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Clinical Study

Sagittal spinal parameters after en bloc resection of mobile spine tumors

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Abstract

BACKGROUND CONTEXT: En bloc resection and reconstruction (EBR) in patients with spinal malignancy aims to achieve local disease control. This is an invasive procedure with significant alterations of the physiological anatomy and subsequently, the spino-pelvic alignment. Sagittal spinal parameters are useful measurements to objectively identify disproportionate alignment on a radiograph. In the field of spinal deformities, there is increasing evidence for a relationship between sagittal alignment and patient reported outcomes.

PURPOSE: To determine sagittal spino-pelvic alignment after EBR in patients with spinal malignancies and the effect of these parameters on surgical and patient reported outcomes.

STUDY DESIGN: A retrospective case series.

METHODS: We included 35 patients who underwent EBR for spinal malignancies between 2000 and 2018. Radiographic measurements were performed using semi-automatic software; the parameters included were pelvic incidence (PI), sacral slope, pelvic tilt (PT), global tilt and lumbar lordosis. We calculated PI-based Global Alignment and Proportion (GAP) scores and prospective patient reported outcome scores Patient-Reported Outcome Measurement Information System −Physical Function (PROMIS-PF) were used.

RESULTS: Twenty-one (60%) patients filled out the PROMIS-PF score at a median of 16 months (Interquartile Range (IQR) 4−108) after surgery with a median score of 39 (IQR 32−42), the median GAP score was 7 (IQR 5−9). Bivariate analysis showed no statistically significant relationship between GAP score and instrumentation failure or need for revision surgery. Multivariable analysis of GAP score and PROMIS-PF score corrected for local disease recurrence showed a statistically significant correlation coefficient of −1.721 (p=.026; 95%CI=−3.216, −0.226).

CONCLUSION: In this cohort, all patients had a moderate or severe disproportioned spinal alignment after EBR and reconstruction surgery. The degree of sagittal spino-pelvic misalignment after EBR for spinal malignancies seems to be associated with patient reported health status in terms of PROMIS-PF scores. Further research with a larger patient cohort and standardized imaging and follow-up protocols is necessary in order to accurately use sagittal alignment as a predictive value for instrumentation failure and revision surgery.

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Introduction

Sagittal spinal parameters are useful measurements to objectively analyze sagittal spino-pelvic alignment and identify deformities on a radiograph. Since the 1980s, sagittal alignment was found to be an important factor in economic standing positions and proper force distribution [1−3]. Several studies have shown a correlation between sagittal alignment and the development of certain spinal deformities, such as idiopathic scoliosis and spondylolisthesis [4−6]. Furthermore, there is increasing evidence that sagittal spinal alignment correlates with clinical outcomes after spinal surgery in patients with adult spinal deformity (ASD) [7−10]. Coronal and particularly sagittal alignment of the spine are of critical importance for the clinical outcome after surgery in terms of quality of life (QOL) [11−14].

To our knowledge, no study has been conducted to examine the relevance of sagittal alignment in patients after en bloc resection (EBR) of spinal tumors for patient outcome. This surgical procedure primarily aims to achieve local disease control and increase survival time. However, it is an invasive procedure with a significant impact on the anatomy of the spine [15−18]. Furthermore, this surgical technique requires reconstruction of the spine, which includes reconstructing sagittal and coronal alignment. Reconstruction is important for QOL because the operation is designed to be curative [16].

The first aim of this study is to determine sagittal spino-pelvic alignment in patients after primary EBR and reconstruction of mobile spine tumors. The second aim is to assess whether sagittal alignment relates to clinical outcome, instrumentation failure, and reoperation rate in spine oncology patients, in a similar manner to that seen in adult deformity patients.

Materials and methods

Study design

This retrospective study was approved by our institutional review board. We included all patients ≥18 years who had a whole-spine lateral standing radiograph after EBR and reconstruction as surgical treatment for a spinal tumor between January 2000 and January 2018 in one of two affiliated tertiary care referral centers. Patients who underwent prior acute decompression without placement of instrumentation were also included. Patients presenting for revision surgery or who underwent revision surgery before the first lateral radiograph were excluded. We identified 214 potentially eligible patients through a computerized CPT (Current Procedural Terminology) code query for vertebral corpectomies (63300-63303) and 330 potentially eligible patients through a CPT code query for spine radiographs (72010, 272081, 72082, 72084, 72090) in patients with a primary or secondary neoplasm in the spine. The eligible patients' radiologic reports were manually screened for "full/entire spine" and "scoliosis." We ultimately included 35 patients with a whole-spine lateral radiograph after EBR and reconstruction.

Outcome variables

The conventional sagittal spinal parameters were measured on whole-spine lateral radiographs using SpiniX (Image Science Institute, Utrecht, The Netherlands), a previously validated semi-automatic analysis method [4,5]. For measurement of global tilt and lumbar lordosis proportions Surgimap Spine software (Nemaris Inc., New York, NY, USA) was used [19].

We used the first postoperative radiographs obtained at least 1 week after the index surgery. In the inclusion period, full-spine lateral radiographs were obtained in the upright position with the arms on the clavicles or on a bar per protocol.

Two trained observers (JM, PO) performed the measurements, one of whom performed the measurements twice (JM) to be able to calculate intra-observer reliability. The following parameters were measured: Thoracic kyphosis (TK), L1-S1 lumbar lordosis (L1-S1 LL), L4-S1 lumbar lordosis (L4-S1 LL), pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), and global tilt (GT). The definitions are given in Table 1 [9,20,21]. Resected vertebrae were estimated based on the surrounding vertebrae. The Global Alignment Proportion (GAP) score was calculated according to Yilgor et al. [9]. They made three categories: a proportioned spine (GAP score 0−2), moderately disproportioned (GAP score 3−6), and severely disproportioned (GAP score 7 or higher).

Explanatory variables

The following explanatory factors were extracted from patients' medical records: age, gender, body mass index in kg/m^2, American Society of Anesthesiologists Physical Status classification (ASA PS class), cancer type, location and diameter of the lesion (in cm), (neo)adjuvant chemo- and radiotherapy, type and approach of surgery, reconstructive instrumentation, location of instrumentation, resected spine levels, iliac involvement, intraoperative complications, intraoperative radiotherapy, operative time (in minutes), estimated blood loss (in mL), surgical margins, tumor histology, short- and long-term complications, oncological outcome, and the postoperative Patient-Reported Outcome Measurement Information System (PROMIS) score for

Table 1
Definitions of the spinal deformity parameters [1,20,21]

	Definition
L1-S1 LL	The angle between the superior endplate of L1 and the superior endplate of S1
L4-S1 LL	The angle between the superior endplate of L4 and the superior endplate of S1
PI	The angle between the line perpendicular to the S1 endplate midpoint and the line between this point and the femoral head axis
PT	The angle between the vertical and the line connecting the S1 endplate midpoint and the femoral head axis
SS	The angle between the horizontal and the line along the S1 endplate
GT	The angle between the line connecting the femoral head axis and the S1 endplate midpoint and the line connecting the center of the C7 vertebra and the S1 endplate midpoint

physical function. The PROMIS score used was the one available at the same day of the radiograph or closest to the date of the radiograph.

Complications were defined as short-term (<30 days) and long-term (>30 days), as well as major and minor, according to the classification of perioperative complications of anterior spinal procedures described by McDonnell et al. [18,22]. Final follow-up date and disease status (alive or death, and cause of death) at final follow-up were extracted from clinical charts.

The reconstructive instrumentation was noted as anterior, posterior and vertebral restoration. Vertebral restoration was further noted as interbody cage or bone grafting.

The PROMIS score is a system to measure patient reported health status, validated for patients after several spinal surgical treatments [23−25]. The PROMIS uses computer adaptive tests, using smaller, targeted subsets of questions while still offering precision and validity [23]. This study used the PROMIS short form Physical Function (PROMIS-PF) score, with scores ranges from 0 to 62; values above 45 are regarded as normal. Only those scores filled out before revision surgery were used.

Statistical analysis

A bivariate analysis was performed for instrumentation failure and revision surgery with the GAP score and with single parameters (TK, LL, PI, PT, SS, or GT). The GAP score was calculated by using the averages of the three measurements, representative of the average of measurements in clinical practice. We performed multivariable analysis for the PROMIS-PF score and single parameters (TK, LL, PI, PT, SS, or GT), and the PROMIS-PF and GAP score corrected for local disease recurrence.

The intra- and inter-observer reliabilities for SS, PT, PI, TK, LL, and GT were calculated using the intra-class correlation coefficient (ICC). The ICC is an index measure of reliability that reflects both the degree of correlation and agreement between measurements and also expresses the proportion of global variability caused by the subjects' variability [19,26]. The ICC's for intra-observer reliability were measured using the first and second measurements of the first observer and the ICC's for inter-observer reliability using the first measurement of both observers.

The ICC estimates and their 95% confidence intervals were calculated using STATA 13 (StataCorp LP, College Station, TX, USA) based on a mean-rating (k=2) absolute agreement, two-way mixed-effects model.

Results

Patient demographics

The median age was 51 years (IQR 33−65) and 27 patients (77%) were men. Further patient characteristics were summarized in Table 2. Median time between diagnosis and surgery was 120 days (IQR 70−173). The median time between surgery and radiograph was 10 months (IQR 2−36). Five patients (14%) underwent prior spinal surgery. Three of these patients underwent prior (acute) decompression without placement of instrumentation, one underwent prior spinal fusion at L4−L5 for degenerative joint disease without instrumentation failure, and one patient underwent prior tumor resection of the paraspinal soft tissue.

Twenty-seven (77%) patients underwent the procedure in a staged fashion (Table 3). All patients underwent posterior fusion. Twenty-seven (77%) patients obtained anterior spinal instrumentation and most patients received a bone graft (21 [62%]) or an expandable cage (11 [32%]) as vertebral restoration.

Twelve (34 %) patients received a dose of 10 Gy intraoperative radiotherapy. No intraoperative complications occurred. Incidental durotomy occurred in four (11.4%) patients and could be repaired primarily. After surgery 27 (81%) patients received an inferior vena cava filter as thromboprophylaxis.

Most patients (24 [69%]) had one short-term postoperative complication. Twelve patients (34%) had more than one short-term postoperative complication. Thirteen patients (37%) had a long-term postoperative complication of which three (9%) had a second long-term complication. Eighteen (49%) patients suffered from a major complication, a total of 38 major complications occurred. A total of 20 minor complications occurred in 17 (46%) cases (Table 4).

Sagittal parameters and surgical outcome

Instrumentation failure occurred in 14 (40%) patients (Table 4). Thirteen patients (35%) experiencing instrumentation failure underwent revision surgery. One patient with a stable, nondisplaced fracture of a lumbar rod was asymptomatic without functional limitations and was therefore treated conservatively. One patient did not experience instrumentation failure but underwent revision surgery to extend instrumentation for cord decompression caused by progressive disease. Five patients (14%) underwent a second revision

Table 2
Baseline characteristics (N=35)

	Median (IQR)
Age (y)	51.4 (33.5−65.4)
BMI (kg/m^2)	28.8 (25.4−30.8)
Time to surgery	120 (70−173)
Tumor diameter (cm)*	4.3 (3.0−5.6)
Preoperative radiation dose (Gy)*	50.4 (35.1−50.4)
	No (%)
Male sex	27 (77.1)
Smoke	
Yes	4 (11.4)
Quit >1 year before surgery	10 (28.6)
Race	
White	32 (91.4)
Black	2 (5.7)
Asian	1(2.9)
Tumor location	
Cervical	3 (8.6)
Thoracic	13 (37.1)
Lumbothoracic	3 (8.6)
Lumbar	16 (45.7)
Tumor type	
Chondrosarcoma	7 (20.0)
Osteosarcoma	1 (2.9)
Chordoma	17 (48.6)
Metastasis	7 (20.0)
Ewing	1 (2.9)
Other	1 (2.9)
Benign	1 (2.9)
Grade	
High/Median	16 (88.9)
Low	2 (11.1)
Preoperative radiotherapy	26 (74.3)
Preoperative chemotherapy	3 (8.6)
Preoperative ASA PS class†	
2	22 (68.8)
3	10 (31.3)

* Values were missing for tumor diameter in one case, for preoperative radiation dose in two cases, for the ASA PS class in three cases.
† ASA PS: *American Society of Anesthesiologists Physical Status*.

Table 3
Surgery characteristics (n=35)

	Median (IQR)
Time between stages (days)	2 (2−6)
Hospital stay (days)	14 (10−16)
Estimated blood loss stage 1 (L)*	2.7 (1.5−4.0)
Estimated blood loss stage 2 (L)*	1.3 (0.7−2.6)
Postoperative radiation dose (Gray)	30 (19.8−40.4)
Total radiation dose (Gray)	70 (64−80)
Numbers of levels fused posterior	6 (5−7)
	No. (%)
2-staged procedure	27 (77.1)
Tomita-saw used	20 (57.1)
Iliac involvement	7 (20.6)
Posterior instrumentation	
Pedicle screws rod construct	29 (82.9)
Wires and isola cross-links	6 (17.1)
Anterior instrumentation	27 (77.1)
Number of involved vertebral levels	
<5	3 (8.6)
5	10 (28.6)
6	10 (28.6)
7	6 (17.1)
>7	6 (17.1)
Vertebral restoration	
Expandable cage	11 (32.4)
Titanium mesh	2 (5.9)
Bone graft only	21 (61.8)
Bone graft type	
1. Autograft	12 (57.1)
2. Allograft	3 (14.3)
3. Auto- and allograft	6 (28.6)
Intraoperative radiotherapy	12 (34.3)
Postoperative inferior vena cava filter	27 (77.1)
Negative resection margins	27 (77.1)0
Postoperative chemotherapy	2 (7.4)
Postoperative radiotherapy	17 (63.0)

* Value was missing for one patient.

surgery. In bivariate analysis pretreatment radiotherapy was not associated with instrumentation failure (p=.262).

All radiographic measurements and the ICC's are shown in Table 5. Bivariate analysis showed no statistically significant association between an individual parameter (TK, LL, PI, PT, or SS) and instrumentation failure (respectively p=.450, p=.194, p=.239, p=.096, p=.772) or revision surgery (respectively p=.660, p=.236, p=.510, p=.069, p=.369). Global tilt was significantly associated with instrumentation failure (p=.026), but there was no significant association with revision surgery (p=.100).

Global alignment and proportion scores and surgical outcome

The median GAP score was 7 (IQR 5−9). Bivariate analysis showed no statistically significant association between the GAP score and instrumentation failure (p=.283) or revision surgery (p=.162).

Patient-reported outcome measurement information system−physical function scores and radiographic outcomes

Tumor recurrence occurred in nine patients (26%), of which three had positive resection margins. Five patients (18%) without metastatic disease at the time of diagnosis and all negative resection margins developed a new metastasis. Four patients (11%) with recurrent disease died. One of these patients had also developed an irradiation related high-grade B-cell lymphoma.

Twenty-one patients (60%) filled out the PROMIS-PF questionnaire (Table 4). The mean time between radiograph and PROMIS-PF questionnaire was 7 months. The median PROMIS-PF score was 39 (IQR 32−42). Multivariable regression analysis of a single parameter (TK, LL, PI, PT, SS, or GT) and PROMIS-PF score corrected for local disease recurrence showed no statistically significant correlation (respectively p=.523, p=.131, p=.851, p=.619, p=.544, p=.119).

Multivariable regression analysis of GAP score and PROMIS-PF score corrected for local disease recurrence showed a statistically significant correlation coefficient

Table 4
Oncologic and long-term outcomes (n=35)

	Median (IQR)
PROMIS-PF score*	38.7 (32.0−41.8)
Follow-up time (mo)	35.7 (11.2−52.3)
	No. (%)
Postoperative complications (<30 d)	24 (68.6)
>1 postoperative complication	12 (34.3)
>2 postoperative complications	3 (8.6)
>3 postoperative complications	3 (8.6)
Postoperative complications (>30 d)	13 (37.1)
>1 postoperative complication	3 (8.6)
Major complications	18 (48.6)
>1 major complication	10 (27.0)
Minor complications	17 (45.9)
>1 major complication	3 (8.1)
Instrumentation failure	14 (40)
Rod breakage	6 (42.9)
Screw loosening	7 (50.0)
Cage failure	2 (14.3)
Infection	1 (7.1)
Nonunion	6 (42.9)
1st revision surgery	14 (40.0)
2nd revision surgery	5 (14.3)
Recurrence	9 (25.7)
New metastasis	5 (17.9)
Death	4 (11.4)

* Scores only available for 21 patients.
PROMIS-PF: Patient Reported Outcome Measurement Information System − Physical Function.

of −1.721 (p=.026; 95% CI −3.216; −0.226). The Figure illustrates the PROMIS-PF scores plotted against the GAP scores.

Discussion

In our study, radiographic sagittal alignment of the spine seems to be associated with patient-reported outcomes. The importance of spinal sagittal alignment is well-known in the field of spine deformity surgery [10,12], yet no study has been conducted on outcomes after EBR and reconstructive surgery in terms of sagittal alignment. We used the GAP score to evaluate the spinal alignment of 35 patients after EBR and reconstruction and found moderate to severe disproportion in all 35 patients. We were also able to find an association with patient reported outcome scores (PROMIS-PF score).

Our study has several limitations. First, caused by the acknowledgement of the importance of full sagittal spino-pelvic alignment [2−5,8], our institution changed its policy for follow-up radiographs after EBR since 2015. Therefore, in this preliminary study, the time to the first postoperative radiograph grossly differs amongst the patients in our sample. This may have introduced bias because some patients may have not yet compensated to a more proportioned global sagittal alignment [12]. Besides, no preoperative full spine radiographs are available to compare the pre- and postoperative sagittal alignment and rule out the influence of any pre-existing malalignment. Second, because of retrospectively collected data, the time between radiograph and PROMIS-PF questionnaire differs. However, in our opinion the mean timespan of 7 months between radiograph and questionnaire does reflect long-term QOL after surgery in the oncologic patient population. Third, caused by the rarity of this treatment, our study has a limited sample size, therefore we could not take into account other possible influencing factors besides disease recurrence. However, to our knowledge, this is the first study on spinal parameters in this specific patient population and therefore contributing for further scientific research projects.

Yilgor et al. [9] validated the GAP score on ASD patients and aimed to predict mechanical complication rates: moderately (GAP score 3−6) and severely (GAP score 7 or higher) disproportioned patients had mechanical complication rates of 47% and 95%, respectively vs. 6% in subjects with low GAP scores. Despite studying a highly different patient population, this percentage in disproportioned patients is in accordance with our finding of an instrumentation failure rate of 63% and an overall median GAP score of 7 (IQR 5−8) in a group of spine oncology patients eligible for EBR. Meanwhile, similar to the study performed by Bari et al. [27], we found there was no statistically significant association between postoperative GAP score and mechanical failure. They studied ASD patients with a median postoperative GAP score of 4 (IQR 2−7) and a mechanical failure rate of 51%.

Table 5
Spinal deformity parameters (n=35)

		ICC for intra-observer reliability		ICC for inter-observer reliability	
Spinal deformity parameter	Median (degrees [IQR])	ICC	95% CI	ICC	95% CI
Thoracic kyphosis (TK)	29.1 (17.5−39.8)	0.977	0.950−0.989	0.763	0.530−0.881
Lumbar lordosis (L1-S1)	43.4 (26.4−58.9)	0.976	0.951−0.988	0.969	0.939−0.984
Lumbar lordosis (L4-S1)	26.2 (17.3−35.9)	0.940	0.862−0.972	0.910	0.817−0.955
Global tilt (GT)	28.8 (20.5−41.5)	0.984	0.968−0.992	0.947	0.866−0.976
Pelvic incidence (PI)	54.9 (47.6−60.4)	0.943	0.887−0.971	0.825	0.621−0.920
Pelvic tilt (PT)	24.8 (19.2−30.8)	0.987	0.974−0.993	0.721	0.455−0.858
Sacral slope (SS)	30.8 (22.2−35.5)	0.955	0.912−0.977	0.868	0.737−0.933
GAP score		0.819	0.641−0.909	0.887	0.777−0.943

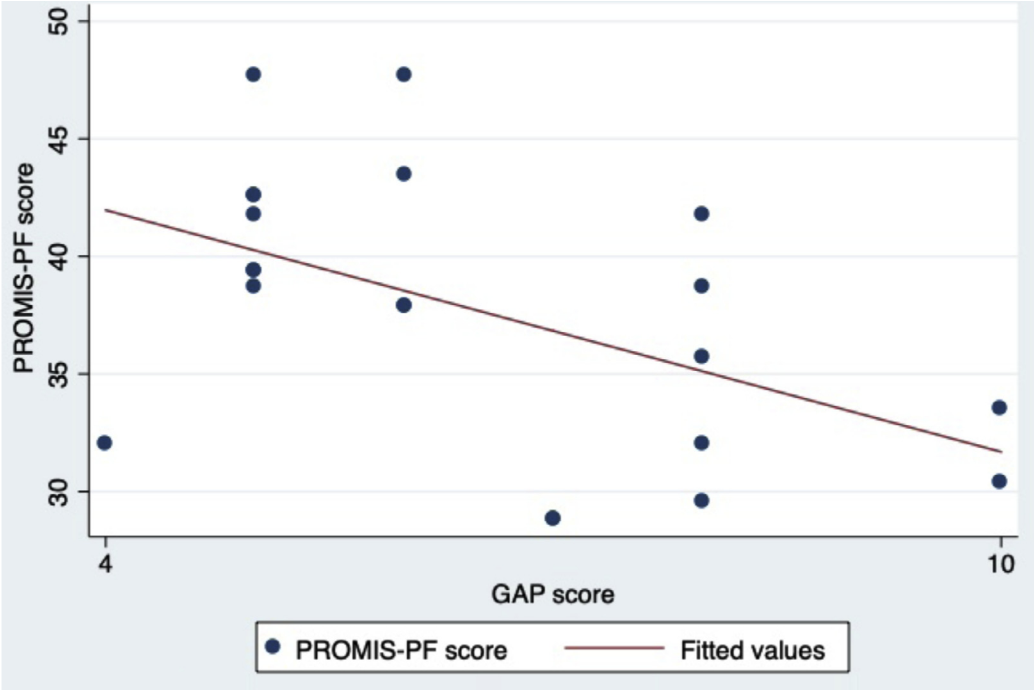

Figure. Correlation between PROMIS Physical Function score and GAP score.

Nevertheless, this does not invalidate the use of the GAP score to define a relationship between postoperative sagittal alignment and PROMIS score. A study by Proptopsaltis et al. [8] found a correlation of spinal alignment and health measures by means of the T1 pelvic angle and Oswestry Disability Index in patients with ASD. Lafage et al. [28] demonstrated that an increased PT correlates with a worse QOL, which is also in accordance with our findings; in a single patient with a given PI, an increased PT would result in a decreased SS and LL and global sagittal malalignment, which subsequently may result in a higher GAP score.

The GAP score does not take into account both intrinsic factors such as gender, race, and bone density, as well as extrinsic factors such as surgical factors. However, these important factors may influence spino-pelvic alignment and the risk of mechanical failure [29]. Merrill et al. [30] showed that women had a greater LL than men and African-Americans had smaller PT and greater SS compared with Caucasians. Therefore, these factors should also be taken into account in patient assessment and preoperative planning to obtain optimal sagittal balance [31,32]. Eventually, studies that evaluate sagittal balance before and after spine surgery may help us distinguish the contribution of these important intrinsic and extrinsic factors to the postoperative outcomes in terms of QOL and mechanical failure rates [31].

In this study, measurements were done on 2D radiographs. However, in a disproportioned sagittal aligned spine the pelvis rotates around the femoral head to compensate for this alteration. Both pelvic rotation and coronal deformity affect the accuracy of the 2D sagittal measurements. Vialle et al. [33] showed the significant relationship between different sagittal parameters in asymptomatic patients. The GAP score uses ratios in relation to the PI, and in this way, partly compensates for patient specific anatomy [9].

Potential future prospective studies on sagittal spinal alignment in spine oncology patients should feature greater and more homogenous patient groups in terms of tumor histology and location, and a standardized protocol for preoperative and follow-up radiographs to make a more accurate assessment of the effect of the sagittal profile and other contributing factors on the long-term outcomes.

Conclusion

The postoperative sagittal spinal alignment in most patients of our cohort is moderately or severely disproportioned—this is associated with patient reported health status after surgery. Further research with a larger patient cohort and standardized imaging, and follow-up protocols is necessary in order to accurately use sagittal alignment as a predictive value for instrumentation failure and revision surgery.

The results of this study suggest that surgeons should take sagittal alignment into account in presurgical planning of EBR to ensure proportioned sagittal alignment. Even in spine oncology patients, sagittal spinal alignment has an influence on postoperative health-related QOL.

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