INFLUENCE OF THE SAGITTAL BALANCE ON THE CLINICAL OUTCOME IN SPINAL FUSION

INFLUÊNCIA DO EQUILÍBRIO SAGITAL NO RESULTADO CLÍNICO DE ARTRODESE DA COLUNA VERTEBRAL

INFLUENCIA DEL EQUILIBRIO SAGITAL EN EL RESULTADO CLÍNICO DE LA FUSIÓN DE COLUMNA VERTEBRAL

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ABSTRACT

Objective: Evaluates which radiographic parameters of the sagittal and spinopelvic balance influence the clinical and functional outcomes of a sample of patients undergoing spinal fusion. Methods: We studied 32 patients who underwent spinal fusion. Radiographs of the total spine were obtained from all patients. The clinical and functional parameters studied were analysis of pain by visual analogic scale (VAS) and Oswestry and SRS-30 questionnaires. We analyzed the correlation between the clinical and functional parameters and radiographic parameters of the sagittal and spinopelvic balance. Results: There was no significant correlation between parameters pelvic incidence (PI), pelvic tilt (PT), lumbar lordosis (LL) and difference between PI and LL (PI-LL) and clinical parameters ($p > 0.05$ and $r < 0.2$). Significant correlation were identified only between Sagittal Vertical Axis (SVA) and Satisfaction with Treatment domain of SRS-30 ($r = 0.402$ e $p = 0.023$) and between thoracic kyphosis (TK) and the total SRS-30 ($r = 0.419$ and $p = 0.017$). Conclusions: According to the study results, it was not possible to precisely characterize the role of the parameters of the sagittal and spinopelvic balance in the post-operative analysis of the clinical outcome of spinal fusion. There was a significant correlation only between SVA and the Satisfaction with Treatment domain of SRS-30 and between TK and total SRS-30.

Keywords: Arthrodesis; Spine; Postural balance; Lordosis; Low back pain; Kyphosis.

RESUMO

Objetivo: Avaliar quais parâmetros radiográficos do equilíbrio sagital e espinopélvico influenciam os resultados clínicos e funcionais de uma amostra composta por pacientes submetidos a artrodese da coluna vertebral. Métodos: Foram estudados 32 pacientes submetidos a artrodese da coluna vertebral. Radiografias da coluna total foram obtidas de todos os pacientes. Os parâmetros clínicos e funcionais estudados foram: análise da dor pela escala visual analógica (EVA) e os questionários de Oswestry e SRS-30. Foi analisada a correlação entre os parâmetros clínicos e funcionais e os parâmetros radiográficos do equilíbrio sagital e espinopélvico. Resultados: Não houve correlação significante entre os parâmetros incidência pélvica (IP), versão pélvica (VP), lordose lombar (LL) e diferença entre IP e LL (IP-LL) e os parâmetros clínicos ($p > 0,05$ e $r < 0,2$). Houve correlação significante apenas entre o eixo vertical sagital (EVS) e o domínio Satisfação com o Tratamento do SRS-30 ($r = 0,402$ e $p = 0,023$) e entre a cifose torácica (CT) e o SRS-30 total ($r = 0,419$ e $p = 0,017$). Conclusões: Pelos resultados do estudo, não foi possível caracterizar precisamente o papel dos parâmetros do equilíbrio sagital e espinopélvico na análise do resultado clínico pós-operatório da artrodese da coluna vertebral. Houve correlação significante apenas entre o EVS e o domínio Satisfação com o Tratamento do SRS-30 e entre a CT e o SRS-30 total.

Descritores: Artrodese; Coluna vertebral, Equilíbrio postural; Lordose; Dor lombar, Cifose.

RESUMEN

Objetivo: Evaluar qué parámetros radiográficos del equilibrio sagital y espinopélvico influencian los resultados clínicos y funcionales en una muestra de pacientes sometidos a la fusión espinal. Métodos: Se estudiaron 32 pacientes que fueron sometidos a la artrodesis de la columna vertebral. Las radiografías de la columna total se obtuvieron de todos los pacientes. Los parámetros clínicos y funcionales estudiados fueron: análisis del dolor mediante escala visual analógica *(EVA) y cuestionarios Oswestry y SRS-30. Se analizó la correlación entre los parámetros clínicos y funcionales y los parámetros radiográficos del balance pélvico sagital y espinopélvico. Resultados: No hubo correlación significativa entre los parámetros incidencia pélvica (IP), la inclinación de la pelvis (IncP), lordosis lumbar (LL) y la diferencia entre la IP y LL (IP-LL) y los parámetros clínicos ($p > 0,05$ y $r < 0,2$). Hubo una correlación significativa sólo entre el eje sagital vertical (ESV) y el dominio de Satisfacción con el Tratamiento del SRS-30 ($r = 0,402$ y $p = 0,023$) y entre la cifosis torácica (CT) y el SRS-30 total ($r = 0,419$ y $p = 0,017$). Conclusiones: De acuerdo con los resultados del estudio, no fue posible caracterizar con precisión el papel de los parámetros del balance sagital y espinopélvico en el análisis post-operatorio de la artrodesis de la columna vertebral. Hubo una correlación significativa sólo entre ESV y el dominio Satisfacción con el Tratamiento de SRS-30 y entre el CT y el SRS-30 total.*

Descriptores: Artrodesis; Columna Vertebral; Balance postural; Lordosis; Dolor de la región lumbar; Cifosis.

Study conducted at the Hospital do Servidor Publico Estadual (HSPE), São Paulo, SP, Brazil.
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INTRODUCTION

The spine is the principal support axis of the human body, essential to achieving both standing and locomotion. Understanding the elements that comprise it is fundamental to the comprehension of its role in balance and corporal alignment.[1-4] In the sagittal plane, the spine can be considered a linear chain connecting the head to the pelvis, in which the form and the orientation of each anatomical segment are closely related and influence the adjacent segments, to maintain a stable posture with the least possible energy expenditure.[5]

Any break in the alignment of this chain, whether in the coronal or sagittal plane, is recognized as a spinal deformity. In most individuals, this deformity is asymptomatic, while in others, pain and functional disability may occur, especially in adult deformities. Thus, quality of life questionnaires are instrumental tools in defining and quantifying pain and disability caused by the deformity.[6-10] A correlation between the results of these quality-of-life-measuring questionnaires and the radiographic parameters associated with vertebral and spinopelvic alignment has also been described in the literature.[8,10,11]

These studies identified specific radiographic parameters that they demonstrated to have a correlation with pain and functional disability, such as lumbar lordosis,[6,7] vertical sagittal axis (C7 plumbline),[8,9] as well as parameters associated with spinopelvic balance (pelvic incidence, pelvic tilt, sacral slope, and the relationship between pelvic incidence and lumbar lordosis).[10,12,13] The SRS-Schwab classification for adult deformity, which is gaining popularity, takes three sagittal modifiers into account (vertical sagittal axis, pelvic tilt, and the difference between pelvic incidence and lumbar lordosis) in addition to the type of curve. Recently, it was shown that there is a correlation between this classification system and the severity of the disease, through a correlation with quality of life measurements.[14]

Instrumented spinal arthrodesis, particularly of the lumbosacral segment, has benefited from the acquisition of more modern implants and the use of intersomatic devices.[1] However, it can significantly change the relationship between the physiological curves of the spine and the pelvis, generating misalignment and deformity that previously did not exist.[15-20] In fusion of the lumbosacral spine, achieving consolidation should not be the only goal. The proper alignment of the fused segment is essential to the surgical outcome.[17]

The objective of this study was to evaluate whether there is a relevant clinical correlation between the radiographic parameters of sagittal and spinopelvic balance and the clinical and functional results in a sample of patients who underwent arthrodesis of the thoracolumbar and lumbosacral spine in the same institution.

METHODS

This is an observational study approved by the IRB of the service where it was conducted (CAAE: 41826514.9.0000.5463), which involved 32 patients who had previously undergone fusion of the thoracolumbar and lumbosacral spine, with a minimum postoperative follow up time of three months. All procedures were conducted in the same service and by the same team. The patients included in the study signed the Informed Consent Form, had degenerative spine disease, adult scoliosis, herniated lumbar discs, and stenosis of the lumbar canal. Patients with primary or secondary neoplastic diseases of the spine or congenital or traumatic spine pathologies were excluded.

Total spine radiographic exams were taken of all patients, including the base of the occiput and the femoral heads, in the standing position, with the fingers placed on the clavicle and with the shoulder elevated to 45 degrees.[21] The digitalized images obtained were analyzed using Surgimap Spine software (Nemaris Inc. New York, USA) to measure the following radiographic global sagittal and spinopelvic alignment parameters: sagittal vertical axis (SVA), sacral slope (SS), pelvic tilt (PT), pelvic incidence (PI), thoracic kyphosis (TK), and lumbar lordosis (LL) as illustrated in Figure 1. We also calculated the difference between PI and LL (PI-LL).

The parameters were evaluated clinically using the following quality of life measurement questionnaires: Visual Analog Scale of pain (VAS), the Oswestry Disability Index, adapted and validated for Portuguese,[22] and the SRS-30, adapted and validated for Portuguese.[23]

Pearson correlations were calculated to determine whether there was any statistical correlation between the quality of life indicator measurements and the radiographic parameters of interest. Multiple linear regression models were then created for each clinically evaluated measurement, according to the relevant radiological measurements, maintaining only the radiological parameters that influenced the clinical measurements statistically in the final model. The tests were conducted with a level of significance of 5%.

RESULTS

We evaluated 32 patients who underwent spinal fusion with minimum postoperative follow-up of three months. Twenty-three (68.75%) of the patients were female and 10 (31.25%) were male. The average age was 68, ranging from 53 to 79 years. The average BMI was 28.98 Kg/m^2. Table 1 shows a mean score of 38.56 (SD: 17.15) obtained from the Oswestry questionnaire, with 17 patients (53.13%) scoring good to excellent results.

Regarding pain, the mean Visual Analog Scale was 5.22 (SD: 2.78). The SRS-30 functional evaluation had a mean score of 91.50 (SD: 12.90), with the different domains scoring 18.38 (SD: 4.14) for function/activity, 17.06 (SD: 3.11) for pain, 29.84 (SD: 5.62) for self-image/appearance, 13.34 (SD: 2.03) for mental health, and 11.63 (SD: 12.61) for satisfaction with treatment.

Table 1 also shows the relevant radiographic parameter results for global sagittal and spinopelvic alignment. The mean values were SVA - 53.27mm (SD: 45.19), TK – 36.59 ° (SD: 13.17°), LL – 43.78° (SD: 13.91°), PI - 55.56° (SD: 10.03°), PT – 21.22° (SD: 9.99°), and PI-LL – 11.66° (SD: 14.47°).

Table 2 shows that the correlations between the radiographic parameters of interest (PI, PT, LL, and PI-LL) and the clinical parameters were not statistically significant ($p > 0.05$), with correlation values always less than 0.02 ($r < 0.02$). Only the correlations between the SVA and the SRS-30 satisfaction with treatment domain and between TK and the total SRS-30 were statistically significant ($r = 0.402/p = 0.023$ and $r = 0.419/p = 0.017$, respectively).

Table 3 shows that a statistically significant inverse correlation exists between LL and PI-LL ($r = -0.749$ and $p < 0.001$).

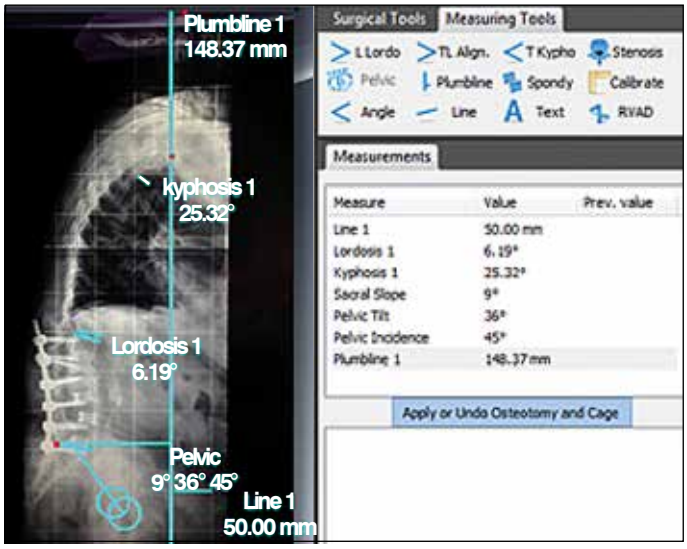

Figure 1. Example of a digitalized image with measurements of the radiographic parameters of interest (SVA, PI, SS, PT, LL, and TK) using Surgimap Spine software (Nemaris Inc. New York, USA).

Table 1. Anthropometric parameters, radiological and clinical parameters.

Variable	Mean	SD	P25	Median	P75	N
Weight (Kg)	79.23	14.32	76.50	55.00	110.00	32
Height (cm)	165.50	9.40	164.00	153.00	188.00	32
BMI (Kg/m^2)	28.96	5.20	28.05	20.90	40.80	32
Abdominal Circumference (cm)	97.69	8.35	98.50	82.00	115.50	32
SVA(mm)	49.51	53.01	41.35	-19.17	210.15	32
SS (°)	34.31	10.93	36.50	0.00	55.00	32
PT (°)	20.63	9.62	18.50	2.00	47.00	32
PI (°)	55.59	10.06	56.00	40.00	75.00	32
TK (°)	36.59	13.17	35.00	14.00	66.00	32
Lumbar lordosis (°)	43.64	14.71	42.50	-3.00	64.00	32
PI-LL (°)	12.00	14.37	9.50	-9.00	56.00	32
Oswestry (%)	39.88	14.86	36.00	18.00	62.00	32
Function/activity	18.38	4.14	17.00	10.00	27.00	32
Pain	17.06	3.11	18.00	11.00	21.00	32
Self-image	29.84	5.62	29.50	17.00	40.00	32
Mental Health	13.34	2.03	13.00	11.00	18.00	32
Satisfaction w/ treatment	11.63	2.61	12.00	6.00	17.00	32
SRS-30 Total	91.50	12.90	94.50	66.00	110.00	32

Table 2. Pearson Correlations between each clinical measurement and each radiological parameter.

Correlation		Oswestry (%)	Function/ activity	Pain	Self-image	Mental Health	Satisfaction w/ treatment	SRS-30 Total
Weight (Kg)	r	0.096	-0.122	-0.093	-0.213	-0.220	-0.255	-0.242
	p	0.600	0.506	0.614	0.242	0.226	0.158	0.182
Height (cm)	r	0.110	-0.069	-0.123	0.132	0.180	0.120	0.026
	p	0.549	0.708	0.504	0.473	0.323	0.514	0.886
BMI (Kg/m^2)	r	0.034	-0.091	-0.009	-0.290	-0.318	-0.309	-0.263
	p	0.853	0.622	0.961	0.107	0.076	0.085	0.146
Abdominal Circumference (cm)	r	-0.010	-0.135	0.056	-0.333	-0.101	-0.327	-0.289
	p	0.955	0.461	0.761	0.062	0.582	0.068	0.108
SVA (mm)	r	0.273	-0.046	-0.089	0.164	-0.024	0.400	0.049
	p	0.131	0.805	0.630	0.370	0.895	0.023	0.788
SS (°)	r	-0.112	-0.145	-0.037	0.164	0.091	-0.005	0.031
	p	0.541	0.430	0.842	0.371	0.620	0.979	0.866
PT (°)	r	0.027	-0.210	-0.011	-0.165	-0.086	0.025	-0.115
	p	0.883	0.248	0.952	0.368	0.640	0.892	0.530
PI (°)	r	-0.060	-0.193	0.033	0.104	0.062	0.078	0.046
	p	0.745	0.290	0.859	0.571	0.734	0.673	0.804
TK (°)	r	-0.272	0.329	0.318	0.253	0.114	0.125	0.419
	p	0.132	0.066	0.076	0.163	0.534	0.496	0.017
LL (°)	r	-0.259	0.142	0.149	0.182	0.143	-0.092	0.160
	p	0.152	0.437	0.417	0.320	0.434	0.616	0.381
PI-LL (°)	r	0.164	0.169	0.340	0.059	0.093	0.010	0.095
	p	0.370	0.356	0.057	0.748	0.612	0.955	0.605

Table 4 shows the results of the linear regression models for each clinical parameter with the radiographic parameters, showing that the clinical parameters could not be explained statistically by the relevant radiographic parameters.

DISCUSSION

Since the study by Duval-Beaupère et al.,[24] which proposed a system that describes the geometric configuration of the pelvis and its orientation in the vertical plane, the role of the pelvis in the sagittal balance of the spine has been recongnized.[25] The analysis of the pelvis in the sagittal plane is obtained by measuring three angles: pelvic incidence (PI), pelvic tilt (PT), and sacral slope (SS). A simple geometric relationship links the anatomical constant, PI, to the two position-dependent angles, SS and PT, that characterize the orientation of the pelvis in the sagittal plane: PI = SS + PT.[26] The global alignment of the trunk can be measured by the SVA, which is considered the "plumbline".[1,2]

According to population studies, and mean value of PI in asymptomatic adults is an angle of 50 degrees,[27] while other studies conducted with individuals with spine diseases suggest values equal to or less than 45 degrees as low PI values and values equal to or greater than 60 degrees as high PI values.[28] Our sample had a mean PI of 55.56° (SD: 10.03°), a value within the expected range for the adult population.

By definition, a positive sagittal balance occurs when the plumbline from C7 passes in front of the sacral reference point, i.e the posterosuperior corner. If the line passes behind the sacral reference point, the sagittal balance is negative. It has been reported that normal sagittal alignment in adults falls within a very narrow margin in the pelvis, with a value of the SVA in asymptomatic adult individuals described by a mean score of 0.5 cm (± 2,5 cm).[3] The mean SVA value obtained in our sample was higher than expected at 53.27 mm (SD: 45.19).

The influence of the radiographic parameters related to sagittal balance of the vertebral spine and spinopelvic balance on functional results has been demonstrated in various articles. Glassman et al.[8,9] showed, both in patients in subjected to prior spinal fusion and in those with no previous surgery, that the quality of life parameters analyzed worsened as the SVA values increased, indicating a loss of sagittal balance. This study shows the importance of analyzing sagittal balance in order to assess patients who

Table 3. Pearson Correlations between the radiological parameters of interest.

Correlation (mm)		SVA	SS	PT	LL
SS	r	-0.416			
	p	0.018			
PT	r	0.461	-0.346		
	p	0.008	0.052		
LL	r	-0.668	0.678	-0.529	
	p	<0.001	<0.001	0.002	
PI-LL	r	0.169	-0.140	0.378	-0.071
	p	0.354	0.444	0.033	0.700

Table 4. Results of linear regression models of each clinical measurement with the radiological parameters.

Variable	Model	Factor	Coefficient	Standard error	*Value t*	p
Oswestry (%)	Initial	Constant	53.74	17.24	3.12	0.004
		VAS	0.049	0.069	0.70	0.489
		PT	-0.455	0.360	-1.26	0.218
		LL	-0.390	0.325	-1.20	0.241
		PI-LL	0.248	0.207	1.20	0.242
	Final	Constant	39.88	2.63	15.18	<0.001
SRS-30 Total	Initial	Constant	81.30	15.52	5.24	<0.001
		VAS	0.072	0.062	1.15	0.260
		PT	-0.178	0.324	-0.55	0.589
		LL	0.343	0.293	1.17	0.251
		PI-LL	0.092	0.186	0.50	0.625
	Final	Constant	91.50	2.28	40.14	<0.001
VAS pain	Initial	Constant	5.879	3.359	1.75	0.091
		VAS	-0.001	0.062	1.15	0.260
		PT	-0.224	0.419	-0.54	0.597
		LL	0.216	0.417	0.52	0.609
		PI-LL	0.205	0.412	0.50	0.623
	Final	Constant	5.219	0.491	10.62	<0.001

complain of back pain and functional limitations and to evaluate the outcomes of surgical treatment More recently, the correlation between the PT parameter and a worsening quality of life was demonstrated, confirming that the pelvic position is correlated to the compromised functional capacity of the patients.[10] High pelvic tilt values indicate pelvic retroversion as a compensatory measure for loss of sagittal balance.

Various authors have investigated the relationship between PI and LL. Using multilinear regression analysis, they developed an arithmetic expression in which LL can be derived from value of PI: "LL = PI + 9° (±9)".[29] This formula predicts the LL required for an individual to achieve spinopelvic harmony, given that PI is a fixed morphological parameter. In terms of adult deformity, the classification system most recently adopted by the SRS[30] takes sagittal and spinopelvic balance parameters into account in addition to the type of curve, including the relationship between the PI and the LL, expressed as PI-LL. This parameter has been closely linked to pain and functional disability[10] and the authors claim that spine surgery should seek to achieve values of PI-LL lower than 10° to obtain better clinical outcomes.[30,31] In our sample, the mean PI-LL value obtained was 11.66° (SD: 14.47°), slightly higher than recommended.

Proper sagittal balance promotes an environment for bone consolidation and preservation of the adjacent level. Low back pain following arthrodesis is more likely to occur in individuals with sacral verticalization (high values of PT and low values of SS), a situation frequently accompanied by a reduction in lumbar lordosis, independently of other factors such as pseudoarthrosis.[17]

The objective of this study was to evaluate the correlation between the clinical and functional states of a sample of patients who underwent spinal fusion at the same institution and the postoperative radiographic parameters of sagittal and spinopelvic balance of these patients. Our hypothesis was that we would demonstrate this correlation, a result similar to those published in the previously referenced articles, but in our results the correlations between the relevant radiographic parameters, PI, LL, and PI-LL, and the clinical parameters were not statistically significant ($p > 0.05$) and the correlation values were always less than 0.2 ($r < 0.2$). Only the correlations between the SVA and satisfaction with treatment and between TK and the SRS-30 total were statistically significant ($r = 0.402/p = 0.023$ and $r = 0.419/p = 0.017$, respectively).

In their prospective study of 95 cases of adult scoliosis, Schwab et al.[6] did not obtain a statistically significant correlation between the radiographic parameters in the sagittal plane, the plumbline, and the rate of pelvic tilt, with pain, as measured by the SVA.

Although the Oswestry and SRS-30 questionnaires used as clinical and functional parameters in this study were adapted and validated for Brazilian Portuguese,[22,23] we noted that some patients in the sample had difficulty filling them out, which could have influenced the data analysis results. Also, the objective of this study was not to evaluate the mental condition of the patients in the sample, or the presence of secondary gain in these patients, a factor that could have influenced the analysis of the clinical and functional parameters. As a follow-up to this study, we plan to evaluate the influence that these factors have on our sample and then reconsider the results of the correlation between the radiographic, and clinical and functional parameters.

CONCLUSION

This study analyzed the correlation between the clinical and functional outcomes of a group of patients who underwent spinal fusion with the parameters of sagittal and spinopelvic balance. There were significant correlations only between the SRS-30 satisfaction with treatment domain and the SVA and between the total SRS-30 score and thoracic kyphosis. The other clinical and functional parameters analyzed could not be explained by the radiographic parameters.

Although various prior studies have demonstrated the effectiveness of using different sagittal balance and spinopelvic parameters in clinical and functional analyses of patients with spinal deformities, from the results of our study, the role of these radiographic parameters in the postoperative analysis of thoracolumbar and lumbosacral arthrodesis postoperative was not well-characterized.

All authors declare no potential conflict of interest concerning this article.

AUTHOR CONTRIBUTIONS: Each author made significant individual contributions to the development of the manuscript. MACC interviewed the patients, organized the data, and wrote the article. RRP conceived the project, assisted in the description and revision of the article. MMM and CB assisted with data collection and organization. CEB, FPS, and CEO supplied the patients considered in the study.

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