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The Impact of Positive Sagittal Balance in Adult Spinal Deformity

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Study Design. This study is a retrospective review of 752 patients with adult spinal deformity enrolled in a multicenter prospective database in 2002 and 2003. Patients with positive sagittal balance (N = 352) were further evaluated regarding radiographic parameters and health status measures, including the Scoliosis Research Society patient questionnaire, MOS short form-12, and Oswestry Disability Index.

Objectives. To examine patients with adult deformity with positive sagittal balance to define parameters within that group that might differentially predict clinical impact.

Summary of Background Data. In a multicenter study of 298 adults with spinal deformity, positive sagittal balance was identified as the radiographic parameter most highly correlated with adverse health status outcomes.

Methods. Radiographic evaluation was performed according to a standarized protocol for 36-inch standing radiographs. Magnitude of positive sagittal balance and regional sagittal Cobb angle measures were recorded. Statistical correlation between radiographic parameters and health status measures were performed. Potentially confounding variables were assessed.

Results. Positive sagittal balance was identified in 352 patients. The C7 plumb line deviation ranged from 1 to 271 mm. All measures of health status showed significantly poorer scores as C7 plumb line deviation increased. Patients with relative kyphosis in the lumbar region had significantly more disability than patients with normal or lordotic lumbar sagittal Cobb measures.

Conclusions. This study shows that although even mildly positive sagittal balance is somewhat detrimental, severity of symptoms increases in a linear fashion with progressive sagittal imbalance. The results also show that kyphosis is more favorable in the upper thoracic region but very poorly tolerated in the lumbar spine.

Key words: adult spinal deformity, positive sagittal balance, lumbar kyphosis. **Spine 2005;30:2024–2029**

Adult spinal deformity is a broad diagnostic classification that encompasses both stable asymptomatic curves and progressive or disabling deformities. Most previous studies of adult spinal deformity have focused on the incidence of clinical symptoms or identification of radiographic findings that might prognosticate curve or symptom progression.[1–6] Although some of these studies have included a relatively large number of patients, the sample size has been too small for a meaningful analysis of diagnostic subgroups. To establish a better understanding of this diverse clinical entity, investigators have begun to apply reproducible evaluation techniques, including standardized radiographs,[7] gait analysis,[8] and validated health status measures.[9–13] Optimally, the combination of larger study populations and more standardized data collection should facilitate a more accurate characterization of the critical elements within the spectrum of adult spinal deformity.

In a recent multicenter study of 298 adults with spinal deformity, positive sagittal balance was identified as the radiographic parameter most highly correlated with adverse health status outcomes.[14] Positive sagittal balance was defined as an anterior deviation of the C7 plumb line measurement. Positive sagittal balance was more significantly associated with pain and disability than curve magnitude, curve location, or coronal imbalance. Although there is a well-recognized incidence of pain and disability with syndromes of postoperative sagittal imbalance such as flat back deformity,[15,16] this study showed a similar occurrence in unoperated deformities. Despite a relatively large study group, the data pool was still insufficient to analyze individual factors contributing to the fact that positive sagittal balance was so poorly tolerated.

Important issues to consider in evaluating patients with positive sagittal balance include the magnitude of the deformity, location of the deformity, and any interaction with concurrent coronal plane deformities or coronal imbalance. The extent of symptoms might also be related to the etiology of the positive sagittal balance, whether primary or postsurgical. The purpose of the present study was to examine patients with adult deformity with positive sagittal balance to define parameters within that group that might differentially predict clinical symptoms.

Materials and Methods

This study evaluated 752 patients, including 645 females and 107 males, with adult spinal deformity enrolled in a multi-

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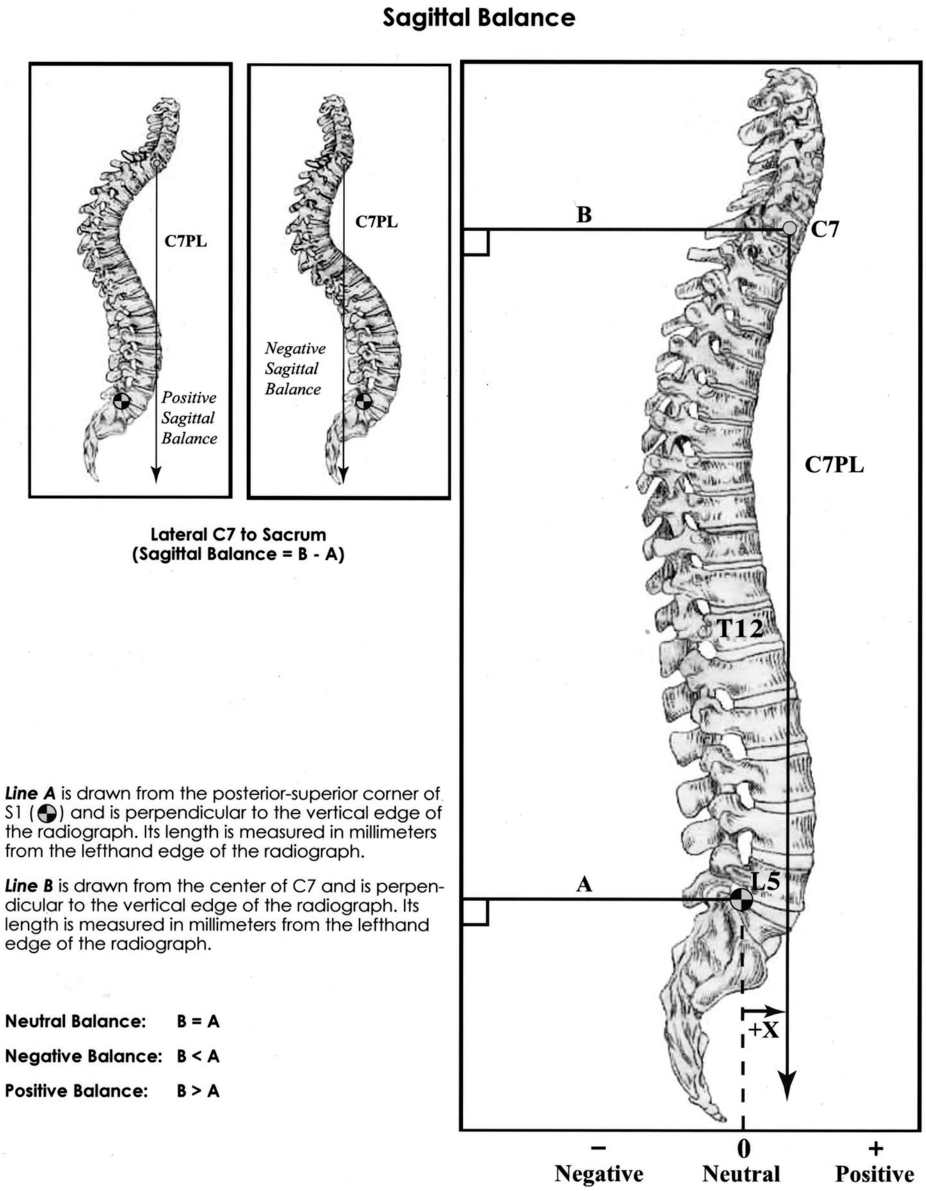

Figure 1. Technique for measurement of sagittal balance.

center prospective database in 2002 and 2003. Enrollment criteria were patients older than 18 years with scoliosis more than 30°, or any other significant coronal or sagittal plane spinal deformity. The cohort also included patients with spinal deformity who had undergone previous surgical treatment of spinal deformity and who are older than 18 months from the time of their index procedure. The baseline assessment consisted of standard demographics, including age, gender, smoking status, and history of prior spine surgery. Radiographic evaluation was performed according to an established positioning protocol[7] for anteroposterior and lateral 36-inch standing radiographs. Patient self-assessment measures of health status collected were the Scoliosis Research Society patient questionnaire (SRS-29), MOS short form-12 (SF-12), and Oswestry Disability Index (ODI).

Radiographic measures of deformity were recorded based on a standardized manual of measurement techniques. Coronal plane parameters included major and minor curve location, curve magnitude by Cobb angle, and coronal imbalance by C7 plumb line deviation. Apical rotation was assessed by Pedriolle technique and lateral listhesis by magnitude of offset. The sagittal balance was determined based on the deviation of the C7 plumb line, originating at the middle of the C7 vertebral body, from the posterior superior endplate of S1 (Figure 1). Positive sagittal balance was defined as an anterior deviation of the C7 plumb line. Sagittal Cobb angles from T2–T5 (high thoracic), T5–T12 (thoracic), T12–L2 (thoracolumbar), and T12 to the sacrum (lumbar) were measured.

Positive sagittal balance was initially assessed as an independent variable. Analysis was performed using the Spearman rank order correlation coefficients. In addition, statistical software was used to classify patients into 10 relatively equal groups of increasingly positive C7 plumb line deviation to show any effect of progressive positive sagittal balance.

The region of highest sagittal deformity was identified in each patient. An abnormally lordotic curve was defined as being one standard deviation below the mean sagittal Cobb angle for that region. A normal curve was within one standard deviation of the mean sagittal Cobb angle, and an abnormally kyphotic curve was higher than one standard deviation above the mean sagittal Cobb angle. This analysis was performed to correlate the region of the spine, giving rise to the sagittal plane

Table 1. Correlation Between Positive Sagittal Balance and Health Status Scores Using SF-12, SRS-29, and ODI Measures

Measure	Spearman rho	No. Cases	P
SF-12v2 PCS	−0.292	284	0.000001
SF-12v2 MCS	−0.075	284	0.206 (NS)
SRS pain	−0.207	351	0.0000917
SRS activity	−0.247	350	0.0000029
SRS total	−0.264	350	0.000001
Oswestry overall	0.281	349	0.000001

MCS = mental health composite score; NS = not significant.

deformity with the severity of any resultant clinical symptoms. It is noteworthy that these comparisons were made in a group of patients, all who had a positive sagittal balance.

Patient reported health status measures, including the SF-12, SRS-29, and ODI, were analyzed to determine a relationship between type, location, or magnitude of deformity, and overall health status, pain, and function. Other potentially confounding variables, including history of previous surgery, coronal balance, smoking, age, and body mass index, were also assessed.

■ Results

A total of 352 patients with positive sagittal balance were identified. There were 289 females and 63 males. The patients had a mean age of 54 years, and 55% of them had undergone prior spinal surgery. Of the patients, 11% were cigarette smokers. The primary diagnosis was adult idiopathic scoliosis in 30.4% and adult *de novo* scoliosis in 9.4% of cases. Kyphotic deformities, including fixed sagittal imbalance, posttraumatic kyphosis, congenital kyphosis, and Scheuermann kyphosis, comprised 20.7% of cases. Combined deformities such as junctional degeneration and iatrogenic imbalance comprised 14% of cases. The remaining 25.5% had miscellaneous diagnosis, including neuromuscular scoliosis, spinal stenosis, or congenital scoliosis. Diagnosis was unidentified in 11.1% of cases.

Positive sagittal balance based on C7 plumb line deviation ranged from 1 to 271 mm (mean 57.7 ± 51.2). The Spearman rank order correlation coefficient analysis showed a high degree of correlation between positive sagittal balance and adverse health status scores for SF-12 physical health composite score (PCS) ($P < 0.000001$), SRS-29 pain domain ($P < 0.0009$), SRS-29 activity domain ($P < 0.000003$), SRS-29 total ($P < 0.000001$), and ODI ($P < 0.000001$) questionnaires (Table 1). The correlation with SF-12 mental health composite score was not statistically significant.

There was clear evidence of increased pain and decreased function as the magnitude of positive sagittal balance increased. All measures of health status (SF-12, SRS-29, and ODI) showed significantly poorer scores as C7 plumb line deviation increased based on analysis of variance and Student-Newman-Keuls *post hoc* testing (Figure 2). Comparison across the entire range of curve location showed that a more distal region of maximal

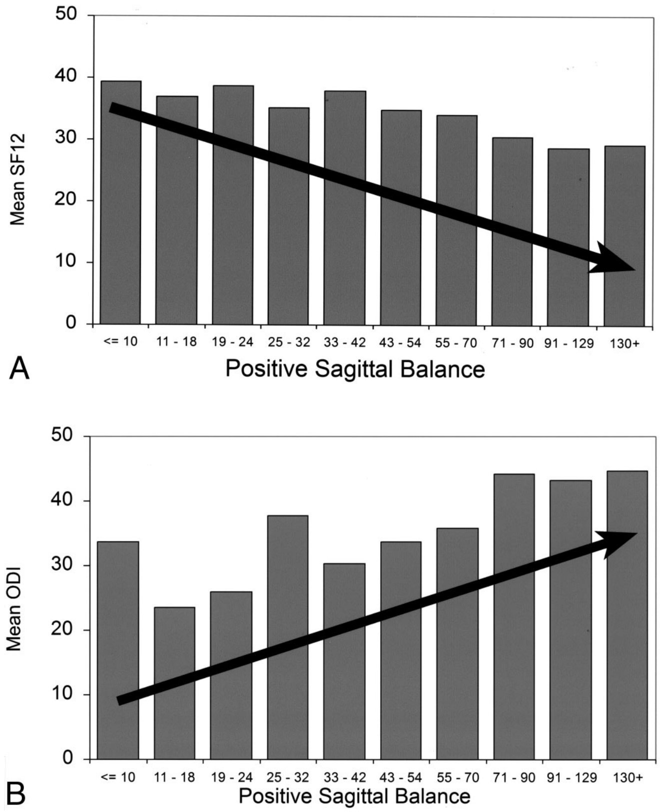

Figure 2. Deterioration in health status measures, including SF-12 physical health composite score (**A**) and ODI (**B**), were shown with progressive positive sagittal balance.

kyphosis generated higher disability on ODI ($P < 0.05$) (Figure 3). There was no statistically significant relationship between any single area of highest kyphosis and SF-12 PCS.

Sagittal Cobb angle measurement for each region of the spine was analyzed to assess the importance of localized regions of deformity. Mean regional sagittal Cobb measures were 12.7° ± 13° in the high thoracic region, 37.6° ± 24.3° in the thoracic region, 11.6° ± 17.2° in the thoracolumbar region, and −29.5° ± 33° in the lumbar region. Within each measured region, the magnitude of sagittal deformity was characterized as lordotic, normal, or kyphotic (Table 2). In the high thoracic region (T2–T5),

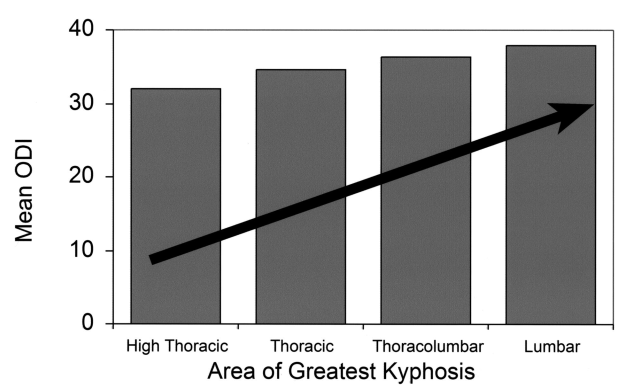

Figure 3. Deterioration in ODI score was noted as the region of maximal kyphosis progressed from high thoracic to lumbar spine.

Table 2. Regional Sagittal Cobb Angle Measures with Extremes of Regional Kyphosis or Lordosis Identified

	Classification	No. of Cases	Mean Angle	Standard Deviation	Minimum	Maximum
Sagittal Cobb T2–T5	Lordotic	58	−3.03	7.36	−44	0
	Normal	245	9.72	4.58	1	19
	Kyphotic	49	26.27	6.24	20	45
Sagittal Cobb T5–T12	Lordotic	43	2.6	10.38	−36	11
	Normal	256	29.3	10.41	12	50
	Kyphotic	46	66.63	13.78	51	121
Sagittal Cobb T12–L2	Lordotic	59	−16.95	6.01	−36	−11
	Normal	230	4.15	8.43	−10	19
	Kyphotic	52	29.1	6.81	20	49
Sagittal Cobb T12–sacrum	Lordotic	41	−74.34	8.74	−97	−65
	Normal	261	−40.62	13.37	−64	−12
	Kyphotic	45	11.58	21.92	−11	79

group mean values were 9.7° for normal, −3.0° in the lordotic group, and 26.3° in the kyphotic group. In the thoracic region (T5–T12), the normal mean sagittal Cobb was 29.3°, whereas patients with lordosis had a mean of 2.6°, and those with kyphosis had a mean of 66.6°. In the thoracolumbar region (T12–L2), the normal mean sagittal Cobb was 4.2°, whereas lordotic curves had a mean of −17.0°, and kyphotic sagittal curves had a mean of 29.1°. In the lumbar region (T12–S1), the normal sagittal Cobb had a mean of −40.6° as compared to the mean of −74.3° in the most lordotic curves and mean of 11.6° for kyphotic curves.

Evaluation based on excessive regional deformity was performed. Patients classified as kyphotic in the lumbar region had significantly more disability (SRS-29 and ODI, $P < 0.05$) than those with normal or lordotic lumbar sagittal Cobb measures (Figure 4). Although the patients with highest lumbar kyphosis did also have a slightly higher mean C7 plumb line deviation, neither parametric (analysis of variance) nor nonparametric testing showed a statistically significant association between C7 plumb line deviation and lumbar kyphosis. In the high thoracic region, patients classified as kyphotic had significantly less pain (SRS-29, $P < 0.05$) and disability (SRS-29 and ODI, $P < 0.05$) than those with normal or lordotic high thoracic sagittal Cobb measures (Figure 5). There was no significant correlation between thoracic or thoracolumbar sagittal Cobb deformity and any of the health status measures.

Evaluation of potentially confounding variables revealed that ODI varied significantly with both smoking status and body mass index. There was no variation based on age, surgical history, or concurrent coronal imbalance. None of these potentially confounding variables interacted significantly with positive sagittal balance and the other measures of health status outcome.

Discussion

Adult spinal deformity is a complex problem that may range from relatively asymptomatic to severely disabling. Unlike adolescent idiopathic scoliosis, our experience in prognosticating important variables such as progression of deformity, development of symptoms, and response to treatment is largely anecdotal. Based on changing demographics and improved surgical and nonsurgical treatment options, an increasing number of patients with adult deformity are seeking medical care. Optimal treatment requires further definition of critical radiographic parameters and correlation with reproducible measures of health status.

The importance of sagittal plane deformity has been well documented, particularly with reference to postsurgical flat back syndromes and posttraumatic kyphosis.[15,17] Symptomatic deformity is often unresponsive to

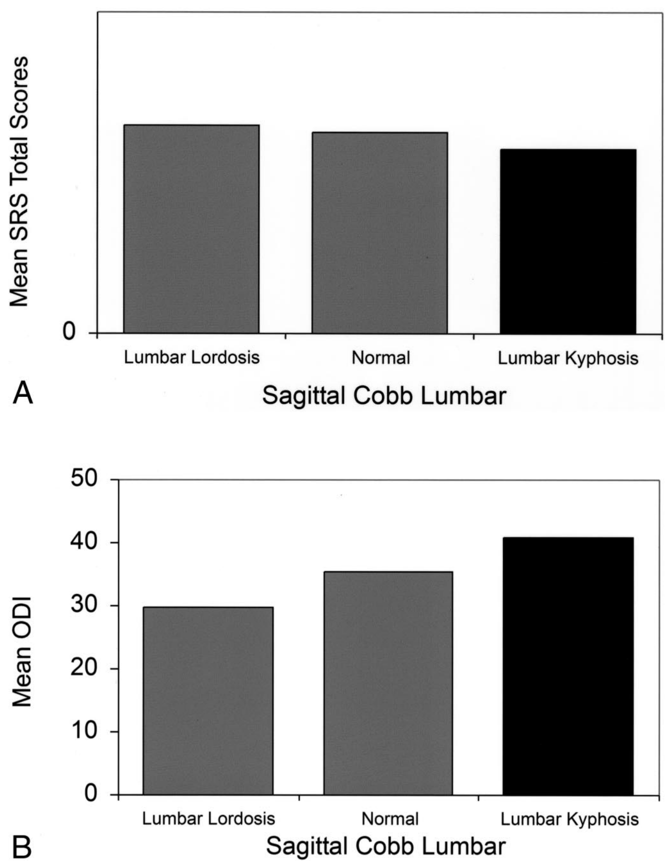

Figure 4. Significantly higher disability was noted in patients with increased lumbar kyphosis on both SRS-29 (**A**) and ODI (**B**) measures.

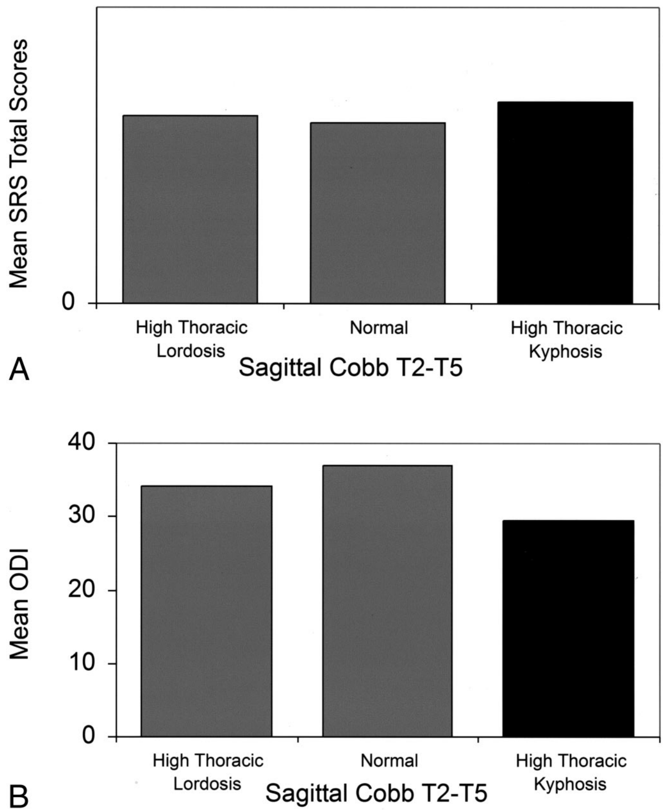

Figure 5. Less pain and disability based on SRS-29 scores (**A**) and ODI (**B**) were noted in patients with increased high thoracic kyphosis.

nonsurgical treatment, and surgical treatment is complex.[18,19] Several studies have shown that adequate restoration of sagittal plane alignment is necessary to improve significantly clinical outcome and avoid subsequent pseudarthrosis.[13,16,18] Positive sagittal balance has also been identified as the radiographic parameter most highly correlated with adverse outcome measures in unoperated adult spinal deformity.[14]

Despite this literature, sagittal balance, like many radiographic measures, is still an inconsistent predictor of clinical symptoms. Studies in asymptomatic volunteers have shown that progressive positive sagittal balance is associated with normal aging.[20,21] In some instances, effective compensation mechanisms may develop in patients, which generate a more acceptable functional sagittal balance. Although some of these patients eventually decompensate, more sophisticated evaluation techniques, such as gait analysis, may be necessary to understand better the progression of these deformities.

In this study, 352 patients were analyzed to define relevant subgroups within the important but broad group of patients with adult deformity with positive sagittal balance. This study shows that although even mildly positive sagittal balance is somewhat detrimental, severity of symptoms increases in a linear fashion with progressive sagittal imbalance. The results also show that kyphosis is more favorable in the upper thoracic region but very poorly tolerated in the lumbar spine. Although it seems intuitively possible that the adverse consequences of lumbar kyphosis and positive sagittal balance might simply be 2 different observations of the same underlying event, our analysis did not support this presumption. The lack of statistical correlation between C7 plumb line deviation and lumbar kyphosis suggests that, at least to some degree, these parameters behave independently.

These findings emphasize the importance of thoroughly accessing sagittal plane alignment in the treatment of spinal deformity. Although the response to nonoperative treatment has not been systematically studied, this research suggests that methods directed at the improvement in standing balance might be beneficial. With surgical treatment, maintenance or restoration of lumbar lordosis appears to be critical, particularly for patients with a positive sagittal balance before surgery. Most important, the study shows the vital role of reproducible radiographic and clinical outcome measures such that our clinical experience can lead to more effective treatment paradigms for patients with adult deformity.

■ Key Points

- Severity of symptoms increases in a linear fashion with progressive positive sagittal balance.
- Relative kyphosis is very poorly tolerated in the lumbar spine.
- Use of reproducible radiographic and clinical outcome measures facilitates the development of more effective treatment paradigms for patients with adult deformity.

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