4	67.2±32.3	2.1±0.3	30.3±11.5
Physican	0.97±0.8	31.2±9.5	1.65±0.9	242.7±656.8
Trainer/physiatrist	3.1±0.7	53.3±14.1	4.6±0.8	124.3±84.6
Patient	1±0.2	17.3±3.4	1.1±0.7	43.7±51.2
Commerical	1.2±0.3	23.2±13.3	1.4±0.61	88.3±16.7
Video content				
Information	1.67±1.52	27.2±15.1	2.82±0.44	54.3±90.3
Exercise training	1.54±0.62	23.1±14.6	1.31±0.85	126.8±173.5
Treatment	1.81±1.4	21.9±9.7	1.04±0.75	544.3±441.6
Patient experience	1±0.6	22.8±13.5	1.2±0.6	75.3±97.5
Advertisement	1±0	1±0.2	1.1±0	47.5±97.1
Total	1.53±0.71	31.9±13.9	1.91±0.65	127.7±180.9

JAMA: Journal of American Medical Association, DISCERN: Quality Criteria for Consumer Health Information, GQS: Global Quality Score, VPI: Video Power Index

Considering the content, the informational videos group JAMA (w=-4.154, p=0.017) had significantly different GQS scores (x^2=9.24, p=0.026) and was the highest scoring group. Treatment videos had higher daily viewing and VPI values than the others (w=2.8818, p<0.050). Patient experience videos had lower DISCERN values (w=-2.813, p=0.019). Surgery videos received more likes than others (w=3.522, p=0.05).

C) Instagram

When 50 Instagram videos were analyzed, the mean duration was 41.2 seconds (±24.9), daily views were 6371 (±12,388) and the number of views was 68,123 (±78045). When the scores were analyzed, JAMA was 1.4 (±0.93), DISCERN 27.4 (±15.7), GQS 2.52 (±1.15), VPI 264.2 (±180.9). The distribution by source was academic 1%, doctor 27%, trainer 35%, patient 31% and commercial 3%. In terms of content, information was 26%, exercise training 39%, treatment 6%, patient experience 28% and advertisement 1%.

A moderate correlation was seen between the DISCERN and GQS in videos on this platform (p=0.652, p=0.043). Similarly, there was a moderate correlation between JAMA criteria and GQS (p=0.176, p=0.050). There was no association between the number of views per day and all video quality assessment scores.

There was a significant difference between GQS (x^2=10.26, p=0.038), DISCERN (x^2=8.47, p=0.045) depending on the source. Trainer group posts were viewed more daily than others (w=4.452, p=0.027). Academic and physician groups had higher GQS values than others (w=3.235, p=0.05). The posts made by the physician group appeared to garner a higher number of likes compared to those made by other groups (w=5.354, p=0.044).

When content groups were evaluated, there was a significant difference in DISCERN (x^2=9.653, p=0.037) and GQS (x^2=10.102, p=0.033). It was clear that the information group received more daily views and GQS values than the others (w=-2.145, p<0.001,

Table 3. Scoring table of Instagram videos

	JAMA	DISCERN	GQS	VPI
Video source				
Academic	1.82±0.89	36.6±26.9	5.1±0.9	14.21±5.35
Physican	2.7±2.15	51.5±17.4	6.2±2.8	609.2±1422.1
Trainer/physiatrist	0.95±0.52	34.6±13.3	2.3±1.7	126.4±106.2
Patient	0.62±0.49	12.0±6.5	1.3±1.1	34.52±51.2
Commerical	0.76±0.47	13.9±10.3	1.7±0.6	94.6±3.41
Video content				
Information	1.20±1.4	36.4±13.8	3.5±1.61	52.4±169.5
Exercise training	1.56±0.63	18.7±10.1	1.37±0.79	117.2±241.4
Treatment	1.1±0.83	16.2±9.3	0.8±0.45	751.3±347.2
Patient experience	0.9±0.74	13.1±16.6	0.6±0.41	64.6±85.7
Advertisement	1.4±0	16.3±7.4	0.9±0.62	49.3±117.1
Total	1.4±0.93	30.4±18.8	2.52±1.15	264.2±249.2

JAMA: Journal of American Medical Association, DISCERN: Quality Criteria for Consumer Health Information, GQS: Global Quality Score, VPI: Video Power Index

Table 4. Correlations of scales on which videos are rated on social media sites

Platform		JAMA	GQS	DISCERN	VPI
YouTube	JAMA	–	++	++	–
	GQS	–	–	+++	–
	DISCERN	–	–	–	–
	VPI	–	–	–	–
Facebook	JAMA	–	++	–	–
	GQS	–	–	++	–
	DISCERN	–	–	–	–
	VPI	–	–	–	–
Instagram	JAMA	–	+++	++	–
	GQS	–	–	+++	–
	DISCERN	–	–	–	–
	VPI	–	–	–	–

+: Low correlation, ++: Medium correlation, +++: High correlation, JAMA: Journal of American Medical Association, DISCERN: Quality Criteria for Consumer Health Information, GQS: Global Quality Score, VPI: Video Power Index

w=-3.897, p=0.017). Exercise videos appeared to receive more likes than others (w=-4.332, p<0.001) and were found to have higher DISCERN scores (w=6.835, p=0.021).

Overall, the study found moderate to strong significant correlations among the JAMA, GQS, and DISCERN scores. However, there was no significant correlation between the VPI and the other scales. These findings can be analyzed using the cross-correlation table with score systems, as shown in Table 3.

DISCUSSION

A simple Google search for the term "kyphosis" yields 212,000 video links. This large volume of data may suggest that the accuracy and quality of the content could be questionable. For this reason, there are many studies examining the accuracy of information sharing, diversity of content and reliability of sources by evaluating the content available on social media platforms[6-8].

However, it can be considered that the content uploader or the content itself is as important as the search algorithms that form the ranking order of how the posts are displayed to the user. Social media algorithms are constantly being developed and updated to enhance the user experience and encourage interaction between content producers and users. Each platform has its own specific algorithm structure and priorities, so the ranking order of content may differ between platforms.

Our study examined the content quality and diversity of videos about kyphosis on different platforms. We also compared the available algorithms and identified different patterns in how evaluation scores such as JAMA, GQS, VPI and DISCERN differ between these platforms. Ensuring that high-quality, accurate medical content is available and easily accessible on these platforms can enhance patient education, improve disease management, and support better clinical outcomes. Therefore, healthcare professionals and organizations should consider focusing their efforts on platforms with higher engagement and better information quality to disseminate reliable health information effectively.

It has been noted that videos on kyphosis on the YouTube platform tend to have the longest duration and attract a significant audience. In a study, the average JAMA score of YouTube videos was determined as 1.36 and the GQS score was 1.68[9]. Similar scores were calculated in our study (JAMA 1.87, GQS 2.1). The high correlation of YouTube videos with JAMA, GQS and DISCERN criteria suggests that this platform has an important role in sharing health information in terms of both reliability and content quality.

When we looked at the content providers, it was observed that the trainer group uploaded the most content with 48%, and at the same time, 37% of the content consisted of exercise videos. This finding reflects that the trainer group plays an important role by providing practical guidance on kyphosis and that the community is interested in exercise-based approaches. Similarly, Erdem and Karaca[9] reported that the highest content uploading group was trainers with 36% and exercise videos with 46%, and that exercise videos attracted more attention in the community.

However, exercise videos had lower scores than informational videos in all scores except VPI (JAMA 1.34, DISCERN 26.3, GQS 1.52, VPI 97.1). Therefore, it can be concluded that the need for improvement in quality standards should not be ignored.

A noteworthy point in terms of content providers is that the academic group, which constituted 6% of the content providers, had the highest scores in all scoring (JAMA: 3.5±0.8, DISCERN: 71.2±39.4, GQS: 5.2±0.5) except for VPI (14.21±5.35). This may indicate that the academic group prioritizes quality over quantity in order to ensure information accuracy and reliability. However, YouTube's algorithm may prioritize science-based content, information from official health organizations, and expert opinions more when ranking videos by evaluating factors such as users' viewing history, interactions, viewing time, and keywords.

Facebook videos show moderate correlations between JAMA, GQS and DISCERN scores when compared to other platforms. In addition, there are high correlations between the number of daily views and VPI and DISCERN scores.

Ng et al.[20] found an average scoliosis-specific content score of 5.7 (0-20) and DISCERN score of 22.5 (16-45) in their content quality study on scoliosis and reported that the quality of information provided was generally poor. Although a higher DISCERN score (31.9±13.9) was found in our study, our findings are in the same direction. When evaluated according to the sources, trainer and physician groups constituted 44% and 34%, respectively. Truumees et al.[21] found 42% and 28%, respectively, which is consistent with our study. However, the JAMA and DISCERN scores of the trainer group videos are higher than the other groups.

The groups with the highest rates in terms of content were exercise and informational videos with 33% and 29%, respectively. Similarly, Erdem and Karaca[9] in 2018 stated that training videos represented a significant proportion of 46% followed by informational videos with 24%. It was observed that informational videos had DISCERN and GQS scores compared to other groups.

The rate of patient experience videos was determined as 23% and this rate was found to be the highest rate together with Instagram (28%). It is clearly seen that patient experience videos have the second highest scores in evaluation scores compared to all other groups. This may suggest that Facebook is a platform where more personal content is shared.

These results suggest that videos shared on the Facebook platform differ from other platforms in terms of all scores, and that certain content and resource groups are differentially dominant on the platform. Therefore, it can be assumed that there are doubts about the reliability of content on this platform. Instagram videos had the highest number of daily views. Instagram Reels videos had 8.4 times more daily views than Facebook videos and 2.2 times more views than YouTube videos.

Trainers were the most frequent content uploaders on this platform, with 35% of content uploaded on this platform, which is usually short and most frequently exercise training-oriented content. Physician-generated videos have higher JAMA, GQS and DISCERN scores than other groups. This may suggest that Instagram is a platform where visual-oriented content is shared and healthcare professionals can effectively produce content on this platform.

However, it is noteworthy that videos where patient experiences are shared are higher than other platforms with a rate of 28%. This is related to the use of Instagram as a platform for sharing the experiences and opinions of individual users, as well as the algorithm of the platform. Instagram's algorithm operates by analyzing users' interactions with others, their preferences, and the relevance of content. On the other hand, the fact that the algorithm does not allow advertising posts may affect the results. Since accounts are treated differently on the Instagram platform, it is rare to find advertising content on Instagram Reels in search results. As we saw in our study, the proportion of commercial content on Instagram videos (3%) is lower than on other platforms. However, despite this difference, at the same time, due to the high number of trainer groups on Instagram, such accounts can be considered as hidden advertising accounts.

The 90 second time limit for Instagram videos makes the platform different from other social media platforms. This restriction is a feature that shapes the visual character of the platform. Indeed, this limitation can be considered as a disadvantage; however, a different picture emerges when VPI scores are analyzed. VPI scores were found to be 1.8 times higher for Instagram videos than YouTube videos and 2 times higher than Facebook videos. In particular, although YouTube videos have high JAMA, GQS, and DISCERN values, the low average VPI score compared to Instagram indicates that the video content and VPI scoring used in the algorithm are inconsistent and do not fully reflect the medical quality of the videos.

In our study, the fact that the videos were rated by a single person through scales can be considered an important limitation. Examining videos from three different social media platforms presents both benefits and challenges. While the diversity of fields addressed by these videos can complicate comparisons, this variability also underscores the uniqueness of the study. Despite difficulties in standardizing the groups, efforts to ensure relative scientific similarity among the compared groups add validity to the findings.

CONCLUSION

Our results of the kyphosis-related videos analyzed on different social media platforms differed in terms of content and quality, but often revealed that the medical quality cannot be considered good and the lack of patients' access to accurate information.

However, it was observed that the content shared on different platforms varied depending on the audience, preferences, and formats. Therefore, considering the increasing need for users to prepare optimal medical videos on kyphosis on social media, it is important for content producers, especially healthcare professionals, to take into account the unique features of the relevant platform and the tendencies of the users in order to effectively reach their target audience.

Ethics

Ethics Committee Approval: This study did not require ethics committee approval because it was conducted as an internet-based research.

Informed Consent: This study did not require informed consent because it was conducted as an internet-based research and did not involve the collection of personal or sensitive data from participants.

Authorship Contributions

Concept: F.E., Design: H.Ç., Data Collection or Processing: H.S.C., Analysis or Interpretation: R.D., Ö.K., Literature Search: F.E., K.B., Writing: H.Ç., K.B.

Conflict of Interest: The authors have no conflicts of interest to declare.

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EVALUATION OF ADOLESCENTS WITH IDIOPATHIC SCOLIOSIS TREATED WITH POSTERIOR SPINAL FUSION

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ABSTRACT

Objective: In this investigation, we sought to assess the surgical and radiological results of patients with adolescent idiopathic scoliosis (AIS) who attended our clinic and underwent treatment.

Materials and Methods: Twenty-eight individuals with AIS with adequate follow-up and documentation who underwent posterior instrumentation and fusion surgery between 2011 and 2022 were retrospectively evaluated. Analysis of the clinical and radiological outcomes from the preoperative period, immediate postoperative period, and final examination were noted. Participants completed the Scoliosis Research Society (SRS)-22 questionnaire during the most recent follow-up.

Results: A total of 78.6% of patients were female and 21.4% were male. The average follow-up was 28.79±16.098 months, and the mean age was 14.79±1.969 years. Lenke classification was as follows: 57.1%, Type I; 3.6%, Type II; 3.6%, Type III; 25%, Type V; and 10.7%, Type VI. According to the Risser findings, 7.1% were in Stage 2, 14.3% in Stage 3, 57.1% in Stage 4, and 21.4% in Stage 5. The mean Cobb angle was 52.11° before surgery, 7.11° postoperatively, and 11.07° final postoperatively. The mean preoperative kyphosis angle was 29.21°, 27.25°, and 29.71°. The mean preoperative lumbar lordosis angle was 41.89°, postoperative 40.07°, and final 41.68°. The Cobb angle changed significantly ($p<0.05$). The preoperative and postoperative SRS-22 questionnaire ratings differed ($p<0.05$).

Conclusion: Early diagnosis and treatment are crucial for scoliosis. Posterior instrumentation and fusion are appropriate treatment options. To assess the complication rates and outcomes more fully, additional studies with larger sample sizes and control groups are required.

Keywords: Adolescent, scoliosis, posterior fusion

INTRODUCTION

Spinal abnormalities are categorized based on age groups and, the etiology of idiopathic scoliosis is not entirely understood. There are three types: adolescent idiopathic scoliosis (AIS) (between 10-18 age), Juvenile Idiopathic Scoliosis (between 3 and 9 years of age), and Infantile Idiopathic Scoliosis (below 3 years of age)[1]. AIS is defined as a lateral curve of the spine greater than 10° after the age of 10. Contrary to congenital, neuromuscular, and mesenchymal-associated scoliosis, it is more frequent. The lack of underlying congenital or neuromuscular defects makes AIS distinct. It has a prevalence of 0.47% to 5.2%[2]. Gender and AIS prevalence are strongly correlated, with females having a higher prevalence[3]. Thoracic curvatures are most commonly seen in AIS. Thoracolumbar and lumbar curvatures are more frequent in males, while thoracic and double curvatures are more common in females. Although the precise cause of AIS is unknown, it is thought to have a complex pathophysiology involving several variables[4]. Some of the most commonly cited causes include melatonin, calmodulin, growth hormone imbalances, leptin deficiency, connective tissue abnormalities with irregular elastic and collagen filaments, platelet conditions, and disorders of central and peripheral nervous system maturation[5]. While many people do not exhibit clinical symptoms throughout their lifetime, individuals with a Cobb angle higher than 40 degrees might experience major respiratory and aesthetic issues as the disease progresses. The treatment of AIS can be observational, supportive, or surgical[4].

The primary hypothesis of this study is that posterior spinal fusion and instrumentation will result in significant improvement in both surgical and radiological outcomes for patients with AIS. Specifically, we hypothesize that these procedures will lead to substantial correction of spinal deformity, as evidenced by changes in Cobb angle, and will also improve patient-reported outcomes as measured by the Scoliosis Research Society (SRS)-22 questionnaire. We aim to provide a comprehensive analysis of surgical results, including the degree of spinal correction achieved and the impact on patients' quality of life.

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MATERIALS AND METHODS

The investigation comprised 28 individuals with a diagnosis of AIS who visited our clinic between 2011 and 2022, underwent posterior instrumentation and fusion surgery, and had sufficient follow-up and documentation. Patients with non-idiopathic scoliosis, those with inconsistent follow-up visits, and people who weren't between the ages of 10 and 18 when their condition was discovered were excluded. Patients received the SRS-22 survey before their most recent follow-up appointment. The common patient-reported outcome measure for young individuals with AIS is the SRS questionnaire. The 22 questions on the 5-point Likert scale make up the SRS-22 scale. There are five domains in the SRS-22 questionnaire. Function/activity (5), pain (5), self-image/appearance (5), mental health (5), and satisfaction with management (2) are the domains and number of questions in each. There are five vocal response options for each question, numbered from 1 (worst) to 5 (best). The mean score for each domain (minimum: 1 point, maximum: 5 points) and the overall score (total sum of the domain divided by the number of items answered) are displayed as the SRS-22r results[6]. A retrospective analysis was done on the outcomes of the clinical and radiographic examinations performed before surgery, just after surgery, and during the last follow-up.

Informed patient consent was obtained from the patients themselves or from their parents. Studies were conducted with the most recent version of the Declaration of Helsinki as their foundation.

The location and direction of the curvature, as well as secondary sexual features including pubic, axillary, and breast hair, were evaluated during the clinical examination. Patients underwent orthopedic and neurological examinations, and the findings were noted.

The radiological examination included standing anteroposterior and lateral X-rays before surgery. Patients deemed necessary were also evaluated with spinal magnetic resonance imaging and computed tomography. Postoperative controls and subsequent visits involved standing anteroposterior and lateral X-rays. The Cobb method was used for calculating the angles of the curvatures. Patients were classified according to the Risser classification based on iliac apophysis in anteroposterior X-rays. The curvatures were categorized using the Lenke classification system before surgery. The following formula was used to get the coronal plane correction rate:

Correction ratio (in %)=[(Cobb angle before surgery-Cobb angle after surgery)/Cobb angle before surgery] * 100

The percentage of corrective loss was determined using standing anteroposterior and lateral X-rays collected at the last follow-up.

Correction lost (in %)=[(Cobb angle at last follow-up-Cobb angle after operation)/Cobb angle before operation] * 100

Surgical Technique

All patients received 1g of intravenous cefazolin sodium 30 minutes before surgery, and for procedures lasting longer than 4 hours, they received another dosage. To avoid abdominal and thoracic pressure, silicone lateral supports were applied from the armpits to the pelvis before turning the patients prone. After sterilizing the surgical area and draping, a vertical surgical incision was made based on the patient's deformity. Incisions reached the thoracolumbar fascia. Subperiosteally dissecting the paraspinal muscles and spinous processes after fascial opening. Each vertebra exposed its transverse processes and facet joint complexes. The facet joint capsule, interspinous, and supraspinous ligaments were all resected. All patients received posterior spinal instrumentation with polyaxial screws, contoured rods, and transverse connectors. The fusion level dependent at the distal stable and proximal neutral vertebrae. From the convex edge of the curve, pedicle screws at the appropriate levels and apical vertebrae started the instrumentation. The scoliotic curvature was straightened out by compression forces on the convex edge, distraction forces on the concave side, then derotation forces at the apex. Before putting the rods, the sagittal plane was contoured to maintain physiological kyphosis and lordosis. Neuro-monitoring devices were employed in all patients during surgery to detect neurological impairment early. To safeguard the fusion, alleviate discomfort, and compensate for secondary lumbar curvatures, all patients received thoracolumbosacral orthosis (TLSO) after surgery. The orthosis mobilized patients on day two after surgery. Patients left after 7 days on average. On day 14, the sutures were removed. The orthosis was used for 3 months.

An example of our cases; A male patient aged 13 arrived with

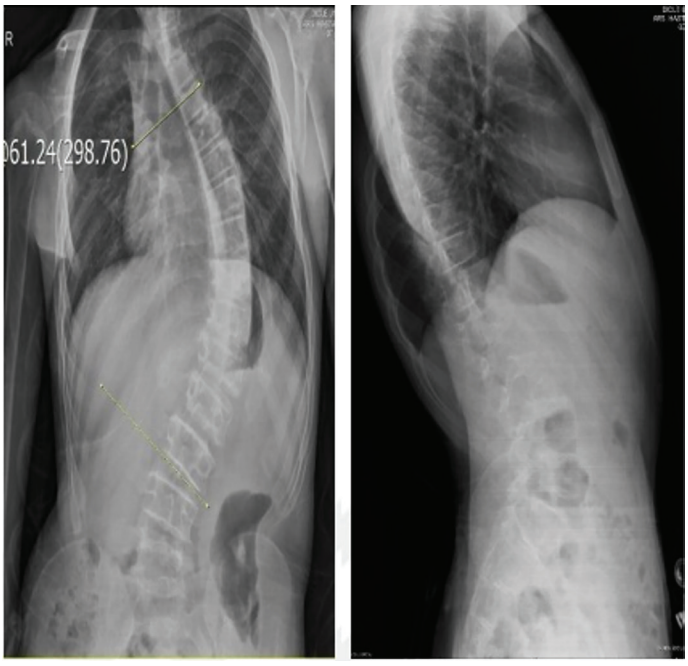

Figure 1. Diagnostic imaging of the patient before surgery

a thoracolumbar curvature of 61 degrees (Figure 1). Posterior segmental instrumentation from T2 to L4 was performed. The patient's final Cobb angle was measured as 9 degrees (Figure 2).

Ethical Approval

Dicle University Faculty of Medicine Non-Interventional Clinical Research Ethics Committee of our university approved this study (approval number: 36, date: 15.02.2022).

Level of Evidence

Level 4, therapeutic study.

Statistical Analysis

The statistical analysis was carried out using SPSS version 26 software. For variables with regularly distributed data, the mean and standard deviation values were given. A dependent t-test was used to evaluate the dependent variables. The Paired Sample t-test was used to assess changes over time in SRS-22 data that satisfied the condition for normal distribution while the Wilcoxon test was utilized for data linked to scoliometer measurement scores that did not meet the normal distribution criteria. Correlation investigations were carried out using the Spearman method. To compare two categorical independent groups, the chi-square test was used. The threshold for statistical significance was set at a p-value of ⩽0.05.

RESULTS

Gender analysis of the patients showed that 78.6% of them were female and 21.4% were male. The mean follow-up duration was 28.79±16.09 months, and the mean age was 14.79±1.96 years. These statistics are reported in coupled with Risser staging details in Table 1. Based on radiological evaluations, Table 2 shows the distribution of Lenke classifications; it was found that 57.1% were categorized as Type I, 3.6% as Type II, 3.6% as Type III, 25% as Type V, and 10.7% as Type VI.

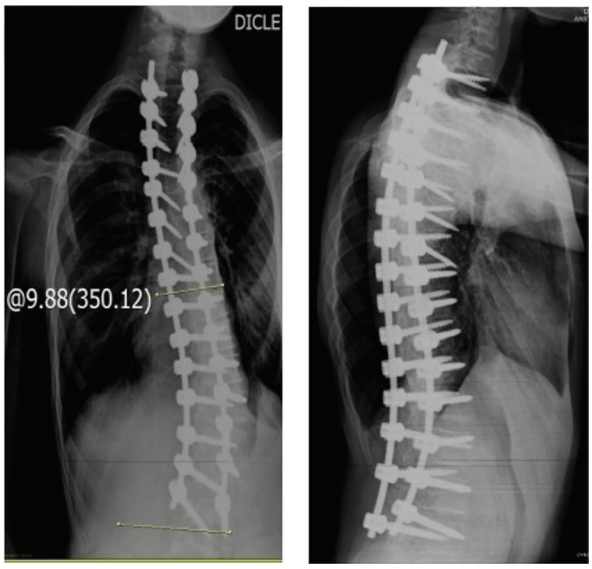

Figure 2. Images of the patient taken after surgery

In the frontal plane analysis of the patients, the correction rate was found to be 87.2%, and the correction loss was 7.5%. The mean values of preoperative, postoperative, and final Cobb angles, mean kyphosis angle and mean lumbar lordosis angle of the patients are shown in Table 3.

In patients, the preoperative Cobb angle (52.11±7.18°) significantly differed from the postoperative Cobb angle (7.11±4.21°) ($p<0.05$). Similarly, the preoperative Cobb angle (52.11±7.18°) significantly differed from the final Cobb angle (11.07±5.60°) ($p<0.05$). Based on the dependent t-test, there was also a statistically significant difference between the postoperative Cobb angle (7.11±4.21°) and the final Cobb angle (11.07±5.60°) ($p<0.05$).

The dependent t-test indicated no significant difference between the preoperative kyphosis angle (29.21±13.15°) and the postoperative angle (27.25±4.98°) ($p>0.406$), also between the preoperative kyphosis angle (29.21±13.150°) and the final angle (29.71±6.970°) were not statistically different ($p>0.846$). But the test showed a significant change between the postoperative kyphosis angle (27.25±4.986°) and the final angle (29.71±6.970°) ($p<0.05$).

Our study includes pre- and post-surgery SRS-22r questionnaires. Pain, looks, function-activity, mental health, and satisfaction averaged 2.9, 2.5, 3.3, 2.9, and 3.53 preoperatively. Postoperative scores were 4.08, 4.27, 4.15, 3.95, and 4.35. All score averages and total scores improved significantly postoperatively. The highest rate of change, at 66%, was observed in the external appearance subgroup (Table 4).

Age, patients' Cobb angles, the results of the SRS-22r scale, and the overall scale scores were all analyzed using Spearman correlation. Age and preoperative mental health were adversely correlated ($p<0.05$, $r=-0.436$). Age did not significantly affect the postoperative total score ($p>0.05$, $r=-0.298$), but it did significantly affect the preoperative total score (p0.05, $r=-0.462$). Cobb angles at the beginning, end, and following surgery did not correspond ($p>0.05$). Age and menarche age had no relationship with preoperative, postoperative, or final Cobb angles ($p>0.05$).

Table 1. Demographics and Risser grading of patients

*(μ±σ)	n	%
Sex		
Female	22	78.6
Male	6	21.4
Average age*	14.79±1.96	
Follow-up period*	28.79±16.09	
Risser classification		
Grade 2	2	7.1
Grade 3	4	14.3
Grade 4	16	57.1
Grade 5	6	21.4

Table 2. Lenke classification of patients

Curve type	Case numbers		Lumbar spine			Thoracic sagittal measures		
LENKE	n	%	A	B	C	-	+	n
Type I	16	57.1	11	2	3	0	2	14
Type II	1	3.6	1	0	0	1	0	0
Type III	1	3.6	0	1	0	0	1	0
Type IV	0	0	0	0	0	0	0	0
Type V	7	25.0	0	0	7	1	0	6
Type VI	3	10.7	0	0	3	0	1	2

DISCUSSION

The study demonstrates that posterior spinal fusion is an effective treatment for AIS, showing significant improvements in spinal alignment and patient-reported outcomes. Specifically, the Cobb angle was significantly reduced from a preoperative mean of 52.11° to 7.11° postoperatively and remained stable at 11.07° at the final follow-up. Specifically, our findings demonstrate an impressive correction rate of 87.2% and a significant improvement in all domains of the SRS-22 scores postoperatively, with the appearance domain showing the highest rate of change at 66%. Scoliosis is by far the most common spinal condition affecting young people. It is a progressive orthopedic condition that can lead to social impairment, emotional disorders, pain in the back, cosmetic deformity, and functional impairment. Due to AIS, the spine is distorted in all three planes the coronal, sagittal, and transverse planes to varying degrees. A full and thorough medical history should be taken before evaluating a kid with scoliosis, with particular attention paid to pain complaints, neurological symptoms such as bowel and bladder problems, physical development, and information regarding sports participation[7]. Over 80% of our patients had moderate discomfort for a long period. However, spine curvature did not affect pain. No patient had neurological impairments. We found that 3.6% of our patients (n=1) had respiratory distress, contrary to Addai et al.[7] scoliosis occurred in the families of six of our patients. We observe that it contradicts the study conducted by Addai et al.[7] These findings could be attributable to the variety of cases considered and to potential racial, ethnic, and socioeconomic differences.

In the Korean study by Suh et al.[8], 1,134.890 children between the ages of 10 and 14 were examined (584,554 boys and 550,336 girls). The prevalence was 3.36%, and the F/M ratio was 2/3, according to the statistics. In Cilli[9] study in Sivas, 3175 children between the ages of 10-15 were evaluated. Girls were found to have AIS twice as often as males in this small patient sample. The F/M ratio in our investigation was discovered to be 3.67:1. It can be seen that the male-to-female ratio in our study is different from that in past studies. It is significant to emphasize that our study only included subjects who required surgical intervention. It is accurate to say that some of our patients receive non-operative follow-ups but don't need surgery right now or in the future.

Table 3. Patients' pre-op, post-op, and final Cobb, kyphosis, and lordosis angles

	n	Minimum	Maximum	Mean ± Standard deviation
Preoperative Cobb angle	28	42	67	52.11±7.18
Postoperative Cobb angle	28	2	21	7.11±4.21
Final Cobb angle	28	2	23	11.07±5.60
Preoperative kyphosis	28	8	57	29.21±13.15
Postoperative kyphosis	28	16	38	27.25±4.98
Final kyphosis	28	16	48	29.71±6.97
Preoperative lordosis	28	10	63	41.89±12.52
Postoperative lordosis	28	16	53	40.07±7.77
Final lordosis	28	27	54	41.68±6.52

Si et al.[10] conducted a retrospective analysis on 112 patients in 2021, 78 of them were female. Fourteen was the mean age. These patients averaged 48 degrees preoperative Cobb angle. 35% of patients were Lenke-1. The postoperative follow-up duration was 32 months[10]. The average Cobb angle of our patients before surgery was 52.11°, and their average age was 14. The majority, 57%, had Lenke-1. The average amount of time for monitoring was 28 months. We closely examined patients with preoperative Cobb angles <40 degrees (5 patients, mean follow-up 6 months) and those in the growth and development stage (Risser 0-1) (3 patients, mean follow-up 9 months) using TLSO braces. We operated on patients with lower Cobb angles that climbed above 40 degrees during follow-ups and lower Risser stages that progressed beyond stage 2. These eight patients had no pulmonary or cardiac pathology. Our study follows the literature[11]. The number of Lenke-1 patients differed from Si et al.[10] data, but the patients' profiles were similar. Race and geography may explain this.

Table 4. Distribution of patients' SRS-22r scoliosis scale in preoperative and postoperative assessments

	n	Mean ± standard deviation	p-value
Pain before surgery	28	2.99±0.39	<0.05
Pain after surgery	28	4.08±0.23	
Appearance before surgery	28	2.57±0.49	<0.05
Appearance after surgery	28	4.27±0.29	
Function before surgery	28	3.35±0.37	<0.05
Function after surgery	28	4.15±0.28	
Mental health before surgery	28	2.90±0.37	<0.05
Mental health after surgery	28	3.95±0.31	
Preoperative satisfaction with the procedure	28	3.53±0.52	<0.05
Postoperative satisfaction with the procedure	28	4.30±0.47	

SRS: Scoliosis Research Society

Ylikoski[12] reported that the average age of menarche was 13.1 years in his research about the prognosis of female patients with AIS. According to one study, the average age of menarche was 12.3 years for girls having AIS and 12.1 years for girls in good health[13]. In our study, menarche was shown to happen on average at the age of 13. The average age of female patients who were subjected to surgery was 14.7 years. Patients continue to grow from the time of their first menstrual cycle until almost 18 months later, according to Faldini et al.[14] Patients are therefore recommended to postpone surgery for between 18 months and 2 years after their first menstruation. The participants in our study underwent surgery about 20 months following their first menstrual cycle.

A child's skeletal maturity is ranked on a scale from 0 to 5 using the Risser system[15]. Particularly, patients in the Risser 0 and Risser 1 stages are known to experience rapid growth, and performing surgery during this period may hinder their growth and result in shorter stature[16]. Literature findings strongly support this observation. At our analysis, 57% of the patients who had surgery were at the Risser 4 stage. In the Risser 0 and Risser 1 groups, we did not do any operations. This part of our research agrees with the prior work.

Twenty-one patients participated in the study conducted by Rodrigues et al.[17], with an average age of 15.2 years, 16 girls (76.2%), and 5 men (23.8%). The study found an initial curve correction of 61.36%, a mean Cobb angle of 62.38° before surgery, and a mean Cobb angle of 38.8° after surgery. However, the length of the follow-up was not examined in their research[17]. Cui et al.[18] investigated patients with AIS who underwent surgical treatment with pedicle screws and were between the ages of 10 and 17. In their case series of 27 individuals, they found a mean Cobb angle loss of 2.5° (equivalent to 19.23% of the preceding adjustment) after a two-year follow-up. In our study, we found a higher correction rate of 87.2% and a mean Cobb angle of 11.07° after surgery, with a corrective loss of 7.5%. Comparing our study to many of the studies described above, we found a greater correction rate. Cui et al.[18] and coworkers reported a loss of 2.5%, whereas our investigation found a corrected loss of 7.5%[18].

The standard treatment for AIS has evolved into posterior spinal fusio[19]. In our study, we also performed all surgeries using a posterior approach. Neurological injury or deficit is the most concerning complication in scoliosis surgery. In Diab et al.[20] series of 1301 cases, the rate of neurological complications was found to be 0.69% (9 cases), including three cases of dural penetration, three cases of nerve root injury, and the rest being neuropraxia, with instrumentation removal reported in only one case. One patient had postoperative lower extremity neurological impairments in our 28 patient trial. Urgent reoperation removed all surgical tools. Intraoperative observations revealed no spinal cord compression from the screws. Postoperative monitoring improved neurological function. The patient's records showed intraoperative hypotension, which may have caused the deficiencies. After a week in the hospital and a posterior segmental instrumentation reoperation, the patient was discharged without neurological impairments. The patient's two-year follow-up was outstanding.

It has been suggested that SRS-22 scores and clinical indicators correlate in non-operative AIS patients. It has been demonstrated that there is a strong correlation between SRS-22 scores and the degree of severity of the curve as assessed by the Cobb angle[21]. Contrarily, Glattes et al.[22] demonstrated that patients with an average Cobb angle between 27° and 32° and those with an angle smaller than 11° obtained the same score. In our study, we gave the SRS-22 scale to the patients who were included both before and after surgery. Between the preoperative and postoperative tests, all score averages and total scores significantly improved. The appearance domain showed the largest rate of change, with a 66% improvement. This element of our study aligns with the body of previous research[23].

When discussing the important aspects of our study, we emphasize the following: This study provides a comprehensive analysis of a follow-up period (mean of 28.79 months) for AIS patients undergoing posterior spinal fusion and instrumentation,

offering valuable insights into outcomes and stability of the surgical correction. A thorough assessment of patient-reported outcomes, emphasizing improvements in pain, function, self-image, mental health, and overall satisfaction is presented by employing the SRS-22 questionnaire preoperatively and postoperatively. The importance of safety measures to minimize neurological complications during scoliosis surgery is underscored by the inclusion of intraoperative neuro-monitoring and a detailed account of postoperative neurological outcomes. A detailed demographic analysis, including age, gender distribution, and Risser staging, which is crucial for understanding the patient population and the timing of surgical intervention concerning skeletal maturity is provided. We have offered a comparative analysis with previous research, highlighting differences in correction rates, complication rates, and patient outcomes. A detailed description of the surgical technique, including the use of polyaxial screws, contoured rods, and TLSO, provides valuable information for surgical planning and execution, potentially serving as a reference for future studies. By analyzing the correlation between SRS-22 scores and clinical indicators such as Cobb angles, we tried to add to the understanding of how surgical correction impacts patient quality of life and functional outcomes. The detailed account of managing surgical complications, such as the case of postoperative lower extremity neurological impairments, provides practical insights into handling such issues effectively, contributing to better patient care practices.

The study on posterior spinal fusion and instrumentation for AIS is constrained by several limitations. Its small sample size of 28 patients, predominantly female (78.6%), limits the generalizability of findings to the broader AIS population. Being retrospective, the study is susceptible to selection and information biases inherent in relying on existing records and patient recall, potentially leading to incomplete or inaccurate data. The mean follow-up duration of 28.79±16.09 months varies widely among patients, necessitating longer periods to fully capture long-term outcomes and complications. The absence of a control group hinders comparisons with non-surgical or alternative surgical treatments, complicating the attribution of outcomes solely to the intervention. Variability in radiographic techniques introduces potential discrepancies in Cobb angle measurements, affecting curvature assessments. Detailed postoperative data on complications, including infection rates and long-term spinal health, were not thoroughly analyzed, limiting comprehensive understanding. Technological advancements over the study period (2011-2022) could also introduce variability in surgical approaches and outcomes. Future research with larger, diverse populations, longer follow-ups, control groups, and comprehensive psychosocial assessments is essential to validate and expand upon these findings, providing a more nuanced understanding of AIS treatment outcomes.

CONCLUSION

In treating adolescents with idiopathic scoliosis, factors like curvature magnitude, type, flexibility, age, and maturity should be considered. Treatment options include observation, conservative measures, or surgery. During surgery, potential risks like decompensation and neurological problems should be evaluated, and fusion levels and curve flexibility precisely determined to avoid excessive correction. Surgical treatment with posterior segmental instrumentation and fusion is effective, successful, and associated with high patient satisfaction, corrective outcomes, and low complication rates.

Ethics

Ethics Committee Approval: Dicle University Faculty of Medicine Non-Interventional Clinical Research Ethics Committee of our university approved this study (approval number: 36, date: 15.02.2022).

Informed Consent: Informed patient consent was obtained from the patients themselves or from their parents.

Authorship Contributions

Surgical and Medical Practices: Y.T., S.A.U., Ş.Y., A.A., Concept: R.A., S.A.U., E.Ö., Design: Y.T., Ş.Y., A.A., Data Collection or Processing: R.A., S.A.U., Ş.Y., A.A., Analysis or Interpretation: Y.T., R.A., S.A.U., E.Ö., Literature Search: R.A., E.Ö., A.A., Writing: Y.T., E.Ö., Ş.Y.

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CERVICAL PROPRIOCEPTION AND VESTIBULAR FUNCTIONS IN PATIENTS WITH NECK PAIN AND CERVICOGENIC HEADACHE: A COMPARATIVE STUDY

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ABSTRACT

Objective: To investigate cervical proprioceptive input and vestibular system function in patients with cervicogenic headaches (CGH). In addition, this study aimed to determine whether abnormal proprioceptive or vestibular inputs are effective in the emergence of cervicogenic dizziness.

Materials and Methods: Thirty patients with CGH and 25 healthy individuals were included in this study. Participants were asked about their recent falls. A visual analog scale was used to evaluate headache severity. Furthermore, static posturography, dizziness handicap index (DHI), neck disability index, subjective visual vertical, cervical vestibular-evoked myogenic potentials (cVEMP), and cervical joint position error test (CJPET) were applied to the participants.

Results: Patients with CGH had more falls in the last year than the control group ($p<0.05$). DHI, standing with eyes closed on a foam surface, cVEMP, and CJPET scores were worse in patients with CGH than in healthy individuals ($p<0.05$). The CJPET score of patients with CGH who reported cervicogenic dizziness was worse than that of patients with CGH who did not report dizziness ($p<0.05$). However, no difference in cVEMP findings was observed between patients with CGH and those without dizziness ($p>0.05$).

Conclusion: It was determined that there were abnormalities in both cervical and vestibular inputs in patients with CGH. However, abnormal cervical proprioceptive inputs, not vestibular responses, were found to play a role in the mechanism of cervicogenic dizziness.

Keywords: Cervicogenic headache, neck pain, vestibular, balance, proprioception

INTRODUCTION

Problems occurring in the muscles, ligaments, discs, bursae, or joints in the cervical region may cause cervicogenic neck pain and secondary headache[1]. Cervicogenic headache (CGH) is a lateralized, non-throbbing headache caused by a nociceptive source in the cervical spine. CGH is the pain with the best understood mechanism among common headaches[2]. It generally results from the disorder of the structures innervated by the upper cervical nerves (C1-C3) and is considered a referred pain related to the trigeminal system[2]. CGH accounts for approximately one-fifth of chronic headache cases[3]. Chronic neck pain and CGH affect the upper extremity functions of individuals, limiting their daily living activities, reducing their quality of life, and causing psychiatric disorders such as stress, anxiety, and depression in individuals[4-6].

The vestibular, somatosensory, and visual input interaction provides balance and postural control. The upper cervical spine has more proprioceptive receptors than the caudal region of the spine[7-9]. Therefore, disorders in the upper cervical structures that cause CGH may affect the proprioceptive system more[10]. Also, abnormal proprioceptive input may cause cervicogenic dizziness in individuals [9,10]. Maintaining balance is important not only to maintain postural stability but also to perform activities of daily living safely. Therefore, abnormal balance is also the main risk factor for falls.

The vestibular and spinal systems interact with the lateral and medial vestibulospinal pathways. The lateral vestibulospinal

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pathway extends to the ipsilateral (mainly) spinal cord and modulates the α and γ motor neurons of intraspinal pathways and antigravity muscles[11]. It stimulates lower extensor motor neurons and suppresses flexor motor neurons. Thus, it plays an important role in maintaining balance by controlling muscle activity and maintaining posture against gravity. The medial vestibulospinal system terminates in the upper cervical regions of the spinal cord and is involved in the control of neck and eye movements, mainly about changes in head orientation[12].

As a result, cervical spinal disorders may affect the balance system through neck proprioception and the medial vestibulospinal tract[12]. However, to our knowledge, no study has investigated cervical proprioceptive inputs and the vestibular system in patients with CGH. This study aims to investigate cervical proprioceptive inputs and the vestibular system in patients with CGH. It also aimed to examine whether abnormal proprioceptive or abnormal vestibular inputs are effective in the emergence of cervicogenic dizziness.

MATERIALS AND METHODS

Participants

This study was conducted on patients referred to the neurosurgery clinic who complained of neck pain and headaches for at least three months. Detailed anamnesis was taken from the patients, and according to the clinical examination and magnetic resonance imaging results, 30 patients who developed CGH due to neck problems that did not require surgery were included in the study. The duration of the patient's headache and neck pain symptoms was recorded. Twenty-five healthy individuals, similar to the patients in terms of age and gender, were included in the study as a control group. Participants were excluded if they had a traumatic neck injury/surgery, true vertigo (benign paroxysmal positional vertigo, vestibular neuritis or Meniere's disease), hearing loss (pure tone average >25 dB) neurological and uncontrollable systemic disease, visual impairment, and musculoskeletal injury/diseases that may affect balance.

Written and verbal consent was obtained from all individuals included in the study. Permission for the study was obtained from the Karabük University Non-invasive Ethics Committee (approval number: 2023/1464, date: 07.11.2023) and the hospital (approvel number: 2023/61), and the study was conducted by the Declaration of Helsinki.

All participants were referred to the hearing and balance clinic for evaluations. Otoscopic evaluation and pure tone audiometry test were applied to the participants, and their falls in the last year were asked and noted. Neck disability index (NDI), static posturography test, dizziness handicap inventory (DHI), head impulse test (HIT), cervical vestibular evoked myogenic potential (cVEMP), subjective visual vertical (SVV), and cervical joint position error test (CJPET) were applied to the participants.

Data Collection

Neck Pain and Headache

The severity of neck pain was evaluated with the Turkish version of the NDI[13]. The index consists of a total of 10 questions, and each question is scored between 0 and 5. An increase in the total index score indicates that the neck problem is increasing. CGH severity in individuals was evaluated with visual analog scale (VAS). The starting point of a 10 cm straight line drawn on paper was 0 (no CGH), and the ending was 10 (excessive CGH). Individuals were asked to mark the point on the line corresponding to the pain intensity. Headache scores were determined by measuring this point with a ruler.

Balance

The balance skills of the participants were evaluated with static posturography. The test was applied in 4 different situations with a Bertech (Bertech Corporation, Ohio, USA) force platform. These situations are as follows: eyes open firm surface, eyes closed firm surface, eyes open foam surface, and eyes closed foam surface. Participants were asked to get on the platform and stand in the desired position for 10 seconds without moving.

Participants' psychometric balance complaints were evaluated with the Turkish version of the DHI[14]. DHI consists of a total of 25 questions. The answers to the questions can be no (score: 0), sometimes (score: 2), and yes (score: 4). An increase in the total score means that the balance problem increases.

Cervical Proprioception

The participants' cervical proprioception sense was evaluated with CJPET. A (target) point was marked on the wall. A straight line was drawn 90 cm from the wall. Patients were asked to stand on the line and were fitted with a laser headband. Patients were asked to place the laser light on the target and close their eyes. Then, he was asked to turn his head left-right/up-down ten times (approximately 45 degrees) with his eyes closed. After his command was carried out, he was asked to guess the target. The distance between the estimated and the target was measured with tape. If the difference was >4.5°, cervical proprioception input was considered abnormal[15].

Vestibular System

The vestibular system was evaluated with HIT, SVV, and cVEMP. For HIT, the patient was asked to look at the clinician's nose, and the head was turned left and right unexpectedly. Observed overt saccades were noted.

The bucket test evaluated SVV. A white vertical line was drawn in the middle of a black bucket. The middle of the bucket was pierced, and a rope passed through the hole. A weight was attached to the end of the string, and a goniometer was attached to the back of the bucket. Participants were asked to look inside the bucket and position the white line vertically. The verticality angle of the line was measured from the back of the bucket.

Neuro-Audio (Neurosoft, Ivanovo, Russia, Version 1.0.104.1) auditory evoked potentials device was used for cVEMP. The test was performed with the patient in a sitting position. Electrode areas were cleaned with abrasive gel. It was obtained by placing the active electrode on the upper 1/3 of the SCM, the reference electrode on the sternoclavicular joint, and the ground electrode on the forehead. Electrode impedances were checked, and the <10-ohm requirement was met for all electrodes. Participants were asked to turn their necks contralateral to the recorded ear and maintain the level of muscle contraction in the desired region by looking at the computer screen. A 500 Hz tone burst stimulus at 100 dB was used in the test.

Beck Anxiety Inventory (BAI)

The Turkish version of the BAI was used to measure the anxiety symptoms level of the participants. The BAI is a 21-item questionnaire to reflect the severity of somatic and cognitive anxiety symptoms during the previous week. Items are scored on a 4-point scale (0-3), and the total score ranges from 0 to 63[16].

Statistical Analysis

IBM SPSS 21 (SPSS Chicago, IL, USA) program was used for statistical analysis. Shappiro-Wilk was used for normality testing. Normally distributed variables were evaluated with a t-test, One-Way analysis of variance, or Pearson's correlation test. The Mann-Whitney U, Kruskal-Wallis, or Spearman's correlation test evaluated variables that did not show normal distribution. Variables with normal distribution are presented as mean ± standard deviation, and variables that do not show normal distribution are presented as median (minimum-maximum). p<0.05 was accepted as the significance level in all statistical analyses.

RESULTS

In the CGH group, 21 (70.0%) of the patients were female, 9 (30.0%) were male, and the average age was 39.23±9.08 (18-52). 14 (56.0%) of the individuals in the control group were female, 11 (44.0%) were male, and the average age was 35.80±8.47 (22-50). There was no difference between the groups regarding age and gender (p=0.116, p=0.283, respectively).

The median headache duration of CGH patients was 30 (3-96) months, the average NDI score was 21.70±8.97, and the average headache severity (VAS) was 5.93±2.49.

Patients with CGH had more falls in the last year compared to the control group [p<0.05, odds ratio: 0.500 (0.379-0.660)]. 15 (50%) of CGH patients had dizziness symptoms compared to 1 (4%) of healthy individuals (p<0.001). There was no difference between the groups regarding eyes open firm surface, eyes closed firm surface, and eyes open foam surface balance scores (p>0.05). However, the eyes-closed foam surface balance score of the CGH group was worse than that of healthy individuals (p<0.05). Also, the DHI score of the CGH group was significantly higher or lower than that of healthy 160 individuals (p<0.05). Fall history, static posturography scores, and DHI scores according to groups are presented in Table 1. The CGH group had no relationship between NDI and DHI and eyes-closed foam surface balance score (p=0.561, p=0.239, respectively). However, there was a negative relationship between the eyes closed foam surface balance score and headache severity and headache duration (p=0.008, r=-0.35; p=0.025, r=-0.30, respectively); there was a positive relationship between DHI and headache severity and headache duration (p<0.001, r=0.62; p=0.002, r=0.40, respectively).

The CJPET score of the CGH group was worse than that of healthy individuals (p<0.05). CJPET score according to groups is presented in Figure 1. There was no relationship between CJPET and headache severity, duration, and NDI (p=0.200, p=0.083, p=0.274, respectively). The mean CJPET score of CGH patients with dizziness symptoms (n=15) was 9.50±6.93, and the CJPET mean score of CGH patients without dizziness symptoms was 4.86±3.67. The CJPET score of CGH patients with dizziness symptoms was worse (0.030) than that of CGH patients without dizziness symptoms.

The HIT result of individuals in both groups was normal. There was no difference in terms of SVV between the groups (p>0.05). In the CGH group, cVEMP could not be obtained unilaterally in 4 patients (13.3%) and bilaterally in 1 patient (3.3%). Bilateral cVEMP was obtained in all participants in the control group. Abnormal cVEMP in the CGH group was higher than in the control group (p=0.041). The cVEMP result of 2 (13.3%) of the CGH patients (n=15) with dizziness symptoms was abnormal, and the cVEMP result of 3 (20%) of the CGH patients without dizziness symptoms was abnormal. There was no difference in terms of cVEMP between CGH patients with and without symptoms of dizziness (p=0.500). There was no difference between the groups regarding normally obtained VEMP latency, amplitude, and asymmetry rate (p>0.05). SVV, VEMP latency, amplitude, and asymmetry rate according to groups are

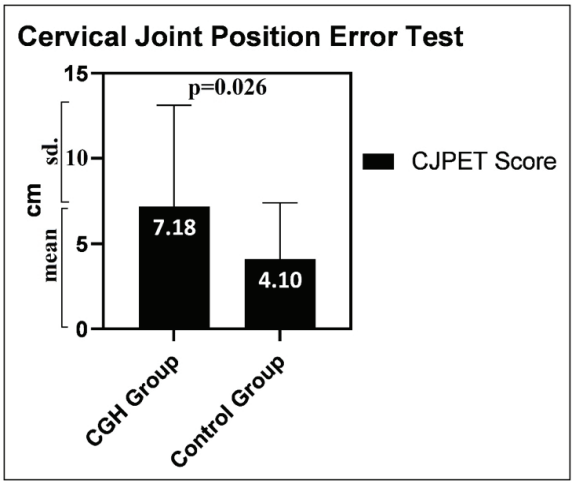

Figure 1. Comparison of cervical joint position error test score according to groups

CJPET: Cervical joint position error test, CGH: Cervicogenic headache

Table 1. Comparison of falls, static posturography and DHI scores according to groups

	CGH group (n=30)	Control group (n=25)	p-value
Falls, n	5 (%16.7)	0 (0.0%)	0.041[a]
Firm surface-eyes open	92.5 (77.8-96.8)	92.9 (74.5-95.9)	0.660[b]
Firm surface-eyes closed	90.4 (43.5-96.7)	91.0 (81.1-95.6)	0.504[b]
Foam surface-eyes open	88.3 (75.1-92.5)	89.4 (62.5-96.2)	0.735[b]
Foam surface-eyes closed	90.9±6.0	85.8 (58.0-92.1)	0.020[b]
DHI	2 (0-86)	0 (0-12)	<0.001[b]

[a]: Fisher's exact test, [b]: Mann-Whitney U test, DHI: Dizziness handicap Inventory, CGH: Cervicogenic headache

Table 2. Comparison of SVV, VEMP latency, amplitude, and asymmetry rate according to groups

	CGH group (n=30)	Control group (n=25)	p-value
SVV, cm	0.0 (-3.0-3.5)	0.0 (-1.0-1.0)	0.558[a]
Asymmetry ratio, %	1.81±18.92	-4.74±18.75	0.305[b]
Right ear			
P1, msec.	14.62±1.11	14.40 (11.20-15.90)	0.754[a]
N1, msec.	21.70 (19.20-25.00)	22.30 (19.30-24.60)	0.095[a]
Amplitude, µV	90.20 (75.00-114.20)	92.80 (76.20-109.20)	0.145[a]
Left ear			
P1, msec.	15.50 (13.00-15.90)	15.00 (13.10-15.80)	0.455[a]
N1, msec.	22.47±1.85	22.40 (19.10-25.70)	0.985[a]
Amplitude, µV	90.50 (44.20-110.40)	90.60 (80.00-99.60)	0.685[a]

[a]: Mann-Whitney U test, [b]: Student's t-test, SVV: Subjective visual vertical, msec.: Millisecond, CGH: Cervicogenic headache, VEMP: Vestibular-evoked myogenic potentials

presented in Table 2.

The BAI scores of the CGH and control groups were 11.10±4.52 and 5.68±2.39, respectively. The mean BAI of the CGH group was statistically higher than the control (p<0.01).

DISCUSSION

The first aim of this study is to investigate cervical proprioceptive inputs and vestibular systems in patients with CGH. The second is to investigate whether abnormal proprioceptive or vestibular inputs are effective in developing dizziness symptoms (cervicogenic dizziness) in patients with CGH. This study showed that patients with CGH had worse postural balance and more abnormal vestibular and proprioceptive inputs than healthy individuals. This study showed that patients with CGH had worse postural balance, more abnormal vestibular and proprioceptive inputs and higher levels of depression than healthy individuals.

Individuals with cervical disorders such as flattening of cervical lordosis or cervical disc herniation may develop imbalance (or dizziness), disorientation, neck pain, limited cervical range of motion, and CGH. Although the mechanism of CGH and neck pain is well known, the mechanism of cervicogenic dizziness is not fully known. It is thought that faulty afferent proprioceptive inputs from the upper cervical region cause incorrect depiction of head and neck orientation in space and cause dizziness[17]. It has been stated that another factor may be pain[18]. Neck pain can cause maladaptive strategies and alter neck muscle coordination. Additionally, neck pain may change the cortical representation and modulation of cervical afferent input[19]. It has been stated that these patients (patients with neck pain and CGH) successfully maintain balance on hard surfaces but have difficulty in difficult conditions[10]. Sremakaew et al.[10] investigated the balance skills of patients with CGH and reported that the balance skills of these patients were worse. It has also been reported that patients with CGH have increased anterior-posterior sway, and they attributed this to faulty cervical proprioceptive input[10]. Similarly, patients with CGH were included in this study. Consistent with the literature, the CGH group's balance skills in challenging static conditions were worse than the asymptomatic group. Also, patients with CGH had a higher risk of falling. In maintaining balance on the foam surface with eyes closed, proprioceptive input is reduced, and visual input is prevented. To maintain balance, reduced proprioceptive inputs must be provided correctly, and the vestibular system must be intact. Therefore, the reason why patients with CGH cannot maintain balance with eyes closed on the foam surface may be abnormal cervical inputs and vestibular abnormalities. In our study, there was no relationship between the eyes-closed balance score and NDI on the foam surface. However, there was a relationship between CGH intensity and duration and DHI and eyes-closed balance score on the foam surface. This shows that as the severity of headaches increases,

the perception of psychometric dizziness and postural instability increases. This relationship between headache and balance supports the hypothesis that cervicogenic dizziness may occur due to pain.

Proprioceptive inputs, defined as awareness of the sense of joint position and joint movement, are one of the primary systems that provide balance. To maintain balance, proprioceptive input is relied on by 70%, visual input by 10%, and vestibular input by 20% on hard ground[20]. Therefore, proprioceptive input is the most important input for balance. Impairment of cervical proprioception due to cervical pathology and pain is an expected situation in patients with CGH. The results of this study support this finding. Our study's main finding is that patients reporting cervicogenic dizziness have more impaired cervical proprioceptive input. Therefore, our study supports the hypothesis that cervicogenic dizziness occurs due to faulty cervical proprioceptive input.

The medial vestibulospinal reflex, which terminates in the motor neurons of the sternocleidomastoid muscle (SCM), originates from the saccule, and extends to the vestibular nuclei via the inferior vestibular nerve[21]. High-intensity sound stimulates the saccule, and this stimulus is recorded from the medial vestibulospinal tract and SCM in the cVEMP test. Therefore, neck problems can affect saccule function and cVEMP testing. Shi et al.[12] investigated cVEMP findings in patients with cervical vertigo. As a result, it has been reported that patients with cervical vertigo have more abnormal cVEMP responses than healthy individuals, and as the severity of cervical vertigo increases, the abnormal cVEMP response also increases[12]. In this study, patients with CGH had more abnormal cVEMP responses than healthy individuals. However, unlike the study by Shi et al.[12] there was no difference in terms of cVEMP findings between CGH patients with and without cervicogenic dizziness. This finding indicates that the vestibular system (cVEMP) is affected in patients with CGH, but abnormal cVEMP responses do not produce dizziness symptoms. The vestibular system has a compensation mechanism, and acutely developing vestibular pathologies heal spontaneously over time[22]. In slowly developing pathologies, patients may not feel any vestibular symptoms. Therefore, abnormal vestibular system function in patients with CGH may not have caused symptoms of dizziness. On the other hand, even if vestibular compensation develops in these patients, they may experience loss of balance, especially under challenging conditions such as complex visual stimuli (optokinetic)[23]. Therefore, even if cVEMPs do not affect the occurrence of dizziness symptoms in patients with CGH, abnormal vestibular functions may pose a fall risk for patients, especially in challenging conditions. Falls can cause fatal fractures and injuries, permanent disabilities, and fear of falling in individuals. Therefore, balance and vestibular exercises can be added to cervical region rehabilitation to reduce the risk of falling and improve the quality of life in patients with neck pain and CGH.

Causes of CGH include neck muscle tension, spinal disc problems, and joint dysfunction[24]. Increased anxiety levels can also contribute to an increase in headaches. Previous studies have shown that high anxiety levels can cause CGH to occur more frequently and more intensely[24]. This can also affect individuals' daily life activities and result in increased disability symptoms. This study also showed that patients with CGHs have higher depression levels, parallel to the literature. Therefore, it is important to evaluate the relationship between CGH and depression, which are bidirectionally related, during the clinical follow-up process[25].

CONCLUSION

The results show that there are abnormalities in both cervical proprioceptive inputs and vestibular inputs in patients with CGH. Therefore, patients with CGH have a higher risk of falling than asymptomatic individuals. However, it has been determined that only cervical proprioceptive inputs play a role in the cervicogenic dizziness mechanism. Therefore, evaluating these systems in patients with CGH and applying appropriate rehabilitative approaches is important.

Ethics

Ethics Committee Approval: Permission for the study was obtained from the Karabük University Non-invasive Ethics Committee (approval number: 2023/1464, date: 07.11.2023) and the hospital (approvel number: 2023/61), and the study was conducted by the Declaration of Helsinki.

Informed Consent: Written and verbal consent was obtained from all individuals included in the study.

Authorship Contributions

Surgical and Medical Practices: A.S.A., E.S., Concept: A.S.A., E.S., M.G., T.G.S., Z.K.A., Design: A.S.A., E.S., T.G.S., Z.K.A., Data Collection or Processing: A.S.A., M.G., Analysis or Interpretation: A.S.A., T.G.S., Z.K.A., Literature Search: A.S.A., E.S., M.G., T.G.S., Z.K.A., Writing: A.S.A., E.S., M.G., T.G.S.

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SURGICAL SITE INFECTION AFTER SPINAL INSTRUMENTATION: REVIEW OF PATHOGENESIS, DIAGNOSIS, PREVENTION AND TREATMENT

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ABSTRACT

Objective: Despite the successful application of spinal instrumentation surgery, the development of surgical site infections (SSIs) remains inevitable even in the most experienced neurosurgery clinics. The aim of this study was to analyze potential risk factors, reassess diagnosis and treatment, and discuss outcomes in line with the literature.

Materials and Methods: The records of 1564 patients who underwent spinal instrumentation surgery between 2016 and 2023 were retrospectively reviewed. Among these patients, 297 developed superficial or deep SSIs in the postoperative period. Diagnosis was based on postoperative positive wound cultures, intraoperative cultures, serum procalcitonin and C-reactive protein (CRP) levels measured in the postoperative period, and gadolinium-enhanced magnetic resonance imaging (MRI) and computed tomography scan. Demographic characteristics and preoperative risk factors of the patients were analyzed.

Results: SSIs were observed in 297 (18.9%) out of 1564 patients who underwent spinal instrumentation surgery. Multiple risk factors for spinal infections following spinal instrumentation surgery, which can manifest in both the early and delayed postoperative periods, were identified. Early diagnosis and prompt initiation of appropriate treatment were associated with better prognosis in 215 patients. Among the 82 patients diagnosed late, all underwent revision surgery for spinal implant removal due to failed medical treatment, with clinical outcomes in 23 of these patients not meeting post-operative expectations. The relationship between early and delayed diagnosis and the need for reoperation were statistically significant ($p<0.001$). Reoperation was required in 92.7% of patients with delayed diagnosis compared with 15.3% of patients with early diagnosis, indicating an approximately 11.6-fold higher risk of reoperation in patients with delayed diagnosis.

Conclusion: Intraoperative culture results are the gold standard for diagnosing SSIs after spinal instrumentation surgery and are also valuable for selecting antimicrobial agents. Monitoring procalcitonin and CRP levels, along with MRI, is highly beneficial for diagnosis. Early detection requires fewer surgical interventions and improves clinical outcomes

Keywords: Procalcitonin, spinal instrumentation, surgical site infection

INTRODUCTION

Surgical site infections (SSIs) occur in 2% to 20% of patients following spinal instrumentation, commonly used in the surgical treatment of spine pathologies[1]. These infections can lead to complications such as pseudarthrosis, spondylodiscitis, neurological sequelae, and even death[2]. SSIs after spinal surgery are multifactorial and can manifest in both early and delayed post-operative periods[3]. Despite strict adherence to aseptic principles, it can occur postoperatively, leading to revision surgeries, prolonged hospital stays, and adverse economic outcomes[4]. The most common cause of postoperative SSIs is gram-positive bacteria originating from the patient's flora[5]. Among gram-positive bacteria, staphylococci are predominant, including *Staphylococcus aureus* and coagulase-negative staphylococci[6]. There is insufficient scientific research in the literature regarding prevention of postoperative SSIs. Additionally, consensus on postoperative care among spine surgeons remains elusive[7].

Complications of spinal surgery such as Dural tear and the use of Dural sealants have been identified as factors increasing the risk of spinal SSIs[8]. Risk factors in the postoperative period include patient incontinence, use of posterior surgical approach, surgical intervention for spinal tumor resection, and morbid obesity[9]. Furthermore, a retrospective study identified diabetes, heart disease, smoking, chronic lung diseases, advanced age, preoperative steroid use, prolonged postoperative hospital stays, multiple blood transfusions, and prolonged operative

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duration as risk factors[10]. Violation of sterile conditions during the use of fluoroscopy, intraoperative computed tomography (CT), and surgical microscopes in spinal surgery has also been shown to increase the risk of postoperative infections[1].

The aim of this retrospective study is to analyze SSIs following spinal instrumentation surgery in our neurosurgery clinic, identify potential risk factors, evaluate management strategies, reassess diagnosis and treatment, and discuss outcomes in line with the existing literature.

MATERIALS AND METHODS

Research and Editorial Ethics

Informed consent was obtained from all patients involved in this study. This study was conducted following the ethical standards set by the Ordu University Faculty of Medicine Non-interventional Clinical Research Ethics Committee (approval number: 168, date: 09.06.2023).

Patient Population

Records of 1564 patients who underwent spinal instrumentation surgery at Ordu University Training and Research Hospital Neurosurgery Clinic between January 1, 2016, and April 1, 2023, were retrospectively reviewed. Among these patients, 297 were identified to have developed superficial or deep SSIs in the postoperative period. Diagnosis involved postoperative positive wound cultures, intraoperative cultures, serum procalcitonin and C-reactive protein (CRP) levels measured in the postoperative period, and gadolinium-enhanced magnetic resonance imaging (MRI) and CT scans. Demographic characteristics and preoperative risk factors of the patients were analyzed.

The following criteria were used for diagnosis:

a) Positive postoperative wound culture results,

b) Intraoperative culture results as the gold standard for identifying the causative microorganism,

c) CRP and procalcitonin levels measured on the 3rd postoperative day, the 3rd week, the 3rd month, and the 6th month,

d) Postoperative gadolinium-enhanced MRI, and

e) Gadolinium-enhanced CT scans. Demographic characteristics of the patients and preoperative risk factors were analyzed.

Incidence, Definitions, and Classifications

In our study, early-onset infections were defined as infections occurring within the first 90 days post-surgery. Late-onset infections were those occurring after the 90th postoperative day. Posterior spinal instrumentation was associated with an increased risk of infection and higher revision surgery rates. Anterior spinal exposures were associated with a reduced infection risk and successful fusion. A total of 297 patients (18.9%) were identified with SSIs. Among these 297 patients, only 27 underwent anterior cervical surgery, and all 27 (9.1%) had superficial wound infections diagnosed within the first 90 days. The remaining 270 patients (90.9%) had undergone posterior spinal approaches. Clinical outcomes were assessed based on fusion quality, symptomatic improvement, neurological status, functional activities of daily living, and infection eradication. The relationship between early and late diagnosis and the need for reoperation was examined using the chi-square test, which showed a significant relationship ($p<0.001$).

Statistical Analysis

All calculations were performed using SPSS v28 (IBM Inc., Chicago, IL, USA). Relationships between categorical variables were examined using the chi-square test, and odds ratios were calculated with a 95% confidence interval for significant variables. A statistical significance level of 5% was considered in statistical tests and interpretation of results.

RESULTS

Demographics and Risk Factors for Post implantation Wound Infection

Between January 1, 2016, and April 1, 2023, records of 1564 patients who underwent spinal instrumentation surgery were retrospectively reviewed, revealing that 297 (18.9%) developed SSIs. Among these, only 27 (9.1%) of those who underwent anterior cervical surgery had superficial wound infections, all diagnosed within the first 90 days postoperatively and successfully treated with antibiotics without requiring reoperation. The remaining 270 (90.9%) patients underwent surgery via posterior spinal approaches: 42 for posterior cervical, 38 for thoracic, and 190 for lumbar surgeries. Of the 270 patients with posterior spinal approach and SSIs, 188 (69.6%) were diagnosed in the early period within the first 90 days, with only 33 (17.5%) requiring revision surgery. In contrast, 82 patients (30.3%) were diagnosed in the late period, more than 90 days postoperatively. Sixteen of these patients did not require surgical treatment but needed prolonged antibiotic therapy for at least 6 months. Among the late-diagnosed 82 patients, 66 (80.4%) underwent reoperation, and 23 (34.8%) of them did not achieve desired clinical outcomes, remaining symptomatic with pain, numbness, and weakness, leading to a diagnosis of failed back surgery syndrome.

Of the 297 patients with postoperative SSIs, 194 (65.3%) were female and 103 (34.8%) were male. All 99 patients who underwent revision surgery were operated on using posterior spinal approaches, with 63 (63.6%) due to spinal trauma and 36 (36.3%) due to spinal stenosis and degenerative spine conditions. Among those who underwent revision surgery, 11 (11.1%) involved 4 spinal segments, while the remaining 88 (88.9%) involved 3 or fewer spinal segments. Multiple risk factors associated with patients facilitated the development of postoperative SSIs following spinal instrumentation surgery. Risk factors for postoperative SSIs are shown in Table 1.

Positive wound culture results were reviewed from patients who developed postoperative superficial or deep SSIs. According to culture results, gram-positive bacteria were most commonly

isolated among the infected 297 patients, with 70 (72.9%) cases identified. Among these, *S. aureus*, including methicillin resistant *S. aureus*-positive cases, was found in 43 patients, *Staphylococcus epidermidis* in 21 patients, *Staphylococcus hemolytic* in 4 patients, and *Enterococcus faecalis* in 2 patients. Gram-negative bacteria were detected in 26 (27.1%) patients, including *Escherichia coli* in 17 patients, *Enterobacter cloacae* in 8 patients, and *Pseudomonas aeruginosa* in 1 patient.

The relationship between early and late diagnosis and the need for reoperation was analyzed using chi-square testing, revealing a significant association (p<0.001) (Table 2). While 84.7% of early-diagnosed patients did not require reoperation, 92.7% of late-diagnosed patients underwent reoperation. Late-diagnosed patients had approximately 11.6 times higher risk of requiring reoperation compared to early-diagnosed patients (Table 3).

Table 1. Risk factors for 99 re-operated patients

Risk factors	Number of patients
Elderly (age >60 years)	73 (17.5%)
Previous spinal surgery	27 (6.5%)
Smoking	26 (6.2%)
Spinal trauma	63 (15.1%)
Body mass index >30	39 (9.3%)
Diabetes mellitus	42 (10%)
Cardiovascular disease	22 (5.2%)
Chronic pulmonary diseases	19 (4.5%)
Steroid use	7 (1.6%)
Blood transfusion	74 (17.8%)
Alcohol use	13 (3.1%)
Hypothyroidism	3 (0.7%)
Concurrent urinary tract infection	8 (1.9%)

Table 2. Pathogenic microorganisms isolated

Gram-positive bacteria (70 patients) (72.9%)	Number of patients
Staphylococcus aureus (MRSA resistance included)	43 (61.4%)
Staphylococcus epidermidis	21 (30%)
Staphylococcus hemolytic	4 (5.7%)
Enterococcus faecalis	2 (2.9%)
Gram-negative bacteria (26 patients) (27.1%)	
Escherichia coli	17 (65%)
Enterobacter cloacae	8 (30.7%)
Pseudomonas aeruginosa	1 (3.8%)

MRSA: Methicillin resistant *Staphylococcus aureus*

DISCUSSION

In our study, laboratory, radiological, and clinical outcomes of 1564 patients who underwent spinal surgery using instrumentation at our clinic were retrospectively analyzed. It was determined that SSI developed in 297 (18.9%) patients. Our infection rates align with statistics reported in the literature[1,3]. When evaluating clinical outcomes, complete eradication of infection, symptomatic and neurological recovery of the patient, and repeat radiological examinations were considered. Early-onset infections in our study were defined as those developing within 90 days postoperatively, whereas late-onset infections were those occurring after 90 days postoperatively. We observed that patients diagnosed early and promptly treated (215 patients) had better prognoses. The timing of infection onset, whether early or late, has been highlighted as a crucial criterion in determining treatment approach[2,3].

Postoperative SSIs can lead to complications such as pseudarthrosis, instrumentation failure, undesirable neurological sequelae, and even death. Among our patients who developed SSIs and were diagnosed late (82 patients), 66 (80.4%) required reoperation. Among these, 23 (34.8%) did not achieve desired clinical responses, experiencing persistent symptoms of pain, numbness, and motor deficits, resulting in failed back surgery syndrome. Studies by Deng et al.[10] underscore the significant morbidity caused by post-spinal surgery infections, substantially impeding functional recovery. These infections are recognized by the Centers for Disease Control and Prevention as occurring within 12 months post-surgery, posing a potentially destructive complication risk[11].

During the postoperative period, measuring CRP levels early on is a reliable test for detecting SSIs and is crucial for early diagnosis[1,3,12]. Erythrocyte sedimentation rate (ESR) and total leukocyte count are routine tests used for diagnosis alongside CRP[1]. Procalcitonin has been found superior to CRP and ESR

Table 3. Relationship between early and late diagnosis and reoperation

	Re-operated patients		Non re-operated patients		Total		*p* value
	n	%	n	%	n	%	
Early diagnosis	33	15.3	182	84.7	215	100.0	**< 0.001[a]**
Late diagnosis	76	92.7	6	7.3	82	100.0	
Total	109	36.7	188	63.3	297	100.0	
OR (95% CI)	11.569 (5.344-25.047)						

[a]: Pearson's chi-squared test, OR: Odds ratio, CI: Confidence interval

as an early indicator of SSI in patients undergoing spinal surgery[13]. In our study, we observed that CRP levels typically peaked around 2-3 days post-surgery and normalized within 2-3 weeks in non-infected patients. ESR peaked around day 5 but took 3-6 weeks to return to normal in non-infected patients. However, in all 297 patients who developed postoperative SSI, CRP, procalcitonin, and ESR levels remained significantly elevated by the end of the first month. Twelve patients showed normal leukocyte counts, seven of whom had a history of long-term steroid use. Among the 143 patients who received prolonged antibiotic treatment, significant ESR reduction was not observed by the end of the third month.

CT and MRI are confidently used in diagnosing[3]. In our study, contrast-enhanced MRI was performed on all 297 patients who developed postoperative SSI, revealing positive signs of pedicle fluid in 163 patients. According to Aljabi et al.,[13] contrast-enhanced MRI is highly beneficial for diagnosing SSIs following spinal surgery[14]. Sierra-Hoffman et al.[15] suggest that early-onset can be treated with 4-6 weeks of intravenous (IV) antibiotics followed by 4-12 weeks of oral antibiotics, without necessitating instrumentation removal. Late-onset, however, may require instrumentation removal despite IV and oral antibiotic treatment[15]. All our patients diagnosed with early-onset SSI received at least 4 weeks of IV antibiotics followed by a minimum of 8 weeks of oral antibiotics.

Choi et al.[16]emphasize the importance of early diagnosis, noting that patients diagnosed late require longer antibiotic use. In our clinic, patients diagnosed late used antibiotics on average four times longer than those diagnosed early. Oikonomidis et al.[17] suggest that late infections may necessitate implant removal. Literature also includes authors recommending retaining instrumentation in cases of postoperative SSIs, achieving successful outcomes with surgical and specific antibiotic treatments[18,19]. Among our patients diagnosed late, 66 (80.4%) underwent reoperation, with complete implant removal in 21 (31.8%) of these cases.

Our study demonstrated that preserving instrumentation and initiating parenteral antibiotic therapy early in the course of spinal surgery lead to better clinical outcomes. Additionally, administering a single dose of prophylactic antibiotics one hour before surgery was found to be sufficient. The best approach to preventing postoperative infections involves thorough preoperative preparation and diligent postoperative monitoring of patients through laboratory, clinical, and radiological assessments. Preventing spinal implant infections should always remain a primary goal in neurosurgery. Early diagnosis of infections related to spinal instrumentation results in a better prognosis and requires fewer revisions.

CONCLUSION

The etiology of SSIs developing in the postoperative period of spinal surgery is multifactorial. Patients diagnosed early in this period generally have better prognoses. The gold standard for identifying the causative microorganism is intraoperative culture results, which are invaluable for selecting the appropriate antimicrobial therapy. Additionally, serum procalcitonin, CRP levels, and MRI are highly useful in diagnosing SSIs. When SSIs are diagnosed early, they often require less surgical intervention and yield better clinical outcomes.

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Ethics

Ethics Committee Approval: This study was conducted following the ethical standards set by the Ordu University Faculty of Medicine Non-interventional Clinical Research Ethics Committee (approval number: 168, date: 09.06.2023).

Informed Consent: Informed consent was obtained from all patients involved in this study.

Authorship Contributions

Surgical and Medical Practices: H.Ö., M.H., Concept: H.Ö., M.H., Design: H.Ö., M.H., Data Collection or Processing: H.Ö., Analysis or Interpretation: H.Ö., Literature Search: H.Ö., M.H., Writing: H.Ö., M.H.

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COMPARATIVE RESULTS IN HEMIVERTEBRECTOMY AND FUSION SURGERY BELOW AND ABOVE 10 YEARS OF AGE

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ABSTRACT

Objective: The aim of this study was to present and compare preoperative and postoperative radiologic results and health-related quality of life scores (HRQoL) in patients below and above 10 years who underwent hemivertebrectomy.

Materials and Methods: We reviewed 22 patients who underwent posterior hemivertebra resection and fusion for congenital or kyphoscoliosis at a single center. The mean follow-up period was 24.5 months. Patients were equally divided into G1 (below 10 y/o) who underwent short-level fixation (SLF) and G2 (above 10 y/o) who underwent SLF or long-level fixation (LLF). Radiological evaluations were performed, and HRQoL questionnaires were examined.

Results: G2 exhibited longer fusion (7.2 vs. 2.5), longer surgery (401.3 vs. 218.2 minute), higher blood loss (818.8 vs. 263.6 mL), and higher blood transfusion (5 vs. 1 unit) compared with G1 ($p<0.05$). Preoperative Cobb angles were higher in G2 than in G1, and both groups experienced decreased Cobb angles in the early and late postoperative periods ($p<0.05$). Other examinations included the thoracic kyphosis angle, lumbar lordosis angle, coronal balance, sagittal balance, shoulder balance, and pelvic obliquity, but no significant differences were observed between the groups ($p>0.05$). In G1, patients' postoperative general health status improved, child and parent satisfaction increased, and activities of daily living increased, but their emotional state worsened ($p<0.05$). In G2, postoperative pain, physical function, self-image, mental health, and satisfaction with treatment management increased ($p<0.05$).

Conclusion: Hemivertebrectomy is a successful surgical treatment for improving radiological and HRQoL scores both below and above 10 years. We recommend SLF for physiological growth and less fusion in children aged 10 years, but psychological support is crucial to prevent emotional deterioration. LLF offers advantageous radiological results in children aged >10 years but may lead to painful HRQoL scores.

Keywords: Congenital scoliosis, congenital kyphoscoliosis, posterior hemivertebrectomy, limited fusion, posterior spinal fusion, health-related quality of life, HRQoL

INTRODUCTION

The primary etiology of congenital scoliosis is believed to be a developmental defect in the paraxial mesoderm[1]. It is associated with a higher incidence of intraspinal, cardiac, renal, and gastrointestinal anomalies compared to the general population[2]. Anomalies in rib number commonly accompany this condition, and Goldenhar syndrome may also be associated with this condition[3,4]. Hemivertebra (HV) is a congenital spine defect, leading to progressive scoliosis and coronal or sagittal imbalance if left untreated. HV is classified into fully segmented, semi-segmented, and unsegmented types. The prognosis of HV-related deformities depends on factors like HV type, defect location, number of defective vertebrae, and the patient's growth potential[5]. Conservative treatment for congenital scoliosis has limited effectiveness, with 75% of curves being progressive and only 5-10% responding to casting or custom-made bracing[6]. Early surgical intervention is often necessary to prevent deformity progression[7]. Surgical treatment options include preventing future deformity, gradual correction, and acute correction[8]. The aim of this study was to present and compare preoperative and postoperative radiologic results and health-related quality of life scores (HRQoL) in patients below and above 10 years of age who underwent hemivertebrectomy.

MATERIALS AND METHODS

Study Design

We reviewed 22 pediatric patients (n=22) who underwent posterior HV resection and spinal fusion for congenital scoliosis or kyphoscoliosis at Başakşehir Çam and Sakura City Hospital between 2021 and 2023 retrospectively. The mean follow-up period was 24.5 months (range 12.1 to 36.9 months). Informed consent was obtained from each patient. Patients were divided

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into two groups: those below 10 years old and those above 10 years old, with 6 females and 5 males in each group (n=11 per group). The mean age was 10.6±4.6 years (range 4.0 to 18.0), the mean coronal main Cobb angle was 49.8°±20.5° (range 21° to 85°), and the mean thoracic kyphosis angle was 46.4°±19.8° (range 5° to 80°). Kyphoscoliosis was present in 2 patients in Group 1 (G1) and 6 patients in Group 2 (G2). The mean age in G1 was 6.5±1.9 years, and the main Cobb angle was 45.5°±22.2°, while in G2, the mean age was 14.6±2.0 years, and the main Cobb angle was 54.1°±18.8°. In G1, 5 patients had type 1 and 6 had type 3 congenital defects, while in G2, 4 had type 1 and 7 had type 3 congenital defects according to the McMaster classification[9].

The inclusion criteria were as follows: age below 18, surgery required for congenital spinal deformity related to HV (failure of conservative treatment and observed increase in curve >5° over 6 months), no previous deformity surgery, regular follow-up. The exclusion criteria were as follows: age above 18, pure congenital kyphosis, no increased curve with conservative treatment, previous deformity surgery, and no regular follow-up. Radiologic coronal and sagittal parameters were compared preoperatively, early postoperatively (early term), and at final follow-up (late term) within and between groups. Additionally, changes in HRQoL scores were analyzed within groups preoperatively and at the final follow-up. The study adhered to ethical standards and received approval from the Başakşehir Çam and Sakura City Hospital Clinical Research Ethics Committee (approval number: KAEK/25.10.2023-533, date: 06.11.2023).

Radiological Examinations

Standard radiographs (posteroanterior and lateral views of the whole spine, including the pelvis) were obtained at preoperative, early, and late terms. Measurements included coronal main Cobb angle, thoracic kyphosis angle (T2-T12), lumbar lordosis angle (L1-S1), coronal balance (C7-CSVL/cm), sagittal balance (C7-S1/cm), shoulder balance (coracoid height difference/cm), and pelvic obliquity (horizontal pelvic angle). Measurements were made on calibrated radiographic images by an independent spine surgeon twice at a one-month interval, with excellent intraobserver reliability (intraclass correlation coefficient=0.986-0.996). Preoperative computed tomography and magnetic resonance imaging were performed to detect possible spinal pathologies such as diastematomyelia, spinal cord anomalies, tethered cord, spinal dysraphism, syrinx, and Arnold-Chiari malformation. Cardiologic and genitourinary evaluations were also performed under detailed ultrasound examination by consultant physicians preoperatively.

Surgical Procedure

HV removal involved a one-stage posterior approach with a midline skin incision. Posterior elements of HV were removed, and the spinal cord and surrounding nerve roots were identified. HV was excised by placing a concave rod, preserving the spinal cord, and removing the upper and lower cartilaginous discs. A convex rod was placed, and the gap was closed with compression. If a large HV was removed, an anterior titanium mesh cage packed with an autograft was used to prevent spinal cord compression and increase fusion. A ponte osteotomy was used for excising the lamina, posterior ligaments, and facet joints. A third rod with supra- and infralaminar hooks was used when necessary in patients with short-level fixation. Intraoperative neuromonitoring was used in all patients to avoid neurological injuries. Autologous bone grafts obtained from HV and facet joints were used for fusion. In G1, one patient underwent surgery for two HVs located in the thoracic and lumbar regions. In addition to hemivertebrectomy, three patients in G2 had a Ponte osteotomy. Two patients in G2 with large osteotomy gaps following HV excision were filled with mesh cages. Short-level fixation was performed in all patients in G1 and in six patients in G2, with long-level fixation in five patients in G2 (Figure 1). Patients in G1 wore a custom-made brace following a postoperative trunk cast, and patients in G2 wore a custom-made brace for six months.

HRQoL Questionnaires

Parents or caregivers completed the Early Onset Scoliosis Questionnaires (EOSQ-24) for those younger than 10 years old and the Scoliosis Research Society Patient Outcome Questionnaires (SRS-22) for those older than 10 years old

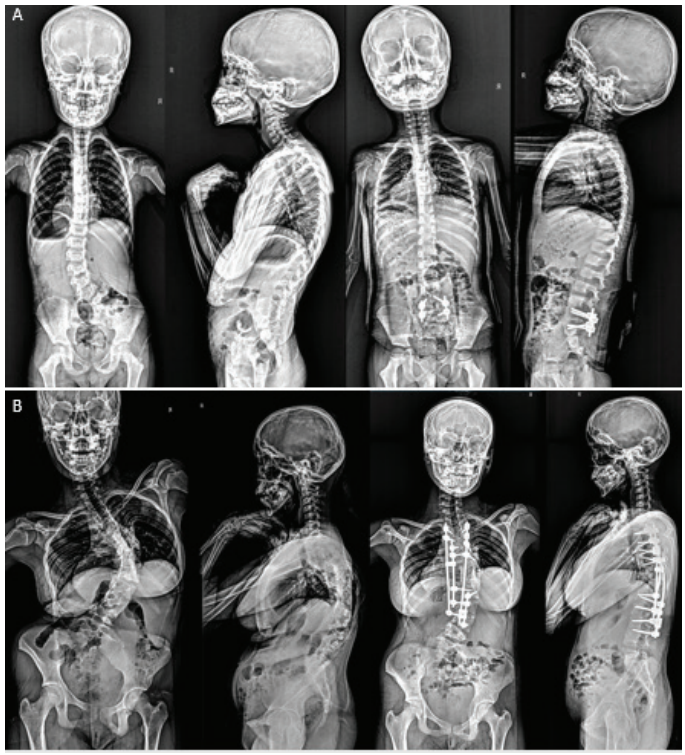

Figure 1. A) Excision and short level fixation of the hemivertebra at the lumbosacral level of the patient with type 1 defect belonging to the Group 1, B) Excision and long level fixation of the hemivertebra at the thoracolumbar level of the patient with type 3 defect belonging to the Group 2

preoperatively and at final follow-up. The SRS-22 questionnaire consists of 22 items, each scored on a scale of 1 to 5, divided into five domains. A high total SRS-22 score indicates better HRQoL. The EOSQ-24 questionnaire consists of 24 items, each scored on a scale of 1 to 5, divided into several domains. A high total EOSQ-24 score indicates better HRQoL and less burden on caregivers.

Statistical Methods

Descriptive statistics included mean, standard deviation, median, minimum, and maximum values. The Kolmogorov-Smirnov test was used to examine the distribution of variables. Quantitative data were compared using Mann-Whitney U tests and independent sample t-tests. For repeated measurements, the Wilcoxon test and paired sample t-test were employed. Qualitative data were compared using a chi-square test. Statistical analyses were performed using SPSS 26.0.

RESULTS

Comparisons of preoperative intraspinal pathologies between the G1 and G2 groups were as follows: Arnold-Chiari malformation: 2 cases in G1 vs. 1 case in G2; tethered cord: 2 cases in G1 vs. none in G2; diastematomyelia: 1 case in G1 vs. none in G2; intraspinal lipoma: 1 case in both groups; and syrinx: 5 cases in G1 vs. 2 cases in G2. Comparisons of previous spinal surgeries performed in the G1 and G2 groups were as follows: myelomeningocele surgery: 1 case in both G1 and G2; tethered cord surgery: 2 cases in G1 vs. none in G2; and intraspinal lipoma surgery: 1 case in G1 vs. none in G2.

Additional system anomalies between the G1 and G2 groups were as follows: cardiovascular anomalies: 1 case in G1 vs. 2 cases in G2; genitourinary anomalies: 3 cases in G1 vs. none in G2; musculoskeletal anomalies: 3 cases in both groups; rib number anomalies: 7 cases in G1 vs. 6 cases in G2; and Goldenhar syndrome: none in G1 vs. 1 case in G2.

Radiologic coronal and sagittal curve measurements are presented in Table 1, and coronal and sagittal balance measurements are presented in Table 2. Patient and surgical data are presented below (G1 vs. G2, respectively):

- Mean age at surgery: 6.5±2.0 years vs. 14.8±2.3 years,
- Mean fusion level: 2.5 0.8 (minimum 2-maximum 4) vs. 7.2±4.6 (minimum 2-maximum 13),
- Mean surgical time: 218.2±56.2 minutes vs. 401.3±159.4 minutes,
- Intraoperative blood loss: 263.6±257.9 mL vs. 818.8±575.7 mL,
- Blood transfusion volume: 1 unit vs. 5 units

These differences were higher in G2 than G1 ($p<0.05$). There were no significant differences in gender distribution, body mass index values, or follow-up times ($p>0.05$).

Curve Measurements

Preoperative Cobb angles were higher in G2 than G1 (p=0.049). No significant difference was found between early and late Cobb angles in both groups (p=0.803 and 0.408, respectively). Cobb angles showed a significant decrease in early and late terms in both groups ($p<0.05$), but the late change in the Cobb angle decrease was higher in G2 than G1 (p=0.039).

There was no significant difference in terms of preoperative, early, and late kyphosis angles in both groups (p=0.090, 0.933, and 0.900, respectively). In G1, early and late changes in kyphosis angles were not significant (p=0.574 and 0.482, respectively). In G2, there was a significant early decrease in kyphosis angle (p=0.036), while the late change was not significant (p=0.091).

There was no significant difference in preoperative, early, and late lordosis angles between G1 and G2 (p=0.507, 0.618, and 0.868, respectively). In G1, early and late changes in lordosis angles were not significant (p=0.472 and 0.621, respectively), whereas in G2, lordosis angles decreased in early and late terms (p=0.018).

Table 1. Radiologic coronal and sagittal curve measurements

	Group 1		Group 2		
	Mean ± SD	Median	Mean ± SD	Median	p-value
Coronal main Cobb angle					
Preoperative period	45.5±22.2	43.0	54.1±18.8	57.0	0.049 [m]
Early postoperative period	23.9±22.2	20.5	22.3±13.8	21	0.803 [m]
Final follow-up	30.7±24.6	29.0	23.9±13.8	25.5	0.408 [m]
Thoracic kyphosis angle (T2-T12)					
Preoperative period	40.2±20.9	40.0	54.6±16.6	53.0	0.090 [m]
Early postoperative period	36.5±11.0	35.0	36.5±7.9	36.0	0.933 [m]
Final follow-up	42.5±13.4	45.0	42.1±16.3	40.0	0.900 [m]
Lumbar lordosis angle (L1-S1)					
Preoperative period	49.5±21.1	50.0	55.4±14.1	56.0	0.507 [m]
Early postoperative period	46.8±16.5	50.0	43.4±10.1	41.5	0.618 [m]
Final follow-up	50.0±17.5	45.0	48.4±15.1	51.5	0.868 [m]

[m]Mann-Whitney U test , SD: Standard deviation

Balance Measurements

Preoperative, early, and late coronal and sagittal balances did not show a significant change within or between groups (p>0.05). Late sagittal balance change was higher in G1 than G2 (p=0.025).

There was no significant difference between the groups in preoperative, early, and late shoulder balance (p=0.741, 0.301, and 0.709, respectively). Early shoulder balance change in G2 was higher than in G1 (p=0.042).

There was no significant difference in preoperative, early, and late pelvic obliquity between and within groups (p=0.137, 0.363, and 0.246, respectively). Leg length inequality and hip contracture were not found on physical examination in both groups.

HRQoL Outcomes

In G1, the following changes were observed:

- Patients' general health status, child and parent satisfaction, and activity of daily living increased (p<0.05)
- There were no substantial changes in postoperative pain or discomfort, pulmonary function, transfer capacity, physical function, fatigue or energy level, parental impact, or financial impact (p>0.05)
- The postoperative emotional state decreased (p<0.05)

In G2, the following changes were observed:

- Postoperative pain, physical function, self-image, mental health, and satisfaction with treatment management increased (p<0.05)

Table 3 provides a detailed comparison of the HRQoL outcomes.

Complications

A proximal adding-on phenomenon was observed in 1 patient in G1, and a superficial surgical site infection developed in 1 patient in G2. No postoperative neurological complications were observed in either group.

DISCUSSION

We observed emotional deterioration in children below 10 years old who underwent hemivertebrectomy and fusion surgery. Emotional states; including anxiety, stress, and disappointment, were assessed according to the questionnaire. Our findings highlight the critical need for perioperative psychological support for these young patients. We also noted that older children might experience higher pain scores due to the complexity of their surgical procedures or inadequate postoperative pain management. Despite these challenges, all other HRQoL scores improved positively in both age groups. Although there was no significant difference between the two groups in terms of postoperative radiological scores, intra-group changes in G2 were higher than G1.

Literature shows varying HRQoL outcomes. For instance, a clinical study with a minimum follow-up of 2 years reported that hemivertebrectomy with short-level fusion resulted in high scoliosis correction rates and increased back pain but improved function[10]. Another study with a 1-year follow-up of patients with congenital scoliosis found that initial postoperative scores for function and pain decreased in the surgical fusion group, but function, image, and satisfaction scores eventually increased[11]. Normal growth of unaffected spine sections is possible if the

Table 2. Radiologic coronal and sagittal balance measurements

	Group 1		Group 2		
	Mean ± SD	Median	Mean ± SD	Median	p-value
Coronal balance (C7-CSVL/cm)					
Preoperative period	1.3±1.3	1.0	0.9±1.0	0.6	0.341 [m]
Early postoperative period	1.6±1.0	1.5	1.7±1.5	1.3	0.901 [m]
Final follow-up	1.1±0.9	0.8	1.2±1.1	1.1	0.589 [m]
Sagittal balance (C7-S1/cm)					
Preoperative period	5.2±3.5	5.5	3.4±2.4	4.2	0.224 [t]
Early postoperative period	3.1±2.5	2.5	4.6±3.0	4.2	0.285 [t]
Final follow-up	2.5±2.1	1.8	2.8±2.1	2.2	0.790 [t]
Shoulder balance (coracoid height difference / cm)					
Preoperative period	1.4±1.2	1.2	1.8±1.4	1.2	0.741 [m]
Early postoperative period	1.1±1.2	0.9	1.6±1.1	1.4	0.301 [m]
Final follow-up	1.2±1.3	0.6	1.0±0.7	0.9	0.709 [m]
Pelvic obliquity (horizontal pelvic angle °)					
Preoperative period	5.2±4.6	4.0	2.9±2.8	2.3	0.137 [m]
Early postoperative period	3.5±3.4	1.8	3.6±5.3	1.5	0.363
Final follow-up	2.5±1.0	2.2	3.3±4.8	1.6	0.246 [m]

[m]Mann-Whitney U test, [t]Independent samples t-test, SD: Standard deviation

Table 3. EOSQ-24 questionnaire results for Group 1 and SRS-22 questionnaire results for Group 2

	Preop		Postop		
EOSQ-24	**Mean ± SD**	**Median**	**Mean ± SD**	**Median**	**p-value**
General health	34.7±23.2	37.5	63.9±18.2	75.0	0.017[w]
Pain/discomfort	70.8±35.9	87.5	83.3±25.8	100.0	0.461[w]
Pulmonary function	70.8±38.5	100.0	94.4±11.0	100.0	0.109[w]
Transfer	58.3±39.5	75.0	66.7±35.4	75.0	0.655[w]
Physical function	65.0±34.7	75.0	87.2±9.3	90.0	0.078[w]
Daily living	57.5±23.7	50.0	75.6±18.4	75.0	0.042[w]
Fatigue/energy level	61.7±33.4	62.5	75.0±25.0	62.5	0.141[w]
Emotion	62.5±24.2	62.5	40.3±16.3	37.5	0.021[p]
Parental impact	53.9±25.0	55.0	57.8±18.0	65.0	0.624[p]
Financial impact	72.2±19.5	75.0	75.0±35.4	100.0	0.783[w]
Child and parent satisfaction	33.3±28.0	25.0	80.6±11.0	75.0	0.017[w]
	Preop		**Postop**		
SRS-22	**Mean ± SD**	**Median**	**Mean ± SD**	**Median**	**p-value**
Pain	2.5±1.0	2.4	3.7±0.8	3.7	0.005[p]
Function	3.3±1.0	3.2	4.0±0.9	3.9	0.022[p]
Self image	2.3±0.5	2.3	3.9±0.6	3.7	0.001[p]
Mental health	2.4±0.7	2.3	3.5±0.7	3.4	0.006[p]
Satisfaction/dissatisfaction with treatment management	2.0±0.8	2.0	4.4±0.7	4.8	0.000[p]

[p]Paired samples t-test, [w]Wilcoxon test, SD: Standard deviation, SRS-22: Scoliosis Research Society Patient Outcome Questionnaires, EOSQ-24: Early Onset Scoliosis Questionnaires

local deformity is corrected with a short fusion segment. Ruf and Harms[12] noted that older children occasionally required longer fusion segments following HV excision[12]. Delayed treatment of advanced deformities necessitates long fusion segments, which are difficult to correct and pose a high risk for neurological injury[13]. Dimeglio et al.[14] reported that puberty peaks between ages 11 and 13 for females and 13 and 15 for males, with significant growth acceleration during the first two years. G2 had a higher mean age at surgery and a higher preoperative Cobb angle compared to G1. G2 also had longer fusion levels and more complex surgeries, resulting in higher surgical time, intraoperative blood loss, and blood transfusion volume than G1. The crankshaft phenomenon was not observed in our series, consistent with Kesling et al.[15] findings in congenital scoliosis patients.

Xu et al.[16] demonstrated that hemivertebrectomy and short-level fixation effectively reduce coronal segmental and main Cobb angles. Our results showed a significant early and late reduction in main Cobb angles in both groups, with a more substantial late reduction in G2, likely due to higher preoperative Cobb angles and longer fusion level surgeries.

Bao et al.[17] observed a significant correction in the following parameters: segmental kyphosis, total major curve, caudal compensatory curves, and segmental scoliosis, from the preoperative to the final follow-up. But the effects of these surgical procedures on the main thoracic kyphosis angle are also controversial. Although Bixby et al.[18] and Wang et al.[19] have shown that hemivertebrectomy and short-level fixation caused an increase in the thoracic kyphosis angle, Oksanen et al.[10] have demonstrated that hemivertebrectomy and short-level fixation did not change the thoracic kyphosis angle at the final follow-up. Our study found no significant changes in kyphosis angles in G1 at any term, but a significant early decrease in G2, likely due to higher preoperative kyphosis angles and additional corrective osteotomies.

Oksanen et al.[10] and Wang et al.[19] reported that hemivertebrectomy and short-level fixation did not change the lumbar lordosis angle at final follow-up, which our findings in G1 support. In G2, early and late lordosis angles decreased, parallel to the early thoracic kyphosis change. The study has shown a significant correlation between lumbar lordosis and thoracic kyphosis reduction after posterior corrective surgery[20]. A trunk decompensation from the C7 plumb line of more than 20 mm was considered a coronal imbalance of the spine, and a distance of more than 40 mm between the upper posterior sacral vertical line and the C7 plumb line was considered a sagittal imbalance[21]. Studies have shown that HV excision in the lumbosacral region improves coronal and sagittal balance, while thoracolumbar excision has a limited contribution[10,22-24].

In our study, the excised HVs were located in 3 thoracic, 5 thoracolumbar, 3 lumbar, and 1 lumbosacral in G1, and 3 thoracic, 6 thoracolumbar, and 2 lumbar in G2. Coronal and sagittal balance improvements were not different between groups at preoperative, early, and late terms. However, late sagittal balance change was higher in G1, likely due to a higher preoperative sagittal imbalance.

Shoulder balance is crucial for evaluating scoliosis surgery results and cosmetic effects. While the studies with hemivertebrectomy and short-level fixation reported improvements in shoulder balance at final follow-up, the results are not significant[12,18]. Shoulder balance did not differ between groups or at any term in G1, but showed a higher early shoulder balance change in G2, indicating the success of longer fusion levels in achieving shoulder balance.

Pelvic obliquity results from various factors, including leg length inequality, hip contractures, and structural scoliosis[25]. In children who are ambulatory and their caretakers, remaining pelvic obliquity at the conclusion of surgical therapy is associated with worse HRQoL scores. These findings imply that for patients with early-onset scoliosis undergoing surgery, pelvic obliquity correction should continue to be the major objective of care[26]. In our study, no leg length discrepancy or hip contractures were found, and pelvic obliquity was attributed to scoliosis. Pelvic obliquity did not differ between or within groups at any term.

In a series of 27 patients younger than 5 years of age who underwent HV excision and posterior spinal fusion, most of the patients developed spinal instability, and their scoliosis worsened at the last follow-up. Early age at surgery, preoperative scoliosis severity, HV location, lack of arthrodesis technique, and adding-on phenomenon may play a role in it[27]. A 6-year-old patient in G1 who required revision surgery with magnetically controlled growing rods due to a progressive proximal adding-on phenomenon and truncal shift. This patient was the youngest in our study, having undergone the first deformity surgery at age 4.

The limitations of the study include the fact that it does not have a large sample size due to its single-center design.

CONCLUSION

Hemivertebrectomy is a successful surgical treatment for improving radiological and HRQoL scores in children, both below and above 10 years old. Postoperative decreases in the Cobb angle were higher in G2 compared to G1. For children below 10 years old, short-level fixation is recommended for physiological growth and less fusion, along with necessary psychological support to prevent emotional deterioration. Long-level fixation provides advantageous radiological results but may lead to painful HRQoL scores.

Ethics

Ethics Committee Approval: The study adhered to ethical standards and received approval from the Başakşehir Çam and Sakura City Hospital Clinical Research Ethics Committee (approval number: KAEK/25.10.2023-533, date: 06.11.2023).

Informed Consent: Informed consent was obtained from each patient.

Authorship Contributions

Concept: Y.Ö., M.B.B., Design: Y.Ö., M.B.B., Data Collection or Processing: Y.Ö., A.V.Ö., Analysis or Interpretation: K.A., M.B.B., Literature Search: Y.Ö., A.V.Ö., Writing: Y.Ö., M.B.B.

Conflict of Interest: The authors have no conflicts of interest to declare.

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THE EFFICACY OF *IN SITU* FUSION FOR LOW-GRADE SPONDYLOLISTHESIS: A RETROSPECTIVE STUDY

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ABSTRACT

Objective: To investigate the clinical and radiological outcomes of lumbar decompression and instrumented fusion without reduction in a cohort of female patients with degenerative spondylolisthesis.

Materials and Methods: A retrospective analysis was conducted on 25 female patients who underwent posterior lumbar decompression and instrumented fusion at a single institution between January 2010 and January 2020, all of whom were followed up for at least 12 months. The study measured changes in pain and disability using the Visual Analogue Scale (VAS) and Oswestry Disability Index (ODI), along with changes in vertebral alignment, olisthesis, grade, and slip angle.

Results: Significant reductions were observed in pain intensity (VAS scores decreased from 7.4 to 4.08, p<0.001) and disability levels (ODI scores reduced from 65.12 to 31.04, p<0.001). Improvements were also noted in the listhesis grade (from 2.08 to 1.28, p<0.001) and a decrease in sacral slope (p=0.017). The change in the slip angle was not statistically significant (p=0.074). No significant changes were observed in pelvic tilt (p=0.353). The only reported complication was adjacent segment degeneration in one patient, which required revision.

Conclusion: *In situ* fusion without reduction can effectively alleviate pain, improve function, and lead to spontaneous correction of olisthesis grade in patients with degenerative lumbar spondylolisthesis, particularly those with low-grade slips. These outcomes support the efficacy of *in situ* fusion as a safer, less invasive alternative to vertebral reduction. This approach could influence clinical decision-making in the management of degenerative spondylolisthesis, although further studies with larger cohorts and extended follow-up are necessary to validate these findings.

Keywords: Spondylolisthesis, *in situ* fusion, instrumented fusion

INTRODUCTION

Spondylolisthesis, defined as the forward displacement of a vertebral body over its adjacent counterpart, is a prevalent spinal disorder affecting approximately 4-6% of the general population[1]. It is classified into five distinct types by Wiltse et al.[2] -dysplastic, isthmic, degenerative, traumatic, and pathologic- and is radiographically assessed using the Meyerding classification, which ranges from Grade 0 (no slippage) to Grade 4 (76-100% slippage)[2,3]. Grade 1 and 2 slips are generally considered low-grade, while Grade 3 and 4 slips are deemed high-grade[1].

Degenerative spondylolisthesis, most commonly presenting as a low-grade slip (Grade 1 or 2), typically manifests with chronic low back pain and, in more severe cases, neurological dysfunction of the lower extremities[1]. Typically, at least three months of nonoperative management, including the use of braces, exercises, and other conservative modalities, yields satisfactory results[4,5]. However, for patients whose symptoms persist or worsen, or those who develop neurological deficits despite these treatments, surgical intervention may be warranted[4,5].

The surgical goal is to decompress the affected neural structures and secure vertebral fusion, which can be performed with or without the reduction of the slipped vertebra[6]. While reduction might theoretically enhance biomechanical alignment and facilitate fusion, it is associated with inherent risks, including potential neurological injury and operative complications[7].

In light of these considerations, this study seeks to investigate the mid-to-long term clinical and radiological outcomes of lumbar decompression and instrumented fusion without reduction in a cohort of female patients with degenerative spondylolisthesis. By evaluating changes in pain, disability, and vertebral alignment over time, this research aims to elucidate the efficacy and safety of *in situ* fusion as a viable surgical strategy for this

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patient population, thereby informing clinical decision-making and ultimately improving patient care.

MATERIALS AND METHODS

A retrospective review was conducted on patients who underwent surgical treatment for degenerative lumbar spondylolisthesis at the authors' institution between January 2010 and January 2020. Patients were included if they had a confirmed diagnosis of degenerative lumbar spondylolisthesis, underwent posterior lumbar decompression (laminectomy) and instrumented fusion, and had at least 12 months of follow-up with complete medical records. Patients with other types of spondylolisthesis, those who did not undergo surgical treatment, those with insufficient follow-up, or those with missing information were excluded. A total of 25 female patients met the inclusion criteria and were included in the study. This was due to the consecutive nature of patient selection, resulting in a higher number of female participants. This approach was essential for maintaining the methodological rigor of the study.

Surgical indications for these patients included persistent pain unresponsive to at least 6 months of conservative treatments, progressive motor deficit, and/or cauda equina syndrome. The surgical procedure consisted of posterior lumbar decompression (laminectomy) and instrumented fusion with pedicle screws (Figure 1, 2). The number of laminectomy levels performed was dependent on the extent of stenosis and the specific surgical goals for each patient. For cases where laminectomy was applied only to the segment with spondylolisthesis, this was explicitly stated as the surgical approach. For patients who underwent long segment fusion, such as the L1-S1 fusion cases, a comprehensive laminectomy was performed at all levels of stenosis, even if not all were associated with spondylolisthesis. This was done to ensure complete neurological decompression and to address multi-level stenosis that might contribute to postoperative outcomes.

Pedicle screws were placed at the levels necessary to achieve stable fixation, spanning from the uppermost instrumented vertebra to the sacrum (S1) in all cases. The inclusion of S1 in the fusion construct was deemed necessary to optimize spinal stability and improve overall outcomes, particularly in patients with osteoporosis or other risk factors for nonunion, as well as to address concomitant lumbar degenerative scoliosis or significant deformity.

The decision for long-segment fusions (spanning three or more levels) was primarily driven by the presence of comorbidities such as multi-level stenosis or degenerative scoliosis. These patients required more extensive surgical intervention to address their complex spinal pathology and ensure adequate correction and stabilization.

The following data were collected from the patient archive: demographic characteristics, follow-up periods, surgical details, complications, preoperative and postoperative Oswestry Disability Index (ODI), Visual Analogue Scale (VAS) scores, and radiographic measurements (Listhesis Grade, Sacral Slope, Slip angle, Pelvic Tilt). The ODI is a validated questionnaire that measures the degree of disability and its impact on daily activities, while the VAS is a scale for assessing pain intensity[8,9].

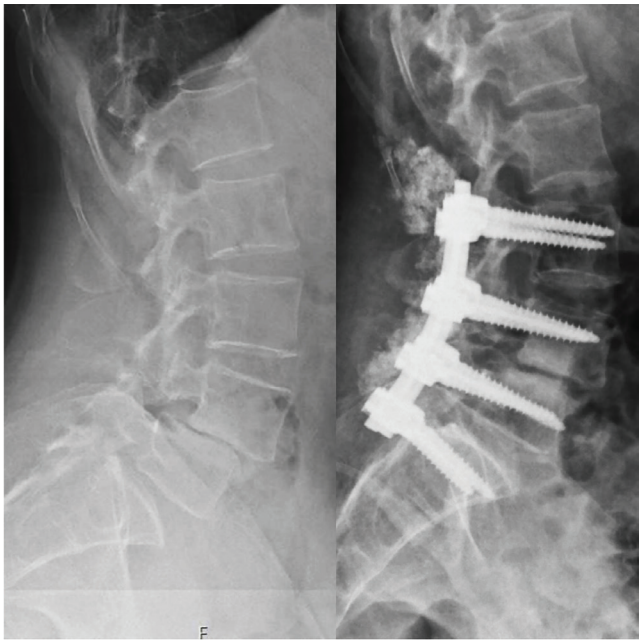

Figure 1. Preoperative and postoperative lateral X-rays of a 57 year-old woman underwent listhesis surgery: the preoperative X-ray (left) showed a Grade 2 listhesis at L4-L5. The postoperative X-ray (right) showed stabilization from L3 to S1 with pedicle screws, improving the alignment to Grade 1

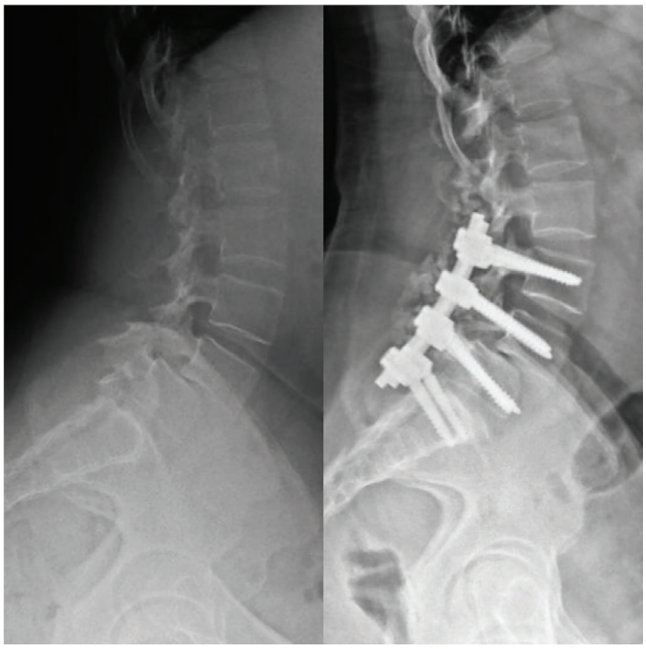

Figure 2. Preoperative and postoperative lateral X-rays of a 63 year-old woman underwent listhesis surgery: the preoperative X-ray (left) showed a Grade 2 listhesis at L4-L5. The postoperative X-ray (right) showed stabilization from L3 to S1 with pedicle screws, the alignment remained unchanged

Radiographic parameters were used to evaluate spinal alignment and spondylolisthesis severity. All radiographic measurements were performed independently by three blinded investigators. Inter-observer reliability was assessed using Cohen's kappa coefficient, which showed a high level of agreement between raters [κ=(0.86)]. Measurements were performed at two different time periods: preoperative and at designated control dates.

The study protocol was approved by the University of Health Sciences Turkey Antalya Training and Research Hospital Ethical Committee (approval number: 5/22-2024, date: 25.04.2024). A written informed consent was obtained from each patient. The study was conducted in accordance with the principles of the Declaration of Helsinki and its subsequent updates.

Statistical Analysis

Statistical analyses were conducted using SPSS 23.0 for Windows (SPSS Inc., Chicago, IL, USA). We first assessed the normality of our data using the Shapiro-Wilk test to determine the appropriateness of statistical tests. Categorical variables were expressed as numbers and percentages [n (%)], and continuous variables were presented as both mean ± standard deviation and median values along with their range (minimum-maximum value). To compare preoperative and postoperative continuous data, we applied the Wilcoxon signed-rank test, which is suitable for paired samples when data are not normally distributed. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Twenty-five female patients with a mean age of 57.4 years (range 40-70) were included in this study. The mean postoperative follow-up time was 51 months (range 17-117). Fusion levels ranged from L1-S1 to L5-S1, with L3-S1 being the most common (40%). Preoperative listhesis grades were mostly grade 2 (76%), and postoperative listhesis grades were mostly grade 1 or 2 (48% each). (Table 1 presents a detailed description of the study participants, focusing on their demographic and clinical characteristics). Fusion occurred in all patients, as confirmed through radiographic and clinical assessments. Continuous bone bridging, minimal loss of disk height, and absence of hardware complications were observed in the radiographs and computed tomography scans, while significant pain reduction and functional improvement indicated successful clinical outcomes. Among 25 patients, one experienced postoperative adjacent segment degeneration (ASD) requiring revision with extended fixation, representing the only complication.

Pain intensity, as measured by the VAS, significantly decreased after surgery (p<0.001). The mean VAS score dropped from 7.4 preoperatively to 4.08 postoperatively. Similarly, disability, assessed using the ODI, showed marked improvement after surgery (p<0.001). The mean ODI score decreased from 65.12 preoperatively to 31.04 postoperatively. Grade of listhesis significantly improved after surgery (p<0.001). After *in situ* fusion, the mean listhesis grade at the final follow-up improved significantly from 2.08 preoperatively to 1.28 (p<0.05). The sacral slope showed a small but statistically significant decrease after surgery (p=0.017). The mean sacral slope decreased from 47.01° preoperatively to 42.69° postoperatively. While the slip angle showed a decrease after surgery, this change did not reach statistical significance (p=0.074). The mean slip angle decreased from 12.62° preoperatively to 9.42° postoperatively. Pelvic tilt did not significantly change after surgery (p=0.353). The mean pelvic tilt was 18.27° preoperatively and 19.45° postoperatively (the clinical findings of this study are presented in Table 2, detailing preoperative and postoperative measures and their statistical significance).

DISCUSSION

The study's most significant finding was that *in situ* spinal fusion alone, without intentional reduction, can substantially alleviate pain (VAS score), reduce disability (ODI score), improve listhesis grade, and lead to a reduction in sacral slope. This

Table 1. Demographic and clinical characteristics of the participants (n=25)

Variables	
Age (year)	
Mean ± SD	57.4±9.01
Median (min.-max.)	59 (40-70)
Gender, n (%)	
Male	0 (0.0)
Female	25 (100.0)
Fusion levels, n (%)	
L1-S1	1 (4.0)
L2-S1	5 (20.0)
L3-S1	10 (40.0)
L4-S1	8 (32.0)
L5-S1	1 (4.0)
Postoperative follow-up time, months	
Mean ± SD	51.04±32.01
Median (min.-max.)	30 (17-117)
Listhesis levels, n (%)	
L1-S1	0
L2-S1	0
L3-L4	1 (4.0)
L4-L5	12 (48.0)
L5-S1	12 (48.0)
Preoperative listhesis grade, n (%)	
Grade 1	2 (8.0)
Grade 2	19 (76.0)
Grade 3	4 (16.0)
Postperative listhesis grade, n (%)	
Grade 0	3 (12.0)
Grade 1	12 (48.0)
Grade 2	10 (40.0)

SD: Standard deviation, min.: Minimum, max.: Maximum

Table 2. Preoperative and postoperative radiological and clinical scores of the patients

	Preop	Postop	p-value*
VAS score			
Mean ± SD Median (min.-max.)	7.4±1.26 8 (5-9)	4.08±2.58 4 (0-9)	<0.001
Total ODI score			
Mean ± SD Median (min.-max.)	65.12±16.44 62 (46-98)	31.04±21.46 30.0 (2-78)	<0.001
Listhesis grade, n (%)			
Mean ± SD Median (min.-max.)	2.08±0.49 2 (1-3)	1.28±0.68 1 (0-2)	<0.001
Sacral slope			
Mean ± SD Median (min.-max.)	47.01°±11.15° 44.3° (29.4°-68.6°)	42.69°±9.07° 43.4° (27.5°-70.3°)	0.017
Slip angle			
Mean ± SD Median (min.-max.)	12.62°±8.82° 10.9° (0.8°-34.3°)	9.42°±8.33° 6.9° (0.5°-35.4°)	0.074
Pelvic tilt			
Mean ± SD Median (min.-max.)	18.27°±10.47° 15.9° (2.7°-45.1°)	19.45°±11.67° 16.2 (4.9°-47.3°)	0.353

*Wilcoxon test, SD: Standard deviation, min.: Minimum, max.: Maximum, ODI: Oswestry Disability Index

suggests that the fusion process itself, by stabilizing the affected segment, can incidentally contribute to improved vertebral alignment and symptom relief.

These pivotal findings not only underscore the efficacy of *in situ* fusion but also pave the way for examining their clinical implications in pain management and functional recovery. The substantial postoperative reduction in VAS scores signifies a marked improvement in pain management, aligning with a core objective of surgical intervention in lumbar spondylolisthesis. This observation is consistent with the commonly held view that neurological decompression and vertebrae fusion are the primary objectives of surgery[10]. Furthermore, the considerable improvement in ODI scores post-surgery reflects a significant enhancement in patient-reported functional outcomes and quality of life. These findings are corroborated by a meta-analysis on "Fusion *In Situ* versus Reduction for Spondylolisthesis Treatment" which documented comparable enhancements in quality of life metrics, including ODI and VAS, following surgical interventions for spondylolisthesis[11]. These collective findings underscore the efficacy of surgical intervention in not only mitigating pain but also in restoring functionality and enhancing the overall well-being of patients with degenerative lumbar conditions.

To better understand the context of our findings, it's important to review the classification of spondylolisthesis and the current treatment approaches for different grades. Spondylolisthesis is classified by the Meyerding system, ranging from Grade 0 (no slippage) to Grade 4 (76-100% slippage). Grades 1 and 2 are considered low-grade, while 3 and 4 are high-grade[1]. The management of spondylolisthesis, especially in high-grade cases, remains controversial, with debate surrounding the benefits and risks of reduction versus *in situ* fusion[6]. Reduction of high-grade spondylolisthesis offers potential advantages over *in situ* fusion, particularly in patients with significant lumbosacral kyphosis[12-14]. These advantages include direct decompression of neural elements by reducing canal and foraminal stenosis, and improvement of the biomechanical environment for fusion by decreasing tension on the fusion mass[12,13]. However, the decision to pursue reduction is not without controversy. The primary concern revolves around the potential for increased intraoperative complications due to nerve root distraction during the corrective procedure. Studies have reported higher rates of neurologic deficits and loss of reduction postoperatively in patients who underwent reduction compared to those who underwent arthrodesis *in situ*[15]. Despite these concerns, research findings regarding neurologic deficits following reduction are not entirely consistent. While some studies have found a significant difference in neurologic deficits between the two procedures[6], a systematic review concluded that reduction was not associated with a greater risk of developing neurologic deficits compared to arthrodesis *in situ*[16]. In addition to the potential for neurologic complications, reduction may also lead to increased operative time[15]. Therefore, the decision to pursue reduction should be made carefully, weighing the potential benefits against the risks and considering individual patient factors.

In contrast to the contentious strategies for high-grade cases, our study predominantly involved patients with low-grade spondylolisthesis, aligning with the literature indicating that degenerative spondylolisthesis commonly presents as a low-grade slip (Grade 1 or 2)[1]. Remarkably, significant improvement in listhesis grade were observed following *in situ*

fusion, which occurred naturally without intentional reduction. This spontaneous reduction often fell below grade 1 and was still statistically significant, aligning with previous research by Lambrechts et al.[17] which indicates that such reductions are safe. By achieving spontaneous correction within this safe range, we avoided potential complications associated with more aggressive reduction techniques while still securing positive patient outcomes. This underscores the notion that achieving stable fusion can inadvertently lead to correction of the slippage over time. Naderi et al.[18] further emphasized that in cases of low-grade spondylolisthesis, the focus should be on achieving solid fusion rather than forcing a reduction, as the fusion itself often leads to a natural correction of the slippage over time. This perspective is supported by the findings of Hagenmaier et al.[19], who concluded that the clinical outcomes in lumbar fusion for low-grade spondylolisthesis are not directly contingent upon the degree of radiographic correction. While some studies propose a positive impact of repositioning the slipped vertebra on clinical outcomes, the lack of comparative studies leaves these results inconclusive[20,21].

Building on these findings, the significance of sagittal spinopelvic balance in the surgical management of spondylolisthesis is further highlighted. A significant reduction in sacral slope was observed following surgery in this study, indicating effective correction of pelvic retroversion. This adjustment enhances spinal alignment over the pelvis, essential for improving outcomes in spinal disorders. Harroud et al.[22] have documented the importance of restoring global sagittal alignment to improve health-related quality of life for patients, especially with high-grade spondylolisthesis. This is supported by additional research which corroborates the link between improved sagittal alignment and better patient outcomes[23,24]. Furthermore, the debate regarding the necessity of reduction versus achieving sagittal balance suggests that restoring sagittal balance may offer crucial biomechanical advantages over mere reduction of slip percentage in spondylolisthesis management[12]. Our results affirm that modifications in spinopelvic parameters can lead to substantial improvements in biomechanical and functional outcomes, thus supporting less invasive surgical strategies that prioritize alignment correction over aggressive repositioning techniques. However, the minimal change in pelvic tilt suggests that either the surgery did not affect the rotational balance of the pelvis or that the pelvis had already adapted to a position that provided the best possible balance, given the pre-existing spinal conditions. This underscores the complexity of spinal biomechanics and the need for individualized surgical planning to optimize each patient's outcome based on their specific anatomical challenges[25,26].

The selection of long segment versus short segment fusion, including the decision to extend the fusion to S1, was based on a comprehensive assessment of the patient's spinal pathology and overall health status. The inclusion of S1 in the fusion construct was necessary to achieve optimal spinopelvic alignment and stability, particularly in cases with multi-level degenerative changes or significant deformities. The potential impact on the sacroiliac joint and the risk of pseudoarthrosis were considered, with long-term outcomes such as VAS and ODI scores being carefully monitored. Patients selected for long segment instrumentation had indications such as multi-level degenerative scoliosis, significant sagittal imbalance, or instability that extended beyond the levels affected by spondylolisthesis, necessitating a more extensive surgical approach.

In addition to the changes in listhesis grade and sagittal alignment, our study also revealed a trend towards improvement in the slip angle postoperatively, although the reduction was not statistically significant. This parameter is essential for understanding the degree of anterolisthesis correction, and while our results did not show a statistically significant change, they do indicate a potential for some biomechanical correction through surgery. This finding aligns with other studies that have noted varying degrees of slip angle correction with stabilization techniques, though these changes are often more pronounced with active reduction strategies[11,16].

While our findings contribute positively to the literature on spinal fusion, it remains imperative to consider the potential complications, which our study also documented. Among these, the incidence of ASD following spondylolisthesis surgery remains a topic of ongoing investigation. Previous studies have reported variable rates of ASD, with incidences ranging from 35% to 75% at 10 year follow-up[27,28]. In contrast, our study observed a lower incidence of just 4% over a mean follow-up of 51 months. This discrepancy may be attributed to several factors, including our relatively short follow-up duration, the natural aging process of the spine, and the spontaneous reduction in listhesis grade observed in our study. Our results align with previous studies suggesting a potential protective effect of *in situ* fusion on ASD development[27-29] but longer-term studies are needed to definitively assess this relationship and elucidate the complex interplay between surgical intervention, spondylolisthesis reduction, and ASD.

Study Limitations

Our study, while providing valuable insights into the efficacy of *in situ* fusion for lumbar spondylolisthesis, is not without limitations. Primarily, the retrospective nature of the study and the relatively short follow-up duration (mean 51 months) may not fully capture the long-term effects of *in situ* fusion, particularly regarding the development of ASD. Additionally, our relatively small sample size and predominance of low-grade spondylolisthesis in our sample may restrict the generalizability of our findings to other spondylolisthesis populations with varying subtypes and severities. Furthermore, all patients in the study were female, which may limit the applicability of the results to a broader population, including males. The absence of a control group prevents direct comparison with other surgical approaches, such as reduction and fusion, making it difficult to isolate the specific contribution of spontaneous correction to the observed outcomes.

The patient group consisted mostly of patients with grade 2 degenerative spondylolisthesis. The improvements in VAS and ODI scores observed may be secondary to decompression. While decompression alone can lead to immediate pain relief and functional improvement, the fusion procedure likely contributed to sustaining these benefits over time by addressing underlying mechanical instability. Future studies should aim to differentiate the effects of decompression alone from those combined with fusion procedures, particularly focusing on long-term outcomes. This will help to further elucidate the specific contributions of each component of the surgical intervention in patients with degenerative lumbar spondylolisthesis.

Future prospective, randomized controlled trials with longer follow-up periods and diverse patient populations are warranted to validate our findings and provide a more comprehensive understanding of the long-term benefits and risks of *in situ* fusion for spondylolisthesis.

CONCLUSION

In conclusion, our study demonstrates that *in situ* spinal fusion alone, without intentional reduction, can lead to significant pain relief, functional improvement, and spontaneous correction of listhesis grade in patients with degenerative lumbar spondylolisthesis, particularly those with low-grade slips. The observed improvement in sagittal spinopelvic balance further supports the notion that restoring spinal alignment plays a crucial role in achieving optimal patient outcomes. While our findings suggest a potential protective effect of *in situ* fusion on ASD development, further investigation with longer follow-up periods is needed to confirm this observation. Overall, our study provides compelling evidence for the efficacy of *in situ* fusion as a less invasive and potentially safer alternative to reduction and fusion in carefully selected patients with degenerative lumbar spondylolisthesis. These findings have the potential to inform surgical decision-making and contribute to improved patient care in the management of this prevalent spinal disorder.

Ethics

Ethics Committee Approval: The study protocol was approved by the University of Health Sciences Turkey, Antalya Training and Research Hospital Ethical Committee (approval number: 5/22-2024, date: 25.04.2024).

Informed Consent: A written informed consent was obtained from each patient.

Authorship Contributions

Surgical and Medical Practices: Ö.F.E., A.Y., Ö.F.K., H.S., V.N., Concept: Ö.F.E., Ö.F.K., M.A.T., V.N., Design: Ö.F.E., A.Y., Ö.F.K., V.N., Data Collection or Processing: A.Y., M.A.T., H.S., Analysis or Interpretation: Ö.F.E., A.Y., M.A.T., H.S., Literature Search: Ö.F.E., A.Y., Ö.F.K., M.A.T., H.S., V.N., Writing: Ö.F.E., A.Y., Ö.F.K., V.N.

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