Clinical Research

Relationship between global sagittal balance and clinical outcome in patients treated with lumbar fusion

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ABSTRACT

Introduction: Normal anatomy of the spine curvature has the function to distribute axial loading, especially in standing position. Sagittal balance parameters consist of pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), lumbar lordosis (LL) and C7 plumb line distance (C7PL). Changes in these parameters may cause pain and other disabilities.
This research aims to show the correlation between the parameters of sagittal balance and clinical outcome measured using ODI score and to show whether the sagittal balance parameters are corrected post-operatively.

Methods: Data was collected in dr. Cipto Mangunkusumo Hospital, Jakarta. The study design is analytic observational with cohort. There were 31 subjects consisted of male and female adult that underwent lumbar fusion from January 2016 to July 2017. In this study, we included 22 patients with degenerative diseases, 8 patients with infection, and 1 patient with malignancy. All patients got whole spine X-rays and filled the ODI score questionnaire before and after the surgery. The sagittal balance parameters were measured using Surgimap software.

Results: The results showed that there was no significant relationship between PT, LL, C7PL and the improvement of patients statistically. However, there was significant correlation between PI and SS and the improvement of patients statistically. The sagittal balance, unfortunately, was not significantly corrected

Conclusion: From a previous study conducted in Indonesia, it is showed that PI and C7PL were significant clinically. However, the present study concluded that PI and SI were the ones influencing the clinical outcome. We found that the current surgical technique did not correct the sagittal balance parameters, which may be due to the difficulty in monitoring the correction intraoperatively.

ABSTRAK

Pendahuluan: *Kelengkungan sagital tulang belakang memiliki fungsi dalam menjaga distribusi beban aksial, terutama pada saat berdiri. Parameter balans sagital mencakup* pelvic tilt (PT)*,* pelvic incidence (PI)*,* sacral slope (SS)*, l*umbar lordosis (LL)*, dan C7* plumb line distance *(C7PL). Perubahan tersebut menyebabkan keluhan nyeri dan deformitas.*

Tujuan: *Penelitian ini menilai korelasi antara parameter balans sagital dan perbaikan klinis yang dibandingkan sebelum dan sesudah operasi, serta melihat tercapainya koreksi dari parameter balans sagital sebelum dan sesudah operasi. Pengambilan data dilakukan di RSUPN dr. Cipto Mangunkusumo, Jakarta. Desain penelitian yang digunakan adalah analitik observasional dengan metode Cohort. Subjek terdiri atas 31 orang pria dan wanita dewasa yang melaksanakan fusi lumbal pada Januari 2016 sampai Juli 2017. Pada penelitian ini, diagnosis pasien dibagi menjadi: 22 pasien dengan penyakit degeneratif, 8 pasien dengan penyakit infeksi, dan 1 pasien dengan keganasan. Pasien mengisi kuisioner IDO dan menjalani pemeriksaan* X-ray whole spine *sebelum dan setelah fusi lumbal. Peneliti melakukan analisis skor IDO dan parameter balans sagittal menggunakan program Surgimap.*

Hasil: *Hubungan antara PT, LL, C7PL ditemukan tidak bermakna secara statistik. Sedangkan PI dan SS menunjukkan hubungan yang bermakna secara statistik. Koreksi parameter balans sagital setelah fusi lumbal tidak memberikan hasil yang signifikan secara statistik.*

Kesimpulan: *Dari penelitian sebelumnya yang dilakukan di Indonesia PI dan C7PL ditunjukkan berkorelasi dengan luaran klinis. Namun pada penelitian ini PI dan SS ditemukan memberikan hasil yang bermakna secara statistik terhadap perbaikan klinis. Tidak didapatkan hasil yang signifikan untuk koreksi parameter balans sagital pasca-fusi lumbal. Hal ini dikarenakan sulitnya mengevaluasi koreksi intraoperatif.*

Keywords: Sagittal Balance, ODI Score, Low Back Pain, Pelvic Tilt, Pelvic Incidence, Sacral Slope, Lumbar Lordosis, C7 Plumb Line Distance, Lumbar Fusion.

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INTRODUCTION

Adult Spinal Deformity (ASD) is one of the most common conditions found today. ASD used to be treated as coronal deformity, by correcting the Cobb Angle. However, recent studies showed that sagittal plane alignment (SPA) is very important as it is related with the quality of life.[1] It is considered as one of the most important goals during spine surgery. Whole standing lateral X-ray is important to measure the sagittal balance of the spine. Sagittal balance is important to distribute axial-loading on the spine. One of the most important angles is lumbar lordosis, which is important in maintaining standing posture. Sagittal imbalance is defined as decreased or increased lordosis or kyphotic angle of the spine. One of the most common causes of sagittal imbalance is iatrogenic spinal fusion with Harrington rod distraction technique that is called flat back deformity.[2] Other causes of sagittal imbalance include degenerative diseases, inflammatory diseases, traumas, or neoplasms.[3] Sagittal balance parameters include: pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS) which is also known as sacral inclination angle (SIA), and C7 plumb line distance (C7PL) which is also known as sagittal vertical axis (SVA). Table 1 shows the normal sagittal balance parameter.[4]

Parameter	Value
Pelvic incidence (PI)*	48-55^0
Pelvic tilt (PT)	12-18^0
Sacral slope (SS)	36-42^0
Lumbar lordosis (LL)	43-61^0
C7 plumb line	<3 cm

Table 1: Normal sagittal balance parameters
Sagittal balance parameters include: pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), lumbarlordosis (LL), and C7 plumb line distance (C7PL)

Recent studies show the importance of maintaining sagittal balance in lumbar surgery, especially if the surgery is using spinal instrumentations.[5, 6] Degenerative process in the spine is marked with facet hypertrophy, joint arthritis, degenerative disk disease, bone remodeling, and atrophy of the extensor muscles that can cause kyphosis on the spine and creating instability. In the patients of the studies, anterior sagittal imbalance, loss of lumbar lordosis, and increased pelvic tilt are usually found.

Spinal fusion will also cause loss of lumbar lordosis and compensatory mechanism resulting in decreasing sacral slope, increasing pelvic tilt, as well as decreased thoracic kyphosis. This increased pelvic tilt is often related to back pain after spinal fusion. Restoration of pelvic tilt is found to be related to good quality of life post-operatively.[4]

Based on the study conducted by Ruiz et al., measurement of the back pain is mostly conducted in Visual Analogue Scale (VAS) and Oswestry Disability Index (ODI). VAS is measured based on the pain in specific regions, whereas ODI give better validity in which it measures correlation between pain and activities of daily living (ADL). Quality of life decreases as ODI score increases.[7]

METHODS

This study was a cohort observational analytic, samples were taken from January 2016 to July 2017 in Cipto Mangunkusumo National Central Hospital, Jakarta, Indonesia. Inclusion criteria includes: male or female adults (> 18 years old) underwent spinal fusion with instrumentation and patients were able to stand without aid. Exclusion criteria include: revision surgery, patients with other masking conditions such as hip disease, or patients refused to join the study. Patients were then asked to fill the ODI questionnaire before and after the surgery. ODI score was taken 1-6 months after surgery. Clinical improvement is reached if there is a decrease of minimum 10 points after the surgery.

Sagittal balance parameters are measured using whole spine lateral standing X-ray showing auricular externa and femoral head (Figure 1). This X-ray is taken before and after the surgery.

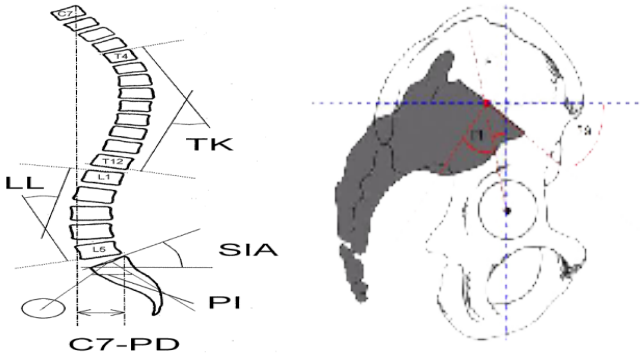

Figure 1. Measurement of sagittal balance parameters. TK: thoracic kyphosis, LL: lumbar lordosis, SIA/SS: sacral inclination angle/sacral slope, C7-PD: C7 plumb line distance,

PI: pelvic incidence.

The radiological parameters that are measured include: lumbar lordosis/LL (Cobb angle from upper end plate L1 to lower end plate L5), sacral inclination angle/SIA also known as sacral slope/SS (angle between upper end plate sacrum with horizontal line), C7 plumb line distance/C7PL also known as sagittal vertical axis/SVA (distance between plumb line through posterosuperior angle C7 and S1 – positive value indicates line anterior or go through sacrum and negative value indicates line posterior to sacrum), pelvic incidence/PI (angle between the perpendicular line of the midpoint sacrum with hip axis), pelvic tilt/PT (pelvic orientation in relation to femur). In adults PI = PT + SS.[8] The sagittal balance parameters were measured using Surgimap (NemarisInc, New York, USA) software, which is used by the spine surgeons overseas.[9-11] Data was then processed using SPSS 20.

RESULTS

The data was collected by using non-probability sampling. There were 31 patients included as samples in this study.

	All samples N=31	P value*
Age, Year (Median)	57 (20-71)	0.022
Age Groups		
·15-59 y.o. (n=20(64.5%))	46.1 ± 11.44	0.079
·≥ 60 y.o. (n=11(35.5%))	63.45 ± 3.29	0.124
Gender		
Male	11 (35.5%)	
Female	20 (64.5%)	
Etiology		
Degenerative	22 (71%)	
Infection	8 (25.8%)	
Malignancy	1 (3.2%)	
Prognosis		
Improvement	26 (83.9%)	
No Improvement	5 (16.1%)	

Results are shown in mean (standard deviation) for numerical data with normal distribution, or median for numerical data with abnormal distribution, and frequency (percentage) for proportional data.
*Normality test was conducted using Shapiro-Wilk test. P Value of ≤0,05 = abnormal data

Table 2. Sample demographics

Varible	N=31	
	Normal	Abnormal
PRE-OPERATIVE		
Pre-Op PT Angle	7 (22.6%)	24 (77.4%)
Pre-Op PI Angle	13 (41.9%)	18 (58.1%)
Pre-Op SS Angle	3 (9.7%)	28 (90.3%)
Pre-Op LL Angle	11 (35.5%)	20 (64.5%)
Pre-Op C7PL	14 (45.2%)	17 (54.8%)
POST OPERATIVE		
Post-Op PT Angle	13 (41.9%)	18 (58.1%)

Post-Op PI Angle	8 (25.8%)	22 (71.0%)
Post-Op SS Angle	8 (25.8%)	23 (74.2%)
Post-Op LL Angle	12 (38.7%)	19 (61.3%)
Post-Op C7PL	16 (51.6%)	15 (48.8%)

Results are shown in frequency (percentage).

Table 3. Sagittal balance parameters before and after surgery

Variable	ODI				
	Improvement	No Improvement	RR	CI (95%)	P Value*
Post PT Angle					
Normal	11 (84.6%)	2 (15.4%)	1.10	0.15-7.74	0.369
Abnormal	15 (83.3%)	3 (16.7%)			
Post PI Angle					
Normal	7 (87.5%)	1 (12.5%)	1.47	0.14-15.55	0.007
Abnormal	19 (82.6%)	4 (17.4%)			
Post SS Angle					
Normal	6 (75%)	2 (25%)	0.45	0.06-3.35	0.007
Abnormal	20 (87%)	3 (13%)			
Post LL Angle					
Normal	10 (83.3%)	2 (16.7%)	0.94	0.13-6.62	0.209
Abnormal	16 (84.2%)	3 (15.8%)			
Post C7 PL					
Normal	12 (92.3%)	1 (7.7%)	4.00	0.36-45.10	0.841
Abnormal	9 (75%)	3 (25%)			

Results are shown in frequency (percentage)
*P value was processed using chi square test for proportional data.
P-value of <0.05 shows significant value

Table 4. Comparison between sagittal balance parameters with ODI score

Variable	Sagittal Balance Parameters Post Op					
	Normal	Abnormal	Total	RR	CI (95%)	P Value*
Pre Op PT Angle						
Normal	4 (57.1%)	3 (42.9%)	7 (22.58%)	2.222	0.402-12.285	0.146
Abnormal	9 (37.5%)	15 (62.5%)	24 (77.42%)			
Pre Op PI Angle						
Normal	4 (30.8%)	9 (69.2%)	13 (41.94%)	1.556	0.308-7.854	0.267
Abnormal	4 (22.2%)	14 (77.8%)	18 (58.06%)			
Pre Op SS Angle						
Normal	2 (66.7%)	1 (33.3%)	2 (6.45%)	7.333	0.564-95.298	0.125
Abnormal	6 (21.4%)	22 (78.6%)	28 (90.32%)			

Pre Op LL Angle						
Normal	5 (45.5%)	6 (54.5%)	11 (35.48%)	1.548	0.345-6.942	1.000
Abnormal	7 (35%)	13 (65%)	20 (64.51%)			
Pre Op C7 PL						
Normal	11 (78.6%)	3 (21.4%)	14 (45.16%)	8.800	1.692-45.761	0.727
Abnormal	5 (51.6%)	12 (70.6%)	17 (54.83%)			

Results are shown in frequency (percentage)
*P value was processed using McNemar test for proportional data.
P-value of <0.05 shows significant value

Table 5. Comparison between sagittal balance parameters before and after surgery

DISCUSSION

Among the sample characteristics, the most common etiology was degenerative diseases (n=22 (71%)). This finding corresponds to the previous studies that showed degenerative diseases can cause sagittal imbalance with back pain. Spondylolisthesis is said to be the most common cause of the sagittal imbalance.[4] This study supported the statement since 22 patients (71%) underwent lumbar fusion because of degenerative diseases, 8 patients (25.8%) because of infection, and 1 patient (3.2%) because of malignancy. This study also found that most patients had improvement (n=26 (83.9%)) characterized by decreasing of ODI score of minimum 10 points post-operatively. According to Copay et al., clinical improvement was found in 454 patients within one year with improvement in ODI score of 12.8 points.[12]

When we compare the sagittal balance parameters with clinical outcome measured with ODI score as seen in Table 4, we found that the parameters statistically significant were PI and SS. Back pain that caused by lumbar fusion with sagittal imbalance is known as flat back syndrome. It was first reported in 1970s which included back pain, forward bent standing position, and changes in gait due to fusion in thoraco-lumbar segment.[13] At that time, the surgical technique used to correct the coronal deformity in thoraco-lumbar region was using distraction type instrumentation, such as Harrington rod. This technique decreased the coronal deformity but the distraction also decreased the thoracal kyphosis and the lumbar lordosis causing sagittal imbalance. These changes caused compensatory mechanism in distal un-fused region. [14]

According to Booth et al. the flatback syndrome may be divided into two types based on the compensatory mechanism: type 1 is segmental deformity with compensated sagittal imbalance, and type 2 is segmental deformity with uncompensated sagittal imbalance.[15] In flatback syndrome type 1, to maintain the sagittal balance, it is found muscle stress on the back and disc degeneration that may cause pelvic retroversion, hip extension and knee flexion. However, in the end the disc becomes degenerated and causes imbalance resulting in further pain.[16] Takahashi et al. created a review regarding Cotrel-Dubosset instrumentation on lumbar and they found that there was an increase in back pain from 3% before operation to 20% in 5-9 years after fusion.[17] Hasegawa et al. also stated that as people age, there were changes in PI and LL worsening the quality of life measured with ODI.[18] According to the studies conducted by Gottfried et al. and Cho et al., the most important parameter in relation to the quality of life is PI.[19,20] They reported that high PI is related to LL as a compensatory mechanism of sagittal imbalance, but when fusion is done, the ability of the body to compensate by hyperlordosis is also diminished, this condition can finally cause backpain.[19, 20] SS is related to LL, reduction in LL will be followed by reduction in SS that is needed to compensate the sagittal balance.[21] However, Radovanovic et al. stated that the most important parameter in patient with degenerative spondylolisthesis is C7PL.[22] A cross sectional study conducted in Indonesia by Tirta et al. reported that the most important parameter are PI and C7PL.[23]

This study also measured the sagittal balance parameters before and after surgery as seen in Table 5. No data was found significant in this study. The validity and reliability of the surgical techniques in this study were considered valid because all surgeries were conducted

by experienced spine surgeons in Cipto Mangunkusumo Hospital using the standard procedures used worldwide. One of the difficulties faced by the spine surgeons was how to restore the sagittal balance parameters to normal, as well as confirming the reduction intraoperatively.

Yang et al. mentioned one of the techniques used to correct the sagittal balance was by using precise rod bending technique.[24] They tried to create correction in the whole spine lateral X-ray and then they bent the 6.0 mm titanium rod according to the correction angle before they sterilized it.[24] Greimel et al. reported that intra-operative measurement of lumbar lordosis in prone position gave the same accuracy as lumbar lordosis measurement conducted post-operatively in standing position.[25] This finding can help the spine surgeons to make sure the correction of sagittal balance intraoperatively.

Another technique that can be used to correct the deformity is by using osteotomy. Yagi et al. stated that pedicle subtraction osteotomy (PSO) technique can help reducing the sagittal balance parameter in patients with ankylosing spondylitis.[26] Another study also reported that correction of sagittal balance with PSO technique gave good clinical outcomes up to 9 years.[2]

Kim et al. in their study suggested that the correction in PT and LL was related to clinical outcome.[27] They mentioned that increased in PT was a compensatory pelvic retroversion due to sagittal spinal malalignment. Low LL was caused by hyperextension of the upper level and, therefore, causing backpain. Le Huec et al. also stated that the loss of LL was compensated with the loss of SS and increased in PT, this increased PT is related to pain.[4] Interestingly, another study found that restoration of sagittal balance parameters in patients with mild grade spondylolisthesis was not related to clinical improvement.[28] They suggested that decompression and stabilization were more important than restoring sagittal balance in order to give clinical improvement.[28] However, since Glassman et al. reported that sagittal balance was related to quality of life in correcting spinal deformity, sagittal balance restoration was considered as one of the most important parameter to be addressed.[29,30]

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