Influence of total hip arthroplasty on sagittal lumbar-pelvic balance: Evaluation of radiographic parameters*

Influência da artroplastia total de quadril sobre o equilíbrio sagital lombopélvico: Avaliação dos parâmetros radiográficos

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Rev Bras Ortop 2019;56:657–664.

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Abstract

Objective To prospectively analyze the radiographic variables of lumbosacral sagittal balance in the pre- and postoperative period of patients submitted to total hip arthroplasty (THA).

Methods A prospective, observational, comparative study that evaluated pre- and postoperative radiographic parameters of 71 patients, submitted to 72 total hip arthroplasties in a 3-year period (2014–2017) for primary coxarthrosis, of whom 28 performed late postoperative control (6 months) through the Surgimap Spine software (Surgimap, New York, NY, USA). Statistical analysis was performed using the Student t-test, the analysis of covariance (ANCOVA) model, and the Kolmogorov-Smirnov test. The data were analyzed using the IBM SPSS Statistics for Windows, Version 20.0 (IBM Corp., Armonk, NY, USA). A p-value < 0.05 indicated statistical significance.

Results A total of 72 cases, presenting a mean age of 57.9 years old, predominantly females (60.6%) and patients > 50 years old (71.8%). There was an overall decrease in lumbar lordosis values in the immediate postoperative period, without major global changes in late evolution. It was found that patients with a pelvic incidence $\geq 60°$ tended to have their other sagittal balance parameters elevated.

Conclusion There was no significant difference between the radiographic variables of sagittal lumbopelvic balance in the evaluated periods. Lumbar lordosis and pelvic incidence were the main modifying factors. Improvement of low back pain after THA, without changes in parameters, suggests different pathology mechanisms still to be clarified.

Keywords
- hip arthroplasty
- spine
- low back pain

* *Work performed at the Orthopedics and Traumatology Service of the Hospital Universitário Cajuru (PUC-PR), Curitiba, PR, Brazil. Originally Published by Elsevier Editora Ltda.*

received
December 23, 2017
accepted
April 10, 2018

DOI https://doi.org/10.1016/j.rbo.2018.04.005.
ISSN 0102-3616.

Resumo

Objetivo Analisar prospectivamente as variáveis radiográficas do equilíbrio sagital da coluna lombossacral no pré e pós-operatório dos pacientes submetidos a artroplastia total de quadril (ATQ).

Métodos Estudo prospectivo, observacional e comparativo que avaliou parâmetros radiográficos pré e pós-operatórios imediatos de 71 pacientes submetidos a 72 ATQs em três anos (2014–2017) por coxartrose primária, dos quais 28 fizeram controle pós-operatório tardio (6 meses), através do programa Surgimap Spine (Surgimap, Nova York, NY, EUA). A análise estatística foi feita com o teste t de Student, o modelo de análise de covariância (ANCOVA, na sigla em inglês) e o teste de Kolmogorov-Smirnov. Os dados foram analisados com o programa IBM SPSS Statistics for Windows, Versão 20.0 (IBM Corp., Armonk, NY, EUA). Valores de $p < 0,05$ indicaram significância estatística.

Resultados Os 72 casos avaliados apresentaram uma idade média de 57,9 anos, com predominância do sexo feminino (60,6%) e de pacientes > 50 anos (71,8%). Houve uma diminuição global nos valores da lordose lombar no pós-operatório imediato, sem grandes alterações globais na evolução tardia. Aferiu-se que pacientes com uma incidência pélvica $\geq 60°$ tendem a ter os demais parâmetros do equilíbrio sagital elevados.

Conclusão Não houve diferença significativa entre as variáveis radiográficas do equilíbrio sagital lombopélvico nos períodos avaliados. A lordose lombar e a incidência pélvica foram os principais fatores modificantes. A melhoria da lombalgia pós-ATQ sem alterações desses parâmetros sugere diferentes mecanismos da patologia ainda a serem esclarecidos.

Palavras-chave
- artroplastia de quadril
- coluna vertebral
- dor lombar

Introduction

As life expectancy increases in our population, more and more patients are experiencing degenerative changes that require surgery. The spine and hip are important disability sources in the elderly, and their symptoms often overlap. The clinical definition of which change is most relevant and should be treated first is difficult.

Sagittal balance (SB) is a mechanical system consisting of osteoarticular and neuromyofascial elements of the spine-pelvis structure of the lower limbs; it depends on the gravity center axis variation with the dual hip-femoral axis. This allows a direct correlation of the postural balance as a predictive and prognostic factor of some spinal disorders, particularly lumbar degenerative diseases.[1]

The concept that the pelvis is part of the spine has been well-established since Duval-Beauperre defined the pelvic vertebra to highlight the impact of pelvic position over spine posture and alignment.[2]

It is very challenging to assess normal pelvic-spine axis values because there is a large group of asymptomatic individuals even at the range extremes for each SB variable. Several radiographic angles and measurements help us understand this relationship. Among them, the most common include lumbar lordosis (LL), pelvic tilt (PT), pelvic incidence (PI) and sacral slope (SS). Their lines and reference values according to Morvan et al[3] are shown in ►**Table 1**, and their schematic drawings are shown in ►**Figure 1**.

During the last 3 decades, spinal surgery specialists have increasingly studied the importance of SB, correlating it to sagittal imbalance and spinal degenerative consequences.

In total hip arthroplasty (THA), the relationship between the pelvis and the spine is necessarily modified; however, little is known about its influence on the posture of the

Table 1 Angles and normal values for sagittal balance variables

SS Variable	Line 1	Line 2	Normal value
Lumbar lordosis (LL)	Superior L1 plate	Terminal S1 plate	$41 \pm 11°/46 \pm 11°$
Pelvic tilt (PT)	Line vertical to the ground	Midpoint from the sacral plate to the femoral head axis	10°–25°
Pelvic incidence (PI)	Perpendicular to the sacral plate	Midpoint from the sacral plate to the femoral head axis	45°–65°
Sacral slope (SS)	Superior S1 plateau	Line horizontal to the ground	30°–50°

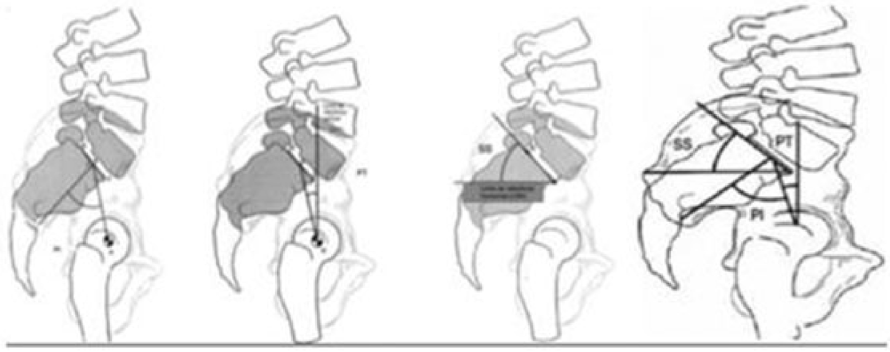

Fig. 1 Schematic drawing of the angular variables of sagittal balance (SS, sacral slope; PT, pelvic tilt).

patients. Theoretically, the anterior dislocation of the vertical axis of the spine results in greater energy expenditure and lumbar spine symptoms.

The present study aims to prospectively compare pelvic lumbar SB radiographic parameters, including the relationship between the spine and the pelvis, in the preoperative, immediate postoperative and late postoperative period of THA, considering the age and gender of the patients, and to determine the impact of the procedure in altering these variables.

Methodology

The present study was approved by the Ethics Committee through the Plataforma Brasil website.

This is a prospective, observational, comparative study in which patients undergoing elective THA surgery for primary coxarthrosis were evaluated according to pelvic lumbar radiographic parameters before and after the procedure.

Radiographs were prospectively taken at 3 defined moments to evaluate SB measurements: at the preoperative period (1 day before surgery), immediate postoperative period (2 to 4 months after surgery), and late postoperative period (4 to 6 months after surgery).

Only patients with surgical indication for primary coxarthrosis were included in the study, thus excluding all patients who received partial prosthesis, with proximal femoral fractures or whose radiographs were deemed inadequate.

From April 2014 to March 2017, 120 THAs for coxarthrosis were performed. A total of 20 patients with no adequate preoperative radiographies were excluded; in addition, 21 patients were excluded due to radiographic technique nonconformation, and 8 were lost to follow-up. Therefore, 71 patients, or 72 surgeries (since 1 patient required a bilateral arthroplasty), complying with all image quality and radiographic conformation requirements, were included. From these patients, 28 had appropriate late postoperative radiographs and were included in the evaluation.

Preoperative and immediate postoperative radiographs were taken during hospitalization, while late postoperative radiographs were taken during returns to the outpatient facility. All of the radiographic examinations were performed according to the following protocol: lateral lumbosacral image in orthostatic position and including the proximal aspect of the femur (►**Fig. 2**).

The ES evaluation was performed using LL, SS, PT and PI measurements. These measurements were analyzed by the same spinal surgery resident using the Surgimap Spine application (Surgimap, New York, NY, USA) (►**Fig. 3**), a free software that makes radiographic measurements more accurately

Fig. 2 Example of measurements: Lateral orthostatic lumbosacral X-ray at the preoperative, immediate postoperative and postoperative period.

Fig. 3 Example of measurements using Surgimap software: Lateral orthostatic lumbosacral X-ray including femoral heads.

compared with printed radiography and that integrates measurements with tools for spine assessment and surgical planning.[4,5]

Quantitative variables results were described by mean, median, minimum and maximum values and standard deviation (SD) of the mean. Qualitative variables were described as frequencies and percentages. The comparison between two evaluations was made considering the Student's t-test for paired samples. The normality condition of the variables was assessed by the Kolmogorov-Smirnov test. P values < 0.05 indicated statistical significance. Data were analyzed using IBM SPSS Statistics for Windows, Version 20.0 (IBM Corp., Armonk, NY, USA).

Results

A total of 71 patients were included, totaling 72 THAs (with 1 bilateral case), of which 28 had late postoperative control data. The average age of the population was 57.9 years old (ranging from 27 to 85 years old), with a higher prevalence of patients > 50 years old (71.8%). There was a higher prevalence of female (60.6%) compared with male patients (39.4%). In addition, the right side was the most commonly instrumented (55%).

The LL evaluation revealed a general decrease in values according to the gender and age of the patients at the immediate postoperative period; in the long term, these values remained similar to the ones obtained before the procedure (►**Table 2**).

Comparing measures obtained at the preoperative and immediate postoperative periods, none of the analyzed variables showed a statistically significant difference. Regarding SS, there was an average difference of 0.4°, which represents a small increase in SS after THA. The PT values decreased, on average, 1.4°, whereas PI showed a decrease of 1.1° (►**Table 3**).

The analysis of results obtained at the preoperative and late postoperative evaluations considered 28 cases with complete data. The mean values of the analyzed variables showed no significant difference. However, PT and PI approached a p-value < 0.05. There was an average increase of 0.7° in SS. The PT and PI values decreased, on average, 2.5° and 2.6°, respectively (►**Table 4**).

At the evaluation of differences between late and immediate postoperative measurements, there was a smaller reduction in all parameters.

Table 2 Lumbar lordosis range at the preoperative, postoperative and late postoperative period classified per grade

LL	Preoperative period		Postoperative period		Late postoperative period	
	n	%	*n*	%	*n*	%
Hyperlordosis[a]	47	65.3	40	55.6	18	64.3
Normolordosis[b]	23	31.9	30	41.7	10	35.7
Hypolordosis[c]	2	2.8	2	2.8	0	0
Total	72	100	72	100	28	100

Abbreviation: LL, Lumbar lordosis.
[a]Women > 57°; Men > 52°.
[b]Women 35° to 57°; Men 30° to 52°.
[c]Women < 35°; Men < 30°.

Table 3 Comparison of values obtained at the pre- and postoperative periods, their difference and statistical analysis

	n	Mean	Median	Minimum	Maximum	Standard deviation	*p-value*[a]
Pelvic tilt							
Preoperative	72	13,3	14,5	−1,3	36	10.1	
Postoperative	72	11,9	11	−11	39	10.30	
Difference (postoperative-preoperative)	72	−1,4	−1	−33	29	9.9	0.219
Pelvic incidence							
Preoperative	72	55,9	53	25	100	13.0	
Postoperative	72	54,8	52	20	100	13.5	
Difference (postoperative-preoperative)	72	−1,1	0	−21	15	6.3	0.158
Sacral slope							
Preoperative	72	42,4	42	−2	74	11.0	
Postoperative	72	42,9	41	23	85	11.5	
Difference (postoperative-preoperative)	72	0,4	0	−25	29	8.5	0.658
Lumbar lordosis							
Preoperative	72	−57,3	−58	−96	-2	13.6	
Postoperative	72	−56,8	−56	−116	-27	14.3	
Difference (postoperative-preoperative)	72	0,5	0	−53	33	12.1	0.750

[a]Student's t-test for paired samples ($p < 0.05$).

Table 4 Comparison of values obtained at the pre- and late postoperative periods, their difference and statistical analysis

	n	Mean	Median	Minimum	Maximum	Standard deviation	*p-value*[a]
Pelvic tilt							
Preoperative	28	16.0	16	0	34	7.8	
Postoperative	28	13.5	13	−4	33	7.5	
Difference (postoperative-preoperative)	28	−2.5	−2	−24	17	7.9	0.105
Pelvic incidence							
Preoperative	28	57.1	57	32	100	12.8	
Postoperative	28	54.5	52	31	87	14.9	
Difference (postoperative-preoperative)	28	−2.6	−3.5	−17	14	7.6	0.085
Sacral slope							
Preoperative	28	40.3	41	18	74	10.7	
Postoperative	28	41.1	39	28	69	10.5	
Difference (postoperative-preoperative)	28	0.7	−2	−13	26	8.2	0.632

[a]Student's t-test for paired samples ($p < 0.05$).

The ES evaluation patients < 50 years old did not reveal changes in the immediate or late postoperative values compared with the preoperative data. In the group > 50 years old, there were no statistically significant differences.

None of the measured variables showed statistically significant differences between genders at any time period.

There was statistical significance in the evaluation of some parameters when the population was divided according to PI $\geq$ 60° and < 60°. The LL, SS, and PT presented significantly higher values in patients with PI $\geq$ 60°. Moreover, in the comparison between the late postoperative and preoperative periods, the PT decrease was greater in patients with PI values < 60° (- 3.3 versus - 1; $p < 0.05$). At the same comparison, SS increased 2.3° in patients with PI $\geq$ 60°; however, in the group with PI < 60°, the SS remained practically unchanged (0.1°; $p < 0.05$) (►**Table 5**).

Dividing the sample into patients with LL $\geq$ 40° and LL < 40°, it was noted that the first group had higher preoperative mean values, both in SS (44.1° versus 26.9°, respectively; $p < 0.001$) and PI (57° versus 46.1°, respectively; $p < 0.05$). The remaining variables were not statistically significant.

Discussion

Since Hippocrates described the spinal elements and curves, 2 thousand years ago, experts have been trying to elucidate

Table 5 Comparison of values obtained at the evaluated periods according to the pelvic incidence (PI) range (≥ 60○ and < 60°), their difference and statistical evaluation

Variable	Evaluation	Preoperative PI	*n*	Mean	Minimum	Maximum	Standard deviation	*p* value[a]
Pelvic tilt	Preoperative	< 60	49	9,8	−13	34	9.0	
		≥ 60	23	20,7	9	36	8.3	< 0.001
	Postoperative	< 60	49	9,1	−11	32	9.4	
		≥ 60	23	17,8	−1	39	10.0	0.157
	Late postoperative	< 60	18	10,5	−4	23	6.4	
		≥ 60	10	18,9	11	33	6.3	0.017
	Difference	< 60	49	−0,7	−33	29	9.8	
	(postoperative–preoperative)	≥ 60	23	−3,0	−33	13	10.2	0.157
	Difference (late postoperative-	< 60	18	−3,3	−24	7	8.0	
	preoperative)	≥ 60	10	−1,0	−10	17	7.8	0.017
	Difference (postoperative-	< 60	18	−0,1	−18	10	6.4	
	late postoperative)	≥ 60	10	−0,6	−19	17	9.1	0.672
Sacral slope	Preoperative	< 60	49	39,3	−2	57	10.1	
		≥ 60	23	49,2	31	74	9.9	< 0.001
	Postoperative	< 60	49	39,4	23	61	9.1	
		≥ 60	23	50,4	31	85	12.6	0.050
	Late postoperative	< 60	18	35,7	28	48	6.1	
		≥ 60	10	50,7	33	69	10.0	0.007
	Difference	< 60	49	1	−25	29	8.9	
	(postoperative–preoperative)	≥ 60	23	1,2	−14	21	7.7	0.050
	Difference (late postoperative-	< 60	18	−0,1	−13	26	8.8	
	preoperative)	≥ 60	10	2,3	−9	13	7.1	0.007
	Difference (late postoperative-	< 60	18	−1,1	-10	11	6.2	
	postoperative	≥ 60	10	0,7	-16	16	8.6	0.112
Lordosis	Preoperative	< 60	49	−53,9	−77	−2	12.6	
		≥ 60	23	−64,5	−96	−34	13.1	0.002
	Postoperative	< 60	49	−53,9	−71	−31	10.6	
		≥ 60	23	−64,7	−116	−27	17.8	0.077
	Late postoperative	< 60	18	−55,2	−75	−39	9.5	
		≥ 60	10	−65,3	−82	−40	11.9	0.402
	Difference	< 60	49	0,8	−32	33	10.9	
	(postoperative–preoperative)	≥ 60	23	−0,2	−53	28	14.6	0.077
	Difference (late postoperative-	< 60	18	−4,2	−32	11	11.5	
	preoperative)	≥ 60	10	−0,8	−14	14	8.6	0.402
	Difference (late postoperative-	< 60	18	−3,8	−20	11	7.7	
	postoperative)	≥ 60	10	3,2	−9	39	14.9	0.263

[a]Student's t-test for independent samples (preoperative evaluation); adjusted analysis of covariance (ANCOVA) for preoperative evaluation (for remaining assessments); $p < 0.05$.

the complex details shaping the SB and its influences on clinical presentations.[6]

The mechanic behavior of the spine and pelvis is complex and synergistic with bony parts, intervertebral discs, muscles and tendons.[7] This set works cohesively and presents defensive features against disc degenerative or facet injuries, even in people with extreme sagittal measurements who tend to develop degenerative injuries. In general, if there is no good elastic and global functionality, the spine morphotypes will determine the mechanical and degenerative behavior of the spine.[1]

A series of radiographic parameters has been proposed to describe an imbalance in sagittal alignment of the pelvic spine; a change in these values would lead to the development of compensatory mechanisms[8], resulting in pain and decreased quality of life[9].

The association between low back pain and osteoarthritis was described by Offierski et al 4 decades ago as hip-spine syndrome;[10] despite several studies performed since then, data are still scarce to understand the exact pathophysiological mechanisms of this condition. It is now believed that hip osteoarthritis may significantly decrease the ability of the hip to maintain postural balance; the decreased mobility and increased joint forces may increase energy expenditure, leading to muscle fatigue. This would result in a fixed hip flexion position, leading to pelvic anteversion, compensatory lumbar hyperlordosis and, consequently, to low back pain due to overload or dislocation of the posterior facets.[7,11]

Duval-Beaupère et al[12] described the relationship between pelvic anatomy and lumbar lordosis, an important correlation between the PI angle and LL; this latter parameter is strongly related to the shape of the pelvis. In our study, considering LL values from the three evaluated periods, a variation with no statistical significance was noted when the lumbar curve was classified as hyperlordotic, hypolordotic or normolordotic. The group presenting values considered normal ranged from 31.9 to 35.7%, while the group with increased curves presented a 1% reduction (►**Table 2**).

Previous studies have shown that characteristic changes in sagittal balance occur with advancing age, resulting in symptoms of low back pain and spinal degeneration.[10,13] Vendantam et al[14] demonstrated that aging leads to a shift from sagittal to anterior alignment on the sacral axis. We attempted to evaluate the influence of variables such as gender and age on the alteration of sagittal balance parameters, but our study showed no correlation with such data. A study published by Kulcheski et al,[15] concluded that obese patients usually present sagittal parameters alterations resulting from compensatory mechanisms related to overweight.

The pelvic view was described by Legaye et al[16] as a morphological pattern varying according to the hip axis and sacral obliquity related to the ilium. It has an important correlation with the spinal-pelvic slope, SS and LL. Lower PI values are related to a decrease in LL and SS. The main statistically significant results consider the fact that patients with high, $> 60°$, preoperative IP values also presented higher values in the remaining variables (►**Table 5**). Vaz et al[17] emphasized that patients with low-grade PI would be less adaptable to changes in sagittal balance variables; on the other hand, in subjects with high-grade IP, SS would not cause this limitation, representing a better power of variation from other angles.

Previous studies showed that the most common PI in the asymptomatic population and, therefore, more mechanically adjusted, is, on average, 50°.[18] These patients present a lower amount of degenerative conditions due to the lower concentration of pressure points on spinal structures (better load distribution).[19] Low PI leads to disc conditions because the tendency to approach the gravity line near the lumbosacral junction generates a lesser dispersion of pressure on the intervertebral disc, increasing forces in the pulpous nucleus. In the high-PI morphotype (hyperlordotic patients), there is an overload on the posterior elements of the lumbar spine, increasing the possibility of lesions on facets and interarticular pars. However, not all patients with extreme PI values develop spinal conditions, just as not all patients with spinal conditions have extreme PI values.[19]

In general, when evaluating the analyzed variables, there were no significant changes between time periods, as previously described in the literature by Ben-Galim et al[20] in a prospective study with 25 patients, which was ratified by Radcliff et al[21] in 2013.

Weng et al,[22] when comparing patients with or without coxarthrosis, found that the first group presented greater pelvic anteversion, greater hip joint flexion, and an anterior inclination of the spine. Eyvazov et al[7] and Ben-Galim et al[20] showed that functional alterations of the hip, such as coxarthrosis, generate sagittal alignment abnormalities, and that joint function correction in hips with advanced arthrosis by means of arthroplasty produces a significant reduction in the visual scale and Owestry score for low back pain. Total hip arthroplasty is increasingly seen as an improvement factor in low back pain, spinal biomechanical function and hip complaints.[23,24]

Theoretically, THA would allow radiographic values compensation due to hip extension recovery, but this has not been demonstrated in the literature. In fact, the PT and the other variables changed slightly after arthroplasty, as previously described.[25,26]

The limitation of the number of patients analyzed, the postoperative follow-up period, and the radiographic technical difficulty in uniformly measuring variables may have influenced the results of this study.

Although there is still controversy on which condition should be treated first, a follow-up with hip and spine specialists is indicated. More recent results have suggested that coxarthrosis should be treated earlier, as it has shown a greater influence on the postoperative improvement of low back pain.[20]

The individualization of patients who are THA candidates is increasingly required, especially in those with low back pain. Sagittal balance assessment can prevent technical errors such as excessive anteversion of the acetabular component, posterior impingement, early component wear, and even major postoperative complications, such as instability and dislocations.[27,28]

Conclusion

The study of SB has been an important orthopedic tool to elucidate the mechanics, pathophysiology and their relationships with spinal disorders. Their responses are directly responsible for better diagnosis, management, planning, therapeutic decision and outcomes.

The present work adds data to the literature, validating other studies already reported. The change in global SB variables was not significant postoperatively, which reinforces previous studies with the theory that there are more complex mechanisms not yet described that would be responsible for the clinical and symptomatic improvement of patients undergoing THA. However, the evaluation of sagittal balance in candidates to this procedure is important, and it should be performed during the surgical planning period. Further studies will elucidate the pathophysiology of a condition which is increasingly common in the current population, with great socioeconomic impact.

Conflicts of Interests
The authors declare that there are no conflicts of interests.

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