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Preoperative Tomographic Needle Marking: A Novel Level Localization Method to Avoid Wrong-Level Spine Surgery in Upper Thoracic Lesions

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Abstract

Objective: The objective of this study is to reduce the incidence of wrong-level surgery in upper thoracic spinal surgery.

Methods: The data of 26 patients whose level was determined by the preoperative fluoroscopy method and 21 patients whose level was determined by the preoperative computed tomography method were analyzed and compared statistically.

Results: A statistically significant difference was identified in the rate of wrong-level surgery between the groups. The rate of additional laminectomy due to wrong-level surgery in the preoperative fluoroscopy group was statistically significantly higher than in the preoperative computed tomography group ($P = .026$). In addition, the average time from positioning to incision in the preoperative fluoroscopy group was found to be statistically significantly higher than in the preoperative computed tomography group ($P < .001$).

Conclusion: The preoperative computed tomography method provides a shorter surgical time and reduces the incidence of wrong-level surgery compared to the preoperative fluoroscopy method.

Keywords: Wrong level surgery, thoracic spine, level localization

Introduction

The incidence of spinal surgery is increasing day by day, which is inevitably associated with higher figures of complications.[1] Although the complication rate cannot be predicted with certainty, complications have been reported to occur in 10%-25% of patients undergoing spinal surgery. Most of these complications were reported as mild, but serious complications developed at a rate of 11%, with a 3% risk of death.[2-5] One of the key predisposing factors for such complications is wrong-level surgery (WLS). The literature has shown that half of the spinal surgeons could operate on the wrong site at least once in their career, and the prevalence of WLS is relatively high.[6] To avoid WLS, it is necessary to obtain excellent radiological imaging and knowledge of the presence of congenital anatomical anomalies. Still, no matter how many precautions are taken, the wrong level can be operated instead of the targeted level in the thoracic (T) vertebra.[6] In this study, a novel level localization method aiming to minimize the error in level detection in upper thoracic spine lesions and the clinical results of the method were presented to the literature, and it was aimed to reduce the frequency of WLS in the spine.

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Material and Method

Ethical Approval

This study was approved by the chairmanship of the Clinical Research Ethics Committee of the Istanbul Haseki Training and Research Hospital of Health Science University (Date: May 25, 2022, approval number: 101-2022).

Study Population

Within the scope of the study, anamnesis, physical examination, magnetic resonance (MR), and computed tomography (CT) imaging of the patients operated on in our hospital between 2015 and 2022 were retrospectively analyzed. The data of 47 patients operated on T2-8 spinal levels due to various pathologies were analyzed retrospectively. The data of 26 patients whose level was determined by preoperative fluoroscopy (PRES) and 21 patients whose level was determined by preoperative computed tomography (PRECT) method were analyzed. Four patients were excluded from the study because they did not meet the inclusion criteria. Forty-three patients who met the inclusion criteria were included in the study. Written informed consent was obtained from all participants who participated in this study.

Inclusion and Exclusion Criteria

We included patients who had surgery for the first time and had no or mild spinal deformity, provided they could undergo MR imaging. Patients with advanced scoliosis and/or kyphotic deformity, those undergoing reoperation, and who were ineligible to undergo MR imaging, e.g., due to an MR-incompatible metallic implant, were excluded.

Preoperative Fluoroscopy *Method*

After general anesthesia was established, the patient was put into a prone position on the operating table, followed by skin antisepsis via povidone-iodine. Starting from the lower lumbar region, multiple marking needles were inserted at intervals of 2-3 vertebral levels. After the needles were inserted, multiple scopy imaging was performed starting from the most inferior needle, and the level was determined. Afterward, the operation was initiated under routine antisepsis conditions.

Preoperative Computed Tomography Method

Before the CT with a marker needle was performed, MR images of the patients were evaluated to determine the length of the needle to be used, and the distance from the skin to the spinal cord was measured. The length of the needle to be used was calculated, so that it would enter between the 2 spinous processes but would not damage the spinal cord and would not be able to move cranially and caudally in the interspinous space, and the amount of stretching of the skin was also taken into account while making this calculation (Figure 1). The skin antisepsis was ensured with povidone-iodine just before the CT scan with a marker needle was performed. After antisepsis, local anesthesia with 5-10 mL of lidocaine 1% was administered to the interspinous space where the marker needle would enter, and a Beybi® 2-mL syringe needle was inserted into the interspinous space in a sterile manner. After the needle was inserted, it was covered with sterile gauze. While CT imaging was performed, gel pillows from the sides supported the back of the patients to leave the marker needle idle. After CT imaging, the interspinous space where the needle was located was confirmed (Figure 2), and the patients were then transferred to the operating room in the prone position. Gel pillows were placed on the stretcher to avoid pressure on the needle, and general anesthesia was established while the patients were in the supine position on the pillows. Afterward, the patients were taken to the operating table in the prone position, the gauze was removed such that the sterility of the marked area would not be impaired, and then the operation area was dyed with povidone-iodine under the routine antisepsis conditions. The skin incision was made after sterile dressing, and the interspinous process where the needle was located was verified. After this confirmation, the needle was removed, and the operation was continued (Figure 3).

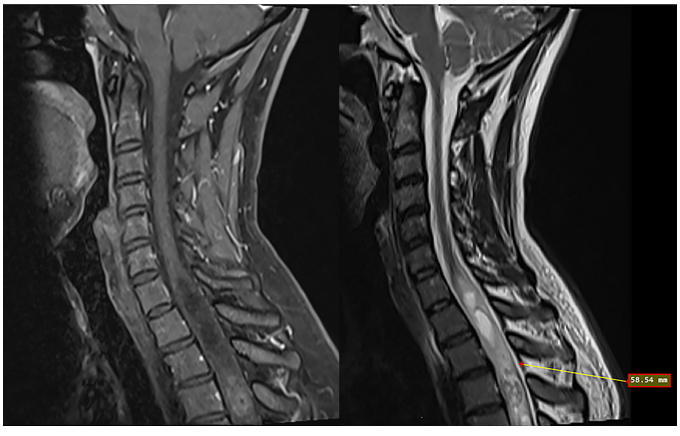

Figure 1. Determination of the length of the marker needle. A marker needle was planned to be inserted through the T2-3 interspinous space for the PRECT method in the patient with an intramedullary mass at the T3 corpus level on contrast-enhanced T1 and T2 sagittal MR images. The maximum length of the needle was calculated as 58.54 mm. MR, magnetic resonance; PRECT, preoperative computed tomography.

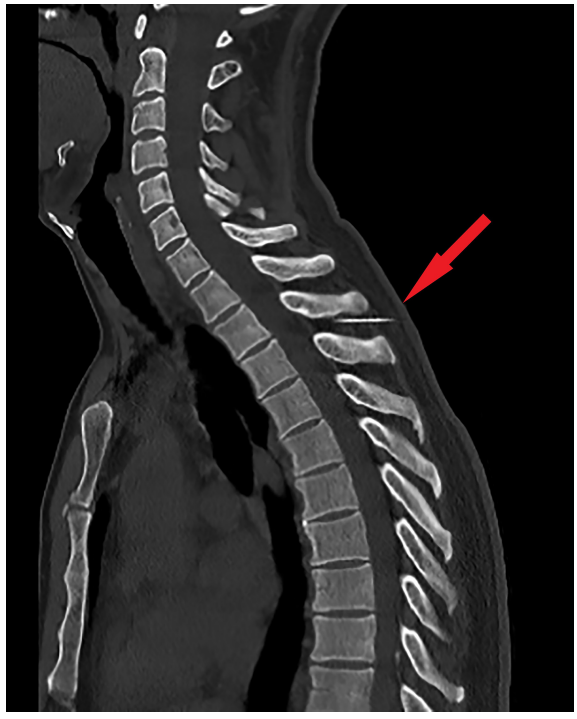

Figure 2. Sagittal CT image with a marker needle. The marker needle (indicated with a red arrow) is shown to be inserted into the T2-3 interspinous space as planned. CT, computed tomography.

Patient Assessment Protocol

After completing the general anesthesia procedure of the patients in both the groups, the time from positioning to incision and the presence of reoperation due to WLS were obtained from their files, and the results between the groups were compared statistically.

Statistical Analysis

We used Statistical Package for Social Sciences Software 15.0 (SPSS Inc., Chicago, IL, USA) for Windows to analyze study data. Descriptive data were expressed as numbers and percentages for categorical variables and as mean, standard deviation, minimum, maximum, and median for continuous variables. We compared categorical variables of the study groups via chi-square test and continuous variables via Student's *t*-test and Mann–Whitney *U*-test for normally and non-normally distributed variables, respectively. We used an overall alpha error level of $P < .05$ to infer statistical significance.

Results

While there were 11 female patients in both the groups, there were 13 male patients in the PRES group and 8 male patients in the PRECT group ($P = .432$). The mean age in the PRES group (49.1 ± 11.5 years) and PRECT group (53.1 ± 13.3 years) was similar ($P = .304$). The lesions in the PRES group were primarily distributed in T3, T4, T5, and T6 levels (n = 4 for each), whereas it was T4 and T6 in the PRECT group (n = 4 for each) ($P = .996$). While 66.7% of the lesions were extradural in the PRES group, it was 47.4% in the PRECT group ($P = .203$). The study groups also did not differ in terms of the rate of comorbidity ($P = .748$) or distribution of pathology ($P = .631$) (Tables 1-3).

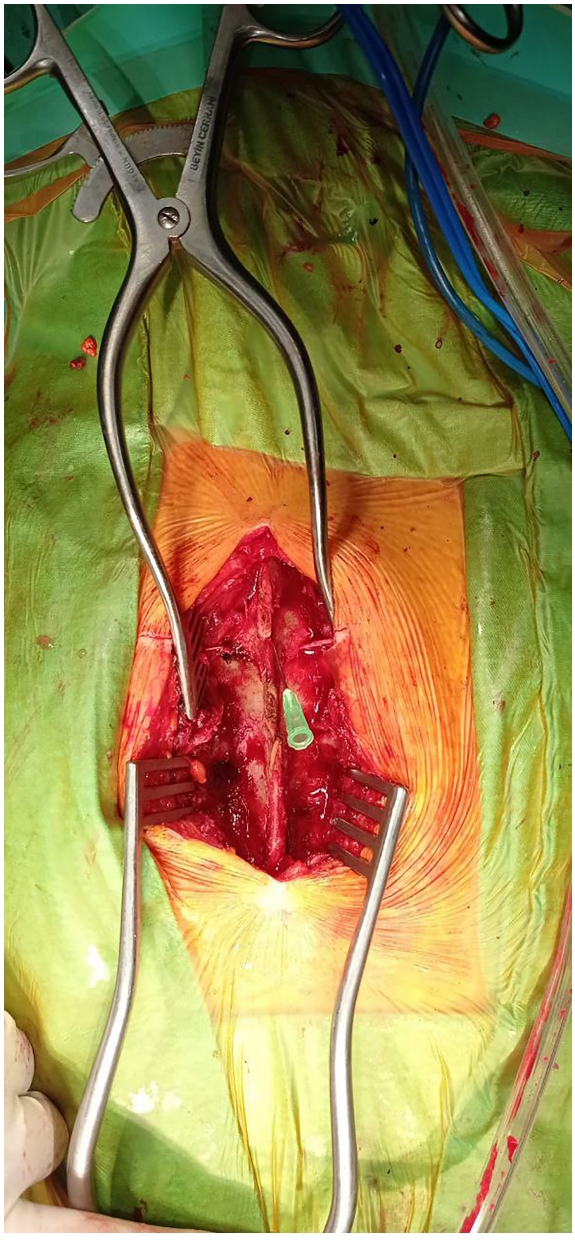

Figure 3. The marking of spinous processes located superior and inferior to the marker needle. In the PRECT method, after the patient takes the prone position, the surgical position, skin antisepsis is provided without disturbing the sterilization of the marker needle. When the incision is completed, the spinous processes superior and inferior to the marker needle are marked, and then the needle is removed. The risk of infection is minimal as routine antisepsis rules are followed. The figure shows that the incision is completed without removing the needle in the T2-3 interspinous space, and the spinous processes superior and inferior to the marker needle are exposed. PRECT, preoperative computed tomography.

We identified a significantly shorter time to the incision in the PRECT group (12.1 ± 2.1 minutes) compared to that in the PRES group (23.5 ± 3.2 minutes, $P < .001$). No patient needed additional laminectomy due to WLS in the PRECT group compared to 7 patients in the PRES group, of which 2 cases required reoperation ($P = .026$). In the latter, the time to incision was 22.0 ± 1.22 minutes and 23.5 ± 4.5 minutes for the patients who required perop additional laminectomy and laminectomy with reoperation, respectively. We detected no significant difference in time to incision between those who required additional laminectomy and those who did not in the PRES group. We also did not find a significant association between the need for additional laminectomy and time to incision (Tables 4-7).

Discussion

Wrong-level surgery is a severe problem that negatively affects the satisfaction rate of the patient and the surgeon. While the problem is increased morbidity due to additional complications for patients,[7] it is legal consequences for the surgeon. Since the legal procedures occur in most cases where the WLS is performed, surgeons could be sentenced to large compensation payments.[8] No matter how experienced or careful the surgeon is, one cannot guarantee that he or she would not perform WLS because the deterioration of the spinal anatomy due to scoliosis, weight, or other pathological conditions could compel the ability to determine the surgical level and may lead to the opening of the wrong level.[6]

Wong-level surgery has multiple etiological factors, including anatomical variations, emergency surgery, fatigue, inadequate or suboptimal radiological imaging, operation above L5-S1 level, and lack of surgical experience.[9] Despite all the measures taken, determining the targeted level is challenging for surgeons, especially in the thoracic spine.[6] The underlying reason is that the radiographic shadows of the scapula, ribs, and humerus may negatively affect the vertebrae count.[10,11] In addition, obesity, osteoporosis, and the distance of the lesion from the occiput to the sacrum make it more challenging to determine the level in the thoracic spine.

Neurosurgeons have proposed numerous techniques to prevent WLS in thoracic spinal surgery. Hsu et al[12] reported that the targeted vertebral level could be determined accurately and safely with intraoperative fluoroscopy performed after percutaneous polymethylmethacrylate injection into the thoracic spine before the procedure in 4 patients who were operated on for thoracic disc herniation. Nevertheless, they concluded that it would be appropriate to use the method, which poses a severe disadvantage of cement leakage in 11%-73%[13-15] of the cases where standard fluoroscopic level detection methods fail.[12] Nowitzke et al[16] reported 100% accurate level detection with a navigation device used in 17 patients who underwent surgery in the mid-lower thoracic and lumbar spinal regions. However, the authors also concluded that as the method is fluoroscopic, it may be relatively contraindicated in cases that impair fluoroscopic image quality, such as upper thoracic surgery and obese and osteoporotic patients.[16] Paolini et al[17] reported a technical note of 6 patients with upper thoracic surgery, where they stated that the correct level could be detected simply and safely by determining the level with an anterior-posterior radiograph performed after marking the estimated level with a needle, and then injecting methylene blue into the area. While seemingly safe, there is no clear explanation about how the correct level can be determined by anterior-posterior X-ray in this method. Rosahl et al.[18] in their technical note, reported that the level could be determined by MRI and then by intraoperative ultrasonography, following the taping of 1-3 specially prepared markers to the skin before surgery. On the other hand, the fact that they stated ultrasonography is insufficient in imaging due to calcification and laminae raises concerns about the method's reliability.[18] Upadhyaya et al[19] introduced the fiducial screw placement method to prevent WLS in thoracic spinal surgery, where they placed percutaneous index screws in the posterior components of the targeted vertebra under sedation. Though effective, the authors also listed its serious disadvantages, such as cost, radiation, infection risk, screw

Table 1. Characteristics of the Patients Whose Level Was Determined by the PRES Method

Patient	Age (Years)	Gender	Localization	Pathology	Comorbidity
1	61	F	Thoracic 5, extradural	Plasmacytoma	Multiple myeloma
2	50	M	Thoracic 8, extradural	Spinal stenosis	–
3	53	M	Thoracic 8, extradural	Fracture	–
4	41	M	Thoracic 2, intradural	Meningioma	–
5	51	F	Thoracic 2, extradural	Metastasis	Lenfoma
6	56	F	Thoracic 3, intradural	Hemangioblastoma	Von Hippel–Lindau
7	38	M	Thoracic 4, intradural	Synovial cyst	–
8	29	M	Thoracic 8, extradural	Hydatid cyst	–
9	45	M	Thoracic 3, intradural	Astrocytoma	–
10	70	F	Thoracic 7, extradural	Fracture	HT, DM
11	63	M	Thoracic 6, extradural	Metastasis	Prostate CA
12	45	F	Thoracic 4, extradural	Metastasis	Breast CA
13	50	M	Thoracic 3, extradural	Fracture	–
14	74	M	Thoracic 7, extradural	Multiple myeloma	Chronic renal failure
15	49	F	Thoracic 5, extradural	Pott's abscess	–
16	43	F	Thoracic 6, intradural	Meningioma	Asthma
17	43	F	Thoracic 6, extradural	Metastasis	Breast CA
18	48	M	Thoracic 4, extradural	Pott's abscess	HT
19	28	M	Thoracic 6, extradural	Fracture	–
20	59	F	Thoracic 4, intradural	Meningioma	COPD, HT
21	38	M	Thoracic 7, extradural	Fracture	–
22	45	M	Thoracic 5, extradural	Abscess	DM
23	41	F	Thoracic 3, intradural	Syringohydromyelia	Asthma
24	60	F	Thoracic 5, intradural	Meningioma	DM

CA, cancer; COPD, chronic obstructive pulmonary disease; DM, diabetes mellitus; F, female; HT, hypertension; M, male; PRES, preoperative fluoroscopy.

Table 2. Characteristics of the Patients Whose Level Was Determined by the PRECT Method

Patient	Age (Years)	Gender	Localization	Pathology	Comorbidity
1	26	F	Thoracic 8, extradural	Fracture	–
2	39	M	Thoracic 3, intradural	Astrocytoma	–
3	82	F	Thoracic 2, intradural	Meningioma	HT, DM
4	59	M	Thoracic 4, extradural	Fracture	–
5	46	M	Thoracic 6, extradural	Metastasis	Lung CA
6	65	F	Thoracic 6, intradural	Meningioma	HT
7	36	F	Thoracic 4, intradural	Schwannoma	–
8	55	F	Thoracic 8, intradural	Meningioma	DM
9	66	M	Thoracic 3, extradural	Metastasis	Prostate CA

(*Continued*)

Table 2. Characteristics of the Patients Whose Level Was Determined by the PRECT Method (*Continued*)

Patient	Age (Years)	Gender	Localization	Pathology	Comorbidity
10	51	M	Thoracic 2, intradural	Meningioma	–
11	61	M	Thoracic 6, extradural	Spinal stenosis	–
12	49	F	Thoracic 3, intradural	Ependymoma	HT, DM
13	53	M	Thoracic 7, extradural	Metastasis	COPD, HT
14	52	F	Thoracic 4, extradural	Metastasis	–
15	45	F	Thoracic 7, extradural	Disc herniation	Chronic renal failure
16	69	M	Thoracic 5, intradural	Meningioma	CAD, HT, DM
17	38	F	Thoracic 4, intradural	Schwannoma	Breast CA
18	54	F	Thoracic 5, intradural	Astrocytoma	DM
19	63	F	Thoracic 6, extradural	Metastasis	DM, asthma

CA, cancer; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; DM, diabetes mellitus; F, female; HT, hypertension; M, male; PRECT, preoperative computed tomography.

Table 3. Statistical Comparison of the Groups in Terms of Gender, Age, Comorbidity, Level, Localization, and Pathology

	PRES (n = 24)		PRECT (n = 19)		
	n	%	n	%	*P*
Gender					
M	13	54.2	8	42.1	.432
F	11	45.8	11	57.9	
Age, mean ± SD (min-max) (years)	49.2 ± 11.5 (28-74)		53.1 ± 13.3 (26-82)		.304
Comorbidity					
–	10	41.7	7	36.8	.748
+	14	58.3	12	63.2	
Lung CA	0	0.0	1	5.3	
Asthma	2	8.3	1	5.3	
DM	3	12.5	6	31.6	
HT	3	12.5	5	26.3	
CAD	0	0.0	1	5.3	
Chronic renal failure	1	4.2	1	5.3	
COPD	1	4.2	1	5.3	
Lymphoma	1	4.2	0	0.0	
Breast CA	2	8.3	1	5.3	
Multiple myeloma	1	4.2	0	0.0	
Level					
Thoracic 2	2	8.3	2	10.5	.996
Thoracic 3	4	16.7	3	15.8	
Thoracic 4	4	16.7	4	21.1	
Thoracic 5	4	16.7	2	10.5	
Thoracic 6	4	16.7	4	21.1	
Thoracic 7	3	12.5	2	10.5	
Thoracic 8	3	12.5	2	10.5	
Localization					
Extradural	16	66.7	9	47.4	.203
Intradural	8	33.3	10	52.6	
Pathology					
Abscess	1	4.2	0	0.0	
Astrocytoma	1	4.2	2	10.5	
Disc herniation	0	0.0	1	5.3	
Ependymoma	0	0.0	1	5.3	
Fracture	5	20.8	2	10.5	
Hemangioblastoma	1	4.2	0	0.0	
Hydatid cyst	1	4.2	0	0.0	
Meningioma	4	16.7	5	26.3	.631
Metastasis	4	16.7	5	26.3	
Multiple myeloma	1	4.2	0	0.0	
Plasmacytoma	1	4.2	0	0.0	
Pott's abscess	2	8.3	0	0.0	

(*Continued*)

Table 3. Statistical Comparison of the Groups in Terms of Gender, Age, Comorbidity, Level, Localization, and Pathology (*Continued*)

	PRES (n = 24)		PRECT (n = 19)		
	n	%	n	%	*P*
Schwannoma	0	0.0	2	10.5	
Synovial cyst	1	4.2	0	0.0	
Syringohydromyelia	1	4.2	0	0.0	
Spinal stenosis	1	4.2	1	5.3	
Prostate CA	1	4.2	1	5.3	
Von Hippel–Lindau	1	4.2	0	0.0	

CA, cancer; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; DM, diabetes mellitus; F, female; HT, hypertension; M, male; PRECT, preoperative computed tomography; PRES, preoperative fluoroscopy; SD, standard deviation.

Table 4. Statistical Analysis of the Time from Position to Incision in Patients With and Without Additional Laminectomy in the PRES Group

Feature		Time from Positioning to Incision Mean ± SD, Min-Max (Median)	*P*
Additional laminectomy due to wrong-level surgery	+	22.4 ± 2.9, 19-28 (22)	.297
	–	23.8 ± 3.4, 18-29 (24)	

PRES, preoperative fluoroscopy; SD, standard deviation.

Table 5. Statistical Comparison of the Groups in Terms of Perop Additional Laminectomy, Additional Laminectomy with Reoperation and Time from Position to Incision

		PRES		PRECT		*P*
Additional laminectomy due to wrong-level surgery, n (%)	Perop additional laminectomy	5	21.7%	0	0.0%	.026
	Additional laminectomy with reoperation	2	8.7%	0	0.0%	
	None	16	69.6%	19	100%	
Time from position to incision, mean ± SD, min-max (median)		23.5 ± 3.2, 18-29 (23.5)		12.1 ± 2.1, 9-16 (12)		<.001

PRECT, preoperative computed tomography; PRES, preoperative fluoroscopy; SD, standard deviation.

malposition, and MR imaging artifact, raising doubts about the safety and reliability of the method.[19] Recently, De Vine et al[20] stated that although a systematic approach was adhered following the International Protocol, which was carefully applied within the institution, WLS is an unfavorable consequence that can occur at any time. De Vine et al[20] stated that surgeon is the only person who can determine the correct spinal level during surgery, and the surgeon must design and implement an exclusive protocol to minimize the rate of incorrect level surgery.

Table 6. Time from Position to Incision and Presence of Additional Laminectomy in the PRES Group

Patient	Age (Years)	Gender	Level	Additional Laminectomy Due to Wrong-Level Surgery	Time from Positioning to Incision (Minutes)
1	61	F	Thoracic 5	–	25
2	50	M	Thoracic 8	–	28
3	53	M	Thoracic 8	–	20
4	41	M	Thoracic 2	Perop additional laminectomy	24
5	51	F	Thoracic 2	–	25
6	56	F	Thoracic 3	–	24
7	38	M	Thoracic 4	–	29
8	29	M	Thoracic 8	Perop additional laminectomy	21
9	45	M	Thoracic 3	Perop additional laminectomy	22
10	70	F	Thoracic 7	–	22
11	63	M	Thoracic 6	–	27
12	45	F	Thoracic 4	–	20
13	50	M	Thoracic 3	–	22
14	74	M	Thoracic 7	–	18
15	49	F	Thoracic 5	–	25
16	43	F	Thoracic 6	Additional laminectomy with reoperation	28
17	43	F	Thoracic 6	–	24
18	48	M	Thoracic 4	–	25
19	28	M	Thoracic 6	–	23
20	59	F	Thoracic 4	Perop additional laminectomy	21
21	38	M	Thoracic 7	–	20
22	45	M	Thoracic 5	–	29
23	41	F	Thoracic 3	Perop additional laminectomy	22
24	60	F	Thoracic 5	Additional laminectomy with reoperation	19

F, female; M, male; PRES, preoperative fluoroscopy.

Table 7. Time from Position to Incision and Presence of Additional Laminectomy in the PRECT Group

Patient	Age (Years)	Gender	Level	Additional Laminectomy Due to Wrong-Level Surgery	Time from Positioning to Incision (Minutes)
1	26	F	Thoracic 8	–	11
2	39	M	Thoracic 3	–	13
3	82	F	Thoracic 2	–	13
4	59	M	Thoracic 4	–	14
5	46	M	Thoracic 6	–	11
6	65	F	Thoracic 6	–	10
7	36	F	Thoracic 4	–	15
8	55	F	Thoracic 8	–	9
9	66	M	Thoracic 3	–	10
10	51	M	Thoracic 2	–	9
11	61	M	Thoracic 6	–	12
12	49	F	Thoracic 3	–	14
13	53	M	Thoracic 7	–	16
14	52	F	Thoracic 4	–	11
15	45	F	Thoracic 7	–	11
16	69	M	Thoracic 5	–	12
17	38	F	Thoracic 4	–	11
18	54	F	Thoracic 5	–	15
19	63	F	Thoracic 6	–	13

F, female; M, male; PRECT, preoperative computed tomography.

Our findings suggest that the PRECT method not only provides a shorter surgical time but also reduces the incidence of WLS compared to the PRES method. In addition, although not included in our study, the PRES method could pose a serious disadvantage in patients with spinal deformity and cause severe errors in level determination. In contrast, the PRECT method can provide safe level determination in all patients, including advanced scoliosis, for providing a CT image. In addition, the PRECT method has additional advantages, such as shortening the operation time, reducing the incidence of WLS, and being an easy-to-apply and inexpensive method. Despite these advantages, the PRECT method also has disadvantages, such as more radiation exposure, infection risk (minimum or none because the procedure is performed under sterile conditions), and compliance problems because it is applied to awake patients.

Wrong-level surgery in spinal surgery is still a matter of concern that challenges surgeons in neurosurgery practice. In fact, leveling becomes more complex, mainly if the lesion is located in the upper thoracic spinal region. Since the PRECT method we presented in this study is a CT-based technique, it provides easy, inexpensive, and effective level detection in all spinal lesions, including patients with spinal deformities and upper thoracic spine lesions. Our study will shed light on future studies in this respect.

The first limitation is that the study was conducted retrospectively. The second drawback was the limited number of patients since the previous years' data could not be fully accessed, and only the patients with complete data were included in the study.

Conclusion

Finally, the effect of lesion level on additional laminectomy due to WLS and the length of time from position to incision could not be evaluated due to insufficient data in the groups. In this context, a prospective study with a large sample size could help verify our findings regarding efficacy and safety.

Ethics Committee Approval: This study was approved by the chairmanship of the Clinical Research Ethics Committee of the Istanbul Haseki Training and Research Hospital of Health Science University (Date: May 25, 2022, approval number: 101-2022).

Informed Consent: Written informed consent was obtained from all participants who participated in this study.

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