Clinical Research

Analysis of factors affecting lumbar lordosis restoration after lumbar fusion operation using posterior instrumentation at Cipto Mangunkusumo national center hospital, Jakarta, 2012-2017

S. Dohar. A. L Tobing,[1] Herjuno Ardhi[2]

[1]Department of Orthopaedic and Traumatology, Faculty of Medicine, Universitas Indonesia, Cipto Mangunkusumo National Hospital, Jakarta, Indonesia
[2]Resident of Orthopaedic and Traumatology Department, Faculty of Medicine, Universitas Indonesia, Cipto Mangunkusumo National Hospital, Jakarta ,Indonesia

ABSTRACT

Introduction: Instrumented spinal fusion is one of the most common procedures performed to manage various pathologies in the lumbar region. The implant construction to restore lumbar lordosis has became a concern to achieve a satisfactory post-operative spinal alignment. Failure to restore lumbar lordosis may result in faster adjacent segment degeneration and disease, chronic back pain, implant failure, and loss of sagittal balance.

Methods: A retrospective study was carried out in 75 patients who underwent instrumented lumbar fusion. The patients were divided into 2 groups based on lumbar lordosis was restored or not. Assessment of fused segment lordosis, rod contouring, sagittal trajectory of pedicle screw, interbody cage implant usage, and the number of fusion levels (LoF) were performed on erect lumbosacral sagittal radiograph. The results were compared with the pre-operative radiograph.

Results: In this study, normal rod contouring in >3 fusion levels (p = 0.024), sagittal trajectory of depressed pedicle screw of the highest fusion segment (p = 0.011), sagittal trajectory of elevated pedicle screw of the lowest fusion segment (p = 0.021), and 1 level of spinal fusion (p = 0.006) affected the restoration of lumbar lordosis. The factors that affected the restoration of lumbar lordosis the most were, respectively, the number of fusion level of 1 level (p = 0.003, aOR = 7.79x), elevation of pedicle screw sagittal trajectory of the lowest fusion segment (p = 0.007, aOR = 8.9x), and depression of pedicle screw sagittal trajectory of the highest fusion segment (p = 0.029, aOR = 7.29x).

Conclusion: Instrument factors significantly affect lumbar lordosis restoration. Synergic combination among factors will increase the lumbar lordosis restoration successfulnes.

ABSTRAK

Pendahuluan: *Fusi spinal menggunakan instrumentasi posterior merupakan salah satu opsi tata laksana patologi dan deformitas pada regio lumbal. Dalam prosedur tersebut, salah satu hal yang diperhatikan adalah restorasi lordosis lumbar untuk mendapatkan* alignment *yang baik dan juga mencegah komplikasi, seperti degenerasi segmen berdampingan* (adjacent segment disease)*, nyeri tulang belakang kronis, kegagalan implan, dan hilangnya keseimbangan sagital. Penelitian ini bertujuan untuk menilai hubungan faktor instrumentasi terhadap restorasi lordosis lumbal sekaligus mengetahui faktor mana yang paling berpengaruh.*

Metode: *Dilakukan studi retrospektif pada 75 pasien yang menjalani operasi fusi lumbal menggunakan instrumentasi posterior, yang dikelompokkan berdasarkan tercapai atau tidaknya restorasi lordosis lumbal. Dilakukan penilaian lordosis segmen fusi, kelengkungan* rod, *trajektori sagital* pedicle screw*, penggunaan implan* interbody cage*, dan jumlah level fusi pada radiografi lumbosacral berdiri pasca-operasi. Hasil kemudian dibandingkan dengan radiografi pra-operasi.*

Hasil: *Pada penelitian ini didapatkan bahwa kelengkungan* rod *normal pada jumlah level fusi >3 level (p=0,024), trajektori sagital* pedicle screw *depresi pada segmen fusi teratas (p=0,011), trajektori sagital* pedicle screw *elevasi pada segmen fusi terbawah (p=0,021), dan jumlah level fusi 1 level (p=0,006) mempengaruhi restorasi lordosis lumbal. Dalam keadaan faktor lain dikontrol, faktor yang paling mempengaruhi restorasi lordosis lumbal adalah jumlah level fusi 1 level (p=0,003, aOR=7,79x), diikuti dengan trajektori sagital* pedicle screw *elevasi pada segmen fusi terbawah (p=0,007, aOR=8,9x), dan trajektori sagital* pedicle screw *depresi pada segmen fusi teratas (p=0,029, aOR=7,29x).*

Kesimpulan: *Faktor instrumentasi berpengaruh terhadap restorasi lordosis lumbal, khususnya jumlah fusi 1 level. Kombinasi sinergis antar-faktor instrumentasi akan meningkatkan keberhasilan restorasi lordosis lumbal.*

Keywords: restorasi lordosis lumbal, fusi spinal, instrumentasi posterior, rod, pedicle screw, interbodyimplant, level of fusion

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Corresponding author : Herjuno Ardhi, MD . herjuno.ardhi@gmail.com

INTRODUCTION

Physiologically, vertebral column in sagittal plane has an alignment consisting of cervicall ordosis, thoracal kyphosis, and lumbar lordosis, where as in coronal plane, the vertebral column has straight alignment. Each human has a unique alignment in the three components of sagittal plane, where balance in these components is responsible to maintain proper posture, and lumbal lordotic component is considered as one of the key postural component.[1]

Lumbar lordosis a curvature with a concaves hapedan teriorly. This curvature consists of L1-L5 vertebrae in which the value is usually measured with Cobb technique (normal value of 40° to 60°), with estimated 30 degrees increment from thoracal kyphosis (e.g. if the degree of lumbar lordosis is 60°, the degree of thoracal kyphosisis 30°).[1] Lumbar curvature consists of two components, both of which consist of two tangentarcs of circle .These variations further classify the lumbar lordosis into four types, which play a role in sagittal balance study as well as lumbar intstrumentation.[2]

In several lumbar pathologies, whether it is caused by infection, degenerative or deformity, lumbar lordosis commonly found. The loss of lordosis indirectly causes increased load in anatomical units of vertebral motion which can actually aggravate the patient's clinical and anatomical conditions.[3]

Spinal fusion is a traditional procedure for treating pathologies of vertebral column, including the lumbal region.[4] Since Albee and Hibbs firstly described this procedure in 1911 to treat spine infection and degeneration, this procedure continued to develop, not ably when Harriton introduced posterior instrumentation for treating scoliosis.[5] Spine implant has evolved – Luque with rod system, followed by Cotrel-Dubous set by using distracted instrumentation system, spinal plate and screw, and the most recent is rod and pedicles crew. Beginning from only posterior instrumentation, spinal fusion instrumentation now involves the anterior.[6] Pedicle screw and rod system has become a popular choice in spinal fusion. Besides making it easier for orthopaedic surgeons to perform surgical manipulation in treating deformity, it also provides rigid and stable construction.[2]

One consideration for instrumentation construction is lumbar lordosis restoration. Barrey et al.[3] stated that post operative lumbar hypolordosis would not only cause mechanical spinal pain, but it would also cause global sagittal alignment and complications such as adjacent segment disease. Umehara et al.[7] reported that post operative hypolordosis would accelerate adjacent segment deterioration by loading the motion segment in a non physiologic way. Not only hypolordosis affects the adjacent segments, it also increases the load on the posterior spinal implant, thereby increasing the risk of developing implant loosening in long term. Roussouly et al.[8] stated that this increased load contributed to degenerative changes in degenerative disk disease (DDD), facet joint arthritis, and lysthesis.

Spinal fusion is the last therapeutic line in the treatment of lumbar pathology. The high risk of this surgery makes patients have to carefully consider their decision to undergo such procedure; moreover, due to this reason, the patients of ten have high expectations of such procedure.[9] On the other hand, posterior spinal instrumentation has a relatively high cost; thus, the surgery should provide high success and satisfactory rate as well as reducing reoperation rate dueto complications.[10] Reoperation, whether caused by instrumentation revision or other additional procedures, could significantly increase the cost for maintaining the health of those who have undergone such procedure.[11]

The aformentioned problems urge the orthopaedic surgeons to restore lumbar lordosis in order to achieve and maintain optimal sagittal balance. The challenge faced is how much correction of lumbar lordosis should be made so that the balance and alignment are corrected as physiologically and anatomically as possible. The development of present instrumentation offers increased accuracy and efficiency of lumbar lordosis restoration. Several factors affecting the restoration of lumbar lordosis that have been identified: surgical techniques (operative position, soft tissue release procedures, osteotomy, sequence and operation approach) and instrumentation techniques (rodcurvature, selection of pedicle screw, interbody cage implant use, and number of level fusion.[4] However, knowledge and identification of good determinants are required so that these benefits are effective in restoring lumbar lordosis.

Several studies have identified and suggested instrumentation components, including rod[4,12,13], pedicle screw[14,15,16], interbody cage[4,17], and total level of fusions[16,18] in deformity correction. However, no study particularly investigates the factors affecting lumbar lordosis restoration in those who have undergone posterior instrumented lumbar fusion, including in ourcountry, Indonesia. We aim to investigate factors affecting lordosis restoration in those who have undergone posterior instrumented lumbar fusion.

RESULTS

During the study period (January 2013 to July 2017), 229 patients underwent posterior lumbar fusion in our hospital and a total of 75 patients were included in the study.

Results Analysis

Parameter Evaluation

We measured lumbar lordosis (LL), local LL, fused segments, and Cobb angle from the upper-end plate of fused segments (to show nett correction in pre- and postoperative spine X-ray). The instrumentation parameters measured in this study were the rod curvature (RC), total diffusion segments and also each local segment diffusion. Pedicle screw sagittal trajectory (PST) consisted of 2 components: the angle of the *pedicle screw-upper endplate* insertion and the angle of *head-body* pedicle screw, assessment of the use of interbody cage (IC) implants, and the total number of fusion levels (LoF). The measurement of local LL and Cobb angle from the upper end plate of fused segments demonstrated the gross and net of the correction of fused LL segments, respectively. The wedge shape of the vertebral body is considered tara. Both values would be used as references to determine whether the RC is normal, underbent, or overbent.

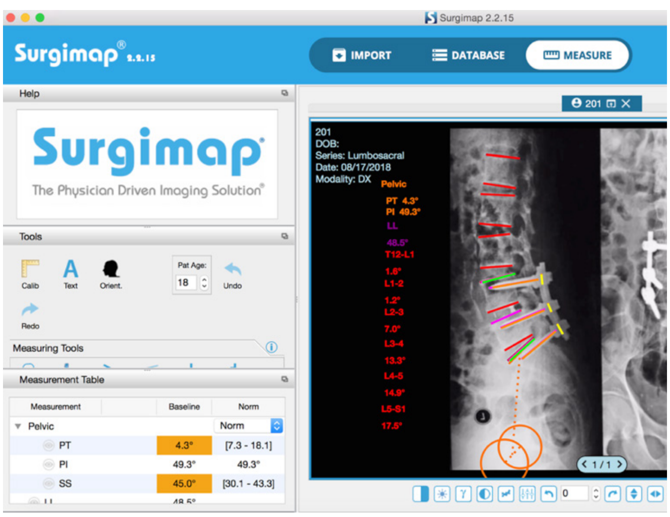

Figure 1. One example of radiology parameter measurement and instrumentation using Surgimap®

Measurement of radiological parameters was carried out using the Surgimap® program (Nemaris Inc., New York, USA) (Figure 1). Angle measurement in the radiological images have been performed by spinal orthopedic surgeon worldwide. The study states that using the program Surgimap® can measure the angle of the spine accurately.

Demographic Characteristics of the Subjects

All subjects in this study were assessed for their demographic profile (age, gender, lumbar pathology), radiology profile (lumbar lordosis), and instrumentation profile (rod curvature (RC), Pedicle screw sagittal trajectory (PST), the use of interbody cage (IC) implant, and total of level of fusion (LOF)). The characteristics are presented in Table 1.

The median age of the subjects was 57 (22-77) years, and 44 subjects (58.7%) were female. Most of the subjects had degenerative lumbar (N=60, 80%), followed by infection (N=13, 17.3%), and trauma (N=2, 2%). Forty-five (60%) had preoperative LL hypolordosis, where as postoperatively, the number of those with hypolordosis decreased into 34 subjects (45.3%). The decreased incidence of hypolordosis LL did not have a linear trend; although 16 subjects had postoperative LL changed from hypolordosis into normolordosis, there were 5 subjects who had normolordosis initially but turned into hypolordosis postoperatively. A total of 45.3% of the subjects had underbent RC, 76% of the subjects had pedicle screw sagittal trajectory (PST) on the highest segment inserted in elevated fashion, 72% had pedicle screw sagittal trajectory (PST) on the lowest segment inserted in elevated fashion,50.7% used IC implant,in which majority used TLIF cage (94.7%), and 32% had two level fusion.

Subjects who had preoperative normolordosis would have increased chance of developing normolordosis 9.06 times compared to those who had preoperative hypolordosis (p=0.027, OR = 9.06, 95% CI = 2.91-28.27) (Table 2). In lumbar pathology, degenerative cause was not significantly associated with postoperative normolordosis (p = 0.643, OR = 1.31, 95% CI = 0.42-4.15).

Comparison Analysis among Instrumentation Parameters

Instrumentation Parameter Evaluation

Analysis of the association between instrumentation parameters and the achievement of lumbar lordosis restoration is presented in Table 3 and 4. Chi-square or Fisher's exact test was used to analyse categorical data, while the Mann-Whitney U test was used for numerical categorical data. A p value of less than 0.05 was considered as

Table 1. Characteristics of the subjects

Variable	Number		median
	n=75	%	(min-max)
Age, years (median)			57 (22-77) mean: 54.95
Gender			
- Male	31	41.3%	
- Female	44	58.7%	
Lumbar pathology			
- Degeneration	60	80%	
- Infection	13	17.3%	
- Trauma	2	2.7%	
Preoperative LL			
- Normolordosis	30	40%	
- Hypolordosis	45	60%	
Postoperative LL			
- Normolordosis	41	54.7%	
- Hypolordosis	34	45.3%	
Rod curvature (RC)			
- Normal	27	36.0%	
- Underbent	34	45.7%	
- Overbent	14	18.7%	
Pedicle screw sagittal trajectory (PST) on the highest fusion segment			
- Depressed	17	22.7%	
- Neutral	1	1.3%	
- Elevated	57	76%	
Pedicle screw sagittal trajectory (PST) on the lowest fusion segment			
- Depressed	21	28%	
- Elevated	54	72%	
Use of interbody cage (IC) implant			
- Present	38	50.7%	
• TLIF cage	36	48%	
• Mesh cage	2	1.3%	
- None	37	49.3%	
Level of fusion (LoF)			2 (1-5)
- 1 level	23	30.7%	
- 2 levels	24	32%	
- 3 levels	12	16%	
- 4 levels	13	17.3%	
- 5 levels	3	4%	

statistically significant. Descriptive parameters of instrumentation parameters with preoperative LL are also presented in Table 4 as a description of the preferences that orthopedic surgeons choose in lumbar fusion surgery at Cipto Mangunkusumo National Center Hospital during 2013-2017.

Table 2. Association of preoperative LL and lumbar pathology with postoperative LL

Variable	Postoperative LL n (%)		P value	OR (95%CI)
	Normolordosis	Hypolordosis		
Preoperative LL				
- Normolordosis	25 (83.3)	5 (16.7)	0,027[mn]	9.06 (2.9128.27)
- Hypolordosis	16 (35.6)	29 (64.4)		
Lumbar pathology				
- Degenerative cause	32 (53.5)	28 (46.7)	0,643[cs]	1.31 (0.42-4.15)
- Nondegenerative causes (trauma and infection)	9 (60)	6 (40)		

cs) Chi-square test
mn) McNemar test

We found that RC was not significantly associated with postoperative LL (p=0.343) (Table 3), and depression of the highest fusion segment ofPST had 5.19 times increased risk of developing normolordosis when compared to elevation of such trajectory (p = 0.011, OR = 5.19, 95% CI = 1.34-20.02). Whereas, elevation of PST of the lowest fusion segment had 3.4 times increased the risk of developing normolordosis compared to the depression (p=0.021, OR = 3.4, 95% CI = 1.18-9.84). In the IC factor, patients who did not use interbody cage were 2.86 times more likely to have normolordosis in postoperative LL compared to those used interbody cages (p = 0.027). In the LoF factor, it was found that there was no difference in postoperative LL results at each level of fusion level with the median value of both being the same at 2 levels (p = 0.168). However, when viewed from its level category, LoF of 1 level was 4.54 times more likely to produce normolordosis in postoperative LL compared to other LoFs (p = 0.006).

We found, although there was no association between RC and postoperative LL, there was an association between underbent RC and postoperative LL normolordosis in 3-5 LoF group(p = 0.024, OR = 1.8, 95% CI = 1.22-2.92) (Table 4).

Both underbent and overbent RC were not significantly associated with postoperative LL (p = 0.333 and p = 0.735, respectively) (Table 5). The same condition was also found in the PST ofthe lowest fusion segment and IC where there was no relationship between PST and cage usage in both hypolordotic and normolordotic groups.

We found significant association between PST of the highest fusion segment with preoperative LL (p = 0.014). This implies that pedicle screw in the highest fusion segment tends to be placed in elevation position in patients with hypolordosis preoperative LL. Another significant association was also seen in LoF where LoFof 2 levels tended to be performed in hypolordosis preoperative LL(p = 0.011). The results are also significant for LoF of 3 levels and 5 levels.

Comparison Analysis Among Instrumentation Parameters

Comparative analysis of instrument parameters in lumbar lordosis restoration is demonstrated in Table 5. The multivariate statistical test used was the logistic regression test for the categorical dependent variables and p and OR. Also, in the Table are the results of the bivariate statistical test along with p and OR values as presented in Table 3 for comparison.

Table 5 demonstrates the results of multivariate analysis on several variables with a p value <0.2 for the postoperative LL variables. RC factors were not included in the multivariate analysis as they did not have a significant association with lumbar lordosis restoration (p = 0.343). Those with depressed PST of the highest fusion segment insertion had the possibility of producing normolordosis as much as 7.29 times compared to the neutral and elevated ones (p = 0.029). Where as in patients with elevated PST of the lowest fusion had the possibility of producing 8.90 times normolordosis compared to the depressed one (p = 0.007). In IC factors, patients, who did not use interbody cage, were 5.80 times more likely to

Table 3. Association of rod curvature and other factors with postoperative LL

Variables	Postoperative LL n (%)		P value	OR (95%CI)
	Normolordosis	Hypolordosis		
Rod curvature (RC)				
- Normal	16 (59.3)	11 (40,7)	Reference	
- Underbent	16 (47.1)	18 (52,9)	0,333cs	1.67 (0.59-4.76)
- Overbent	9 (64.3)	5 (35,7)	0,735cs	0,8 (0.22-2.92)
Pedicle screw sagittal trajectory (PST) highest fusion segment				
- Depressed	14 (82.4)	3 (17,6)	0,011cs	5,19 (1.34-20.02)
- Zero	0 (0)	1 (100)	>0,999f	0,55 (0.05-6.44)
- Elevated	27 (47.4)	30 (52.6)	Reference	
Pedicle screw sagittal trajectory (PST) lowest fusion segment				
- Elevated	34 (63)	20 (37)	0,021cs	3,40 (1.18-9.84)
- Depressed	7 (33.3)	14 (66.7)		
Interbody cage (IC) implant usage				
- None	25 (67.6)	12 (32.4)	0,027cs	2.86 (1.11-7.35)
- Present	16 (42.1)	22 (57.9)		
Level of fusion (LoF)	2 (1-4)	2 (1-5)	0.168mw	
- 1 level	18 (78.3)	5 (21.7)	0.006cs	4.54 (1.46-14.08)
- 2 levels*	7 (29.2)	17 (70.8)		
- 3 levels*	7 (58.3)	5 (41.7)		Reference
- 4 levels*	9 (69.2)	4 (30.8)		
- 5 levels*	0 (0)	3 (100)		

cs) Chi-square test
f) Fisher's exact test
mw) Mann-Whitney test
*) combined into a single variable for hypothetical testing purposes

Table 4. Association of rod curvature with postoperative LL on different level of fusion (LoF) group

Variables	Postoperative LL n (%)		P value	OR (95%CI)
	Normo-lordosis	Hypo-lordosis		
Rod curvature (RC) in LoF of 1-2 levels				
- Normal	10 (47.6)	11 (52,4)	Reference	
- Underbent	6 (50)	6 (50)	0.606cs	1.67 (0.59-4.76)
- Overbent	9 (64.2)	5 (35,8)	0.302cs	1.8 (0.22-2.92)
Rod curvature (RC) in LoF 3-5 levels				
- Normal	6 (100)	0 (0)	Reference	1.8 (1.22-2.92)
- Underbent	12 (54/5)	10 (45.5)	0.024f	

cs) Chi-square test
f) Fisher's exact test

produce normolordosis than those used interbody cage(p = 0.007). Patients who received LoFof 1 level had the possibility of producing normolordosis 7.79 times compared to LoF>1 level (p = 0.003). Based on the multivariate analysis above, it can be concluded that the LoF factor is the most influencing factor for lumbar lordosis restoration.

Table 5. Parameter characteristics of rod curvature and other instrumentations for preoperative LL

Variables	Preoperative LL n (%)		P value
	Normolordosis	Hypolordosis	
Rod curvature (RC)			
- Normal	15 (55.6)	12 (44.4)	Reference
- Underbent	23 (67.6)	11 (32.4)	0,333[cs]
- Overbent	7 (50)	7 (50)	0,735[cs]
Pedicle screw sagittal trajectory (PST)			
Highest fusion segment			
- Depressed	11 (64,7)	6 (35,3)	Reference
- Zero	1 (100)	0 (0)	>0.999[f]
- Elevated	18 (31.6)	39 (68.4)	0.014[cs]
Pedicle screw sagittal trajectory (PST)			
Lowest fusion segment			
- Elevated	6 (28.6)	15 (71.4)	0.208[cs]
- Depressed	24 (44.4)	30 (55.6)	
Interbody cage (IC) implant usage			
- None	17 (45.9)	20 (54.1)	
- Present	13 (34.2)	25 (65.8)	0.300[cs]
Interbody cage implant (n = 38)			
- TLIF cage	13 (36.1)	23 (63,9)	0.538[f]
- Mesh cage	0 (0)	2 (100)	
Level of fusion (LoF)	1 (1-4)	2 (1-5)	0,011[mw]
- 1 level	16 (69.6)	7 (30,4)	Reference
- 2 levels*	5 (20.8)	19 (79.2)	0.001[cs]
- 3 levels*	4 (33.3)	8 (66.7)	0.040[cs]
- 4 levels*	5 (38.5)	8 (61.5)	0.069[cs]
- 5 levels*	0 (0)	3 (100)	0.046[f]

cs) Chi-square test
f) Fisher's exact test
mw) Mann Whitney U test

DISCUSSION

Comparison of Instrumentation Parameters with Lumbar Lordosis Restoration

Lumbar hypolordosis after lumbar fusion surgery is associated with faster segmentation, adjacent spinal pain, and loss of sagittal balance with anterior body inclination, shifting of the center of the body to the anterior, and compensatory mechanisms such as cervical segment hyperextension and thoracic, knee flexion, and hip extension.[2] The compensation cascade pattern was reported inthe 1970s as a flatback syndrome. Existing evidence reported the effects of irreversible lumbar lordosis on the structure and function of the vertebral column in general. Booth et al. divided the flatback syndrome effect into 2 groups based on the sagittal balance compensation abil-

Variables	Postoperative LL n (%)		Total	nilai p	OR (95% CI)	nilai p	aOR (95% CI)
	Normo-lordosis	Hypo-lordosis					
Pedicle screw sagittal trajectory (PST) highest fusion segment							
- Depressed	14 (82.4)	3 (17.6)	17	0.011cs	5.19 (1.34-20.02)	0.029	7.29 (1.22-43.42)
- Neural*	0 (0)	1 (100)	1	>0.999f	0.55 (0.05-6.44)		
- Elevated*	27 (47.4)	30 (52.6)	58	Reference			
Pedicle screw sagittal trajectory (PST) lowest fusion segment							
- Elevated	34 (63)	20 (37)	54	0.021cs	3.40 (1.18-9.84)	0,007	8.90 (1.83-43.28)
- Depressed	7 (33,3)	14 (66,7)	21				
Interbody cage (IC) implant usage							
- No	25 (67.6)	12 (32,4)	37	0.027cs	2.86 (1.11-7.35)	0,007	5.80 (1.63-20.71)
- Yes	16 (42.1)	22 (57,9)	38				
Level of fusion (LoF)							
- 1 level	18 (78.3)	5 (21.7)	23	0.006cs		0,003	
- 2 levels*	7 (29.2)	17 (70.8)	24	Reference			
- 3 levels*	7 (58.3)	5 (41.7)	12		4.54 (1.46-14.08)		7.79 (1.98-30.61)
- 4 levels*	9 (69.2)	4 (30.8)	13				
- 5 levels*	0 (0)	3 (100)	3				

*) combined into a single variable for hypothetical testing purposes

ity which appears from the changes in parameters, such as reduced thoracic kyphosis (TK), increased pelvic retroversion, hip extension, and knee flexion.[19] Takahashi et al. completed Booth et al's statement by stating that there was also an increase in pain in the lower spine 5-9 years postoperative and an increase in degenerative processes.[19] Umehara et al. added that there was an increased risk of loosening implants in lumbar fusion surgery with posterior instrumentation which did not achieve postoperative normolordosis due to increased moment of force on the implant.[7]

Barrey et al.[3] stated that the factors affecting the lumbar lordosis restoration include operative position, release procedure, osteotomy, instrumentation techniques, and sequences and surgical approaches. Studies in the form of review of surgical recapitulation, medical records, surgery reports and implant use reports described that, in Cipto Mangunkusumo National Center Hospital, lumbar fusion surgeries with posterior instrumentation were carried out almost entirely in one operating sequence, posterior approach, prone position (prone) with the abdomen supported by kambin frame. From a review of the operation reports, it was also stated that 96% of the surgeries used a polyaxial-type pedicle screws. In almost all surgeries, a routine release procedure was carried out in the form of a spinous process resection, and sub periosteal exposure was carried out in all operations. The procedure for osteotomy, such as smith-petersen osteotomy, pedicle subtraction osteotomy, and vertebral column resection, is limited only to cases of severe lumbar kyphosis. Therefore, all cases were excluded, including non-kyphosis cases underwent osteotomy. Aside from the exclusion, the subjects had non-instrumentation factors with a homogeneous character, so that the theactual instrumentation factors that could affect lumbar lordosis restoration could be analyzed.

The validity and reliability of operating techniques in this study are said to be valid because they are carried out by orthopedic experts in the senior spine division at Cipto Mangunkusumo National Center Hospital who perform surgical techniques based on SOPs that have been applied in the world.

In this study, the median age of subjects was 57 (22-77) years old with a range of 22-77, and majority of them had lumbar pathology.[7,8,20,21,22] Female gender dominated the number of surgeries in the study with 44 patients (58.7%) compared to male with 31 patients (42.3%). This female: male ratio of 1.38: 1 is also in accordance with previous studies that showed female sex had more prevalence in a variety of lumbar pathologies, both treated conservatively and operatively.[29,30,44] We also found that there was a relationship between LL pre- and post-operative but this was not clinically valuable because what we assessed was the relationship betweeni nstrumentation factors andl umbar lordosis restoration. The absence of a relationship between the underlying lumbar pathology and the restoration of lumbar lordosis indicates compliance with previous studies which stated that lordosis restoration was released from the underlying lumbar pathology and made possible in any basic pathology.[7,21,22]

Cidambi et al. found that overbent RC allowed for achieving vertebral deformity correction by estimating the rod curvature and the loss correction due to sagittal trajectory for pedicle screw insertion.[13] However, Barrey et al. still suggested that RC according to the normal local segment LL range which diffused according to the hypothetic model of Janik et al.[7,12] gave no significant difference between RC and lumbar lordosis restoration (p=0.343). This is obviously demonstrated by the results showing unconvincing ratio of postoperative normolordosis and hyperlordosis in normal and overbent RC. On the contrary, several subjects with underbent RC achieved lumbar lordosis restoration. This may be due to correction deviation owing to other factors, such as sagittal trajectory for pedicle screw insertion and LoF. The results from previous studies actually appeared in patients who were fused with LoF>3 (p = 0.024). The more the amount of fusion means the more rods that must be curved, which indirectly increases the risk of fatigue rod. This might explain the concerns and reluctance of orthopedists to bend rods in LoF> 3, which ends in underbent RC.

According to Wang et al. monoaxial PS and axial saddle, compared to polyaxial, had better performance than both coronal and transversal planes in correcting deformity (8% and 30%, respectively).[15] Chen et al. emphasized a wise combination of monoaxial or polyaxial PS with preoperative localized LL segment –Local LL large segments reduce monoaxial PS stiffness.[14] Suk et al. reported differences in the importance of PS insertion in each vertebral body: insertion in the upper and lower segments determines correction especially in the sagittal plane, while insertion in the middle segment diffusion increases correction in all three fields simultaneously.[16] From the results of the present study, it was found that pedicle screw sagittal trajectory (PST) had a relationship with lumbar lordosis restoration, both in the highest fusion segment (p = 0.011) and the lowest fusion segment (p = 0.021). Although not directly comparing monoaxial PS with polyaxial, these results can provide an overview in the lumbar lordosis restoration plan regardless of any PS used by orthopedic experts. For example, in PS insertion in the highest fusion segment, orthopedic experts can use a monoaxial PS with depressed trajectory or polyaxial PS with a cross-neutral direction but tighten the nut with a PS head-body angle that remains depressed as according to this study, depressed PST of the highest fusion segment was 5.19 times more likely to produce normolordosis in postopeartive LL compared to the elevated one. The same applies to the PST of the lowest fusion segment, where elevation is 3.4 times more likely to produce normolordosis than depression.

Suk et al. revealed that there were differences in the importance of PS insertion in each vertebral body. Insertion in the top and inthe bottom segments determines correction, especially in the sagittal plane, whereas insertion in the diffusion middle segment increases correction in all three fields simultaneously.[16] Senkoylu et al.[23] stated that the more rigid a deformity, the more segments need to be instrumented in correction operations. However, the decision on the number of diffusion segments need to be instrumented should always return to the assessment of the orthopedist since spontaneous correction to other segments due to selective segment fusion is still possible (coupling phenomenon).[23] The results of the present study showed that there was no difference in the results between postoperative LoF LL in each level of the fusion level with the median of two levels is the same at 2 levels (p = 0.006). However, when viewed from its level category, it can be concluded that LoF 1 level was 4.54 times more likely to produce normolordosis in LL postop compared to the other LoFs. This result may be related to numerous factors that should be considered with the increasing number of fusion/instrumentation, such as RC.

The association of IC factors with lumbar lordosis restoration has been discussed repeatedly in various previous studies in which the majority stated that the combination of the use of interbody cage implants and compression of posterior instrumentation resulted in a 5° increase per segment in lordosis.[17] Barrey et al. also summarizes the rate of increment of local lordosis segments as follows: 2-11° on ALIF, 8° on PLIF, 7° on TLIF.[2] The results of this study actually show the opposite, where patients not using interbody cage have a 2.86 times greater chance to have normolordosis in postoperative LL compared to those using interbody cage (p = 0.027). We expect this to be related to other stronger factors. The results of the IC cross table with LoF showed a significant correlation between the use of IC and LoF>1 level (p = 0.029).

Another possible explanation is lack of compression in the posterior column of the rod-pedicle screw system so that the interbody cage function as fulcrum for local lordosis is not optimal.We found significant association betweeninstrumentation factors and preoperative LL in sagittal trajectory for pedicle screw insertion and LoF. The highest fusion segment of sagittal trajectory of pedicle screw insertion tended to be placed in elevation position in preoperatively polordosis (p = 0.014). LoFof 2, 3, and 5 levels were significantly associated with postoperative normolordosis (p = 0.011, p = 0.040, and p = 0.046, respectively). Thesef indings, which are contrary to the previous explanation, may have contributed to the failure of lumbar lordosis restoration.

Comparison Among Instrumentation Parameters

The development of posterior instrumentation in the rod-pedicle screw system has brought orthopedic surgeons to the advantage of correction of deformity and overcoming the short comings that existed in previous generations. Barrey et al. has emphasized the technical aspects of instrumentation, including rod curvature, rod-pedicle screw connections, and the use of interbody implants related to lumbar lordosis restoration and deformity correction. Despite having many advantages and disadvantages, all remain to the expertise of orthopedists in preparing the best construction for optimal use advantages of the rod-pedicle system.[13,14,15,16,17,18] Orthopedists need to have profound knowledge of identification of factors that increase and decrease the success of deformity correction, as intraoperative conditions are often not always in accordance with preoperative planning.

In this study, multivariate analysis of the instrumentation factors was carried out after the previous bivariate test proved the association of these factors with restoration of lumbar lordosis. RCs were not included in the multivariate analysis because they did not have a significant relationship with lumbar lordosis restoration (p = 0.343). Multivariate analysis showed that the LoFof 1 level, after being controlled by other factors, had the possibility of producing normolordosis 7.79 times more compared to LoF>1 level (p = 0.003) making the factors in the number of LoF fusion levels as the most influencing factor for lumbar lordosis restoration. This result is in line with the coupling phenomenon described by Senkyolu et al.[18] correction of some segments to the supposed configuration with fewer instruments will be followed by spontaneous correction of other segments.This advantage may also be related to the fewer number of instruments that should be controlled so as to minimize the accuracy of orthopedic experts in arranging instrumentation construction.

The next factor that should be considered is the pedicle screw sagittal trajectory,particularly if the surgeon intends to fuse many levels. Elevated pedicle screw trajectory of the lowest fusion segment had the possibility of producing 8.90 times normolordosis compared to the depressed one (p = 0.007), followed by depressed pedicle screw sagittal trajectory of the highest fusion segment, after being controlled by other factors, that produced normolordosis as much as 7.29 times compared to the neutral and the elevated ones (p = 0.029). This is essential given the limitations of the rod, which decrease in resistance to fatigue over time, making the rod face bending more.[24]

CONCLUSION

Factors that significantly affect lumbar lordosis restorationis normal rod curvaturein surgery with fusion level greater than 3, depressed pedicle screw sagittal trajectory of the highest fusion segment, elevated pedicle screw sagittal trajectory of the lowest fusion segment, and total fusion level of one level. There are differences in the relationship among thef actors affecting the restoration of lumbar lordosis, with the most influential factors being successive number of fusion levels (LoF), followed by pedicle screw sagittal trajectory of the lowest fusion segment.

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