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ORIGINAL ARTICLE

Clasped position for measurement of sagittal spinal alignment

Hidekazu Suzuki · Kenji Endo · Jun Mizuochi · Hiroto Kobayashi · Hidetoshi Tanaka · Kengo Yamamoto

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Abstract Lateral whole-spine radiography is a useful tool in the management of spinal deformity, but the most appropriate arm position during radiography has yet to be determined. In this prospective study, we evaluated 26 adult volunteers and 22 patients with lumbar spinal canal stenosis. Lateral whole-spine radiographs were acquired in the most stable and relaxed position while the subjects were standing with their arms extended and their hand gently clasped in front of the trunk (clasped position). The following parameters were measured: sagittal vertical axis (SVA), lumbar lordotic angle (LLA), pelvic angle (PA), pelvic lordosis angle (PRS1), pelvic tilt (PT), and pelvic incidence (PI). The reliability of measurements was assessed by interclass correlation coefficients. The SVA was slightly positive in volunteers. LLA, PA, PRS1, PT, and PI were compatible with standard normal values. The results showed "almost perfect agreement" with regard to intra- and interobserver reliability. The clasped position can be used effectively and reliably for measurement of sagittal spinal alignment for the lumbar region in adults.

Keywords Sagittal spinal alignment · Arm position · Sagittal vertical axis · Clasped position

Introduction

Sagittal spinal alignment is an important aspect for the clinician to consider in the evaluation and treatment of spinal deformities. Global sagittal spinal alignment is described by a plumb line dropped from the center of the C7 vertebral body [8]. Studies in normal adult subjects indicate that the typical sagittal vertical axis (SVA) is neutral or slightly positive [9, 15]. Aging is associated with a decrease in spinal mobility and lumbar lordosis, as well as pelvic backtilt and forward bending trunk [4, 5, 18]. Optimally, the standing position during radiographic acquisition is functionally representative of relaxed standing posture. Though relaxed standing is a functional and easily assumed position, the presence of the arms on the sides prohibits adequate radiographic visualization of the spinal landmarks. Standing with the arms forward flexed to allow radiographic visualization of the spine results in negative shift of SVA [3, 6, 15, 21]. There is no general agreement on the most appropriate arm position when taking a lateral whole-spine radiograph.

The aim of the present study was to evaluate the reliability of our technique, clasped position, in the measurement of spinal sagittal alignment, and in addition, to determine if the position represents a functional stance for accurate sagittal balance evaluation.

Materials and methods

This prospective study included 26 adult volunteers (15 males and 11 females) and 22 consecutive patients with lumbar spinal canal stenosis (LSCS) (12 males and 10 females). The average age of volunteers was 32.7 years (range 22–51) and for patients was 62.0 years (range 25–82). All human subjects had lateral long cassette radiographs of the whole-spine performed in the most stable and relaxed position while the subjects were standing with their arms extended and their hand gently clasped

H. Suzuki (✉) · K. Endo · J. Mizuochi · H. Kobayashi · H. Tanaka · K. Yamamoto
Department of Orthopedic Surgery, Tokyo Medical University, 6-7-1 Nishi-Shinjuku, Shinjuku-ku, Tokyo 160-0023, Japan
e-mail: hidekadu@hotmail.com

in front of the trunk (clasped position) (Fig. 1). To evaluate radiographic parameters in the most natural upright posture of each subject, the position of the lower limbs was not standardized. Two radiographs were taken 1–4 weeks apart. The radiographs were measured twice by the first observer (HS, experienced spine surgeon), then independently measured at other days by a second observer (JM, resident, orthopedic surgery).

On unmarked X-rays, the following radiographic parameters were measured manually as described previously [7, 11, 14, 22]: SVA (defined as the distance between the C7 plumb line and the posterior superior corner on the superior margin of S1), lumbar lordotic angle (LLA, the angle from the upper endplate of L1 to the lower end plate of L5), pelvic angle (PA, the angle between the line connecting the posterior superior corner of S1 to the bicoxofemoral axis and the vertical plane), pelvic lordosis angle (PRS1, the angle between the line connecting the posterior superior corner of the S1 to the bicoxofemoral axis and the upper endplate of S1), pelvic tilt (PT, the angle between the line connecting the midpoint of the sacral plate to the axis of the femoral heads, and the vertical), and

Fig. 1 Clinical picture (**a**) and lateral whole-spine radiograph (**b**) in clasped position

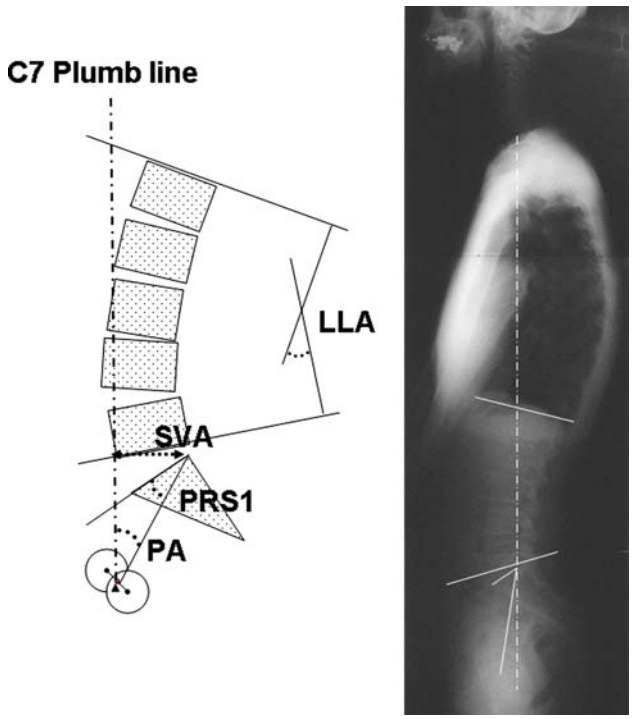

Fig. 2 Measurements of spinal and pelvic sagittal balance. *SVA* sagittal vertical axis, *LLA* lumbar lordotic angle, *PA* pelvic angle, *PRS1* pelvic morphologic angle

pelvic incidence (PI, the angle between the line perpendicular to the sacral plate at its midpoint and the line connecting the point to the middle axis of the femoral heads) (Figs. 2, 3).

Values were expressed as mean ± SD. The measurements were tabulated and analyzed using Excel (Microsoft, Redmond, WA). The reliability of measurement was analyzed by using intraclass correlation coefficients (ICC) and 95% confidence interval (95% CI) [19]. The ICC values were interpreted according to the Landis-defined categories for the interpretation of the kappa [13]; values from 0 to 0.2

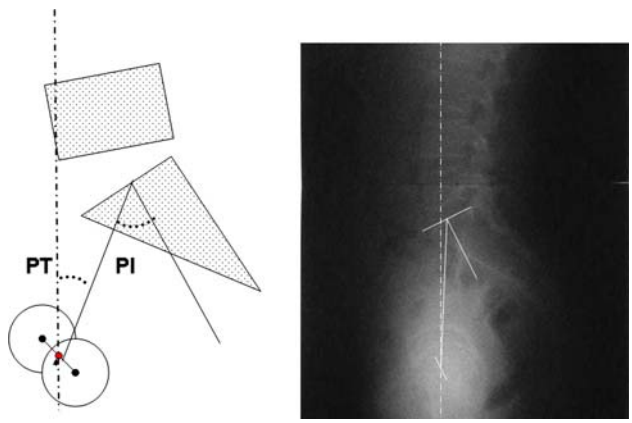

Fig. 3 Measurements of spinal and pelvic sagittal balance. *PT* pelvic tilt, *PI* pelvic incidence

Table 1 Sagittal parameters for adult volunteers and patients with lumbar spinal canal stenosis (LSCS)

	Adult volunteers	Age-adjusted standard values to adult volunteers	Patients with LSCS
n	26		22
Age (years)	32.7 ± 8.3		62.0 ± 15.4
SVA (mm)	2.3 ± 18.6	6.1 ± 24.1[a]	32.8 ± 41.5
		14 ± 19[b]	
LLA (°)	46.8 ± 11.5	44.3 ± 12.5[a]	26.2 ± 10.9
PA (°)	17.9 ± 5.8	19.4°[c]	26.3 ± 9.8
PRS1 (°)	37.1 ± 9.9	35.5°[c]	34.6 ± 8.9
PT (°)	11.3 ± 9.4	10.8 ± 5.5[d]	21.0 ± 9.8
PI (°)	46.3 ± 11.1	46.7 ± 8.7[d]	49.7 ± 10.4

Values are expressed as mean ± SD

[a] Matsuoka et al. [16] (in clasped position)

[b] Aota et al. [1] (in relaxed position with arms-at-side)

[c] Ochiai et al. [17]

[d] Kanemura et al. [12]

represent slight agreement, 0.2 to 0.4 are fair agreement, 0.4 to 0.6 indicate moderate agreement, 0.6 to 0.8 show substantial agreement, and 0.8 to 1.0 represent almost perfect agreement.

The study protocol was approved by the Human Ethics Review Committee of Tokyo Medical University and a signed consent form was obtained from each subject.

Results

The SVA was slightly positive in normal adult subjects (2.3 ± 18.6 mm), which was similar to the reported age-matched normal values [1, 16, 17]. The LLA, PA, PRS1, PT, and PI of the normal subjects were also similar to the standard values matched by age for Japanese (Table 1). Patients with LSCS had larger SVA, smaller LLA, larger PA, and similar PRS1, compared with the respective values of the adult volunteers (Table 1), and these results were comparable with our previous report [20].

The ICC value of SVA, LLA, PA, PRS1, PT, and PI were as follows: intrarater reliability of normal subjects 0.84 (95% CI 0.68–0.92), 0.92 (95% CI 0.84–0.96), 0.89 (95% CI 0.77–0.95), 0.92 (95% CI 0.83–0.96), 0.97 (95% CI 0.94–0.99), and 0.97 (95% CI 0.93–0.99), intrarater reliability of patients 0.86 (95% CI 0.64–0.97), 0.91 (95% CI 0.80–0.96), 0.86 (95% CI 0.78–0.90), 0.90 (95% CI 0.77–0.96), 0.93 (95% CI 0.85–0.97), and 0.94 (95% CI 0.86–0.98), interrater reliability of volunteers 0.95 (95% CI 0.90–0.98), 0.97 (95% CI 0.94–0.99), 0.93 (95% CI 0.85–0.97), 0.98 (95% CI 0.96–0.99), 0.97 (95% CI 0.88–0.97), and 0.96 (95% CI 0.92–0.98), respectively (Tables 2, 3). The intra- and interobserver agreement rates with measurements in clasped position were high, i.e., all results showed 'almost perfect agreement'.

Table 2 Intrarater reliability of measurements

	Adult volunteers		Patients with LSCS	
	ICC[a]	95% CI[b]	ICC[a]	95% CI[b]
SVA	0.84	0.68–0.92	0.86	0.64–0.97
LLA	0.92	0.84–0.96	0.91	0.80–0.96
PA	0.94	0.87–0.97	0.86	0.78–0.90
PRS1	0.92	0.83–0.96	0.90	0.77–0.96
PT	0.97	0.94–0.99	0.93	0.85–0.97
PI	0.97	0.93–0.99	0.94	0.86–0.98

[a] ICC: intraclass correlation coefficients

[b] 95% CI: 95% confidence interval

Table 3 Interrater reliability of measurements

	Adult volunteers	
	ICC[a]	95% CI[b]
SVA	0.95	0.90–0.98
LLA	0.97	0.94–0.99
PA	0.93	0.85–0.97
PRS1	0.98	0.96–0.99
PT	0.97	0.88–0.97
PI	0.96	0.92–0.98

[a] ICC: intraclass correlation coefficient

[b] 95% CI: 95% confidence interval

Table 4 Reliability of sagittal parameters in the clasped position and other positions

	Clasped position		90° of shoulder flexion		45° of shoulder flexion	
	Intrarater	Interrater	Intrarater	Interrater	Intrarater	Interrater
SVA	0.84	0.86	0.52–0.96[a]	0.78–0.94[a]	N/A	N/A
LLA	0.92	0.91	0.95–0.98[a]	0.97[a]	0.88[c]	0.97[c]
PA	0.94	0.86	0.96–0.99[a]	0.98–0.99[a]	N/A	N/A
PRS1	0.92	0.90	0.95[b]	0.88[b]	N/A	N/A
PT	0.97	0.93	N/A	N/A	0.99[c]	0.99[c]
PI	0.97	0.94	0.98[b]	0.90[b]	0.99[c]	0.98[c]

[a] Jackson and Hales [7]

[b] Jackson et al. [11]

[c] Dimar II et al. (computer-assisted) [2]

N/A: data not available/reported

Discussion

In the present study, the SVA values of adult volunteers were not negative in clasped position, and the spinopelvic parameters were similar to the normal values for age-matched Japanese [1, 12, 16, 17], with high reliability comparable to the findings of other studies [1, 7, 11] (Table 4). Data of patients with LSCS also showed high agreement (Table 2).

When taking a lateral whole-spine radiograph, the best body position is close to the relaxed standing position with good reliability and good visualization of the spine. Several studies have examined the effects of arm position on radiographic measurements of sagittal spinal alignment [3, 6, 15, 21]. Vedantam et al. [21] observed differences in SVA at 30° and 90° of shoulder flexion, and they recommended the position of 30° shoulder flexion because of a less negative shift in SVA. The negative shift in SVA was a consistent finding when a subject stood with 45° shoulder flexion relative to relaxed standing [15]. When subjects have a designated standing base to position the feet and an arm support to standardize their arm flexion angle, the positioning does not standardize the distribution of weight or center of mass, which may affect sagittal parameters [3]. While Faro et al. [3] proposed fists on clavicles position, which offered less negative SVA than 45° of shoulder flexion, Aota et al. [1] reported a negative shift of SVA even in fists on clavicles position compared to relaxed standing with arms-at-side. Raising arms with shoulder flexion could theoretically result in a posterior shift of the trunk to counterbalance the lever arm [21]. Elbow flexion with placement of both fists on the ipsilateral clavicles could be accompanied by some shoulder flexion, which causes a negative shift of SVA. In the present study, the clasped position offered slightly positive value for SVA, which is compatible with the value in relaxed standing with arms-at-side [1]. The spinopelvic parameters measured at the clasped position were similar to the normal values for age-matched Japanese subjects [1, 12, 13].

The reliability of the SVA measurement was questioned by Jackson et al. [10] because of poor visualization of the C7 vertebra on lateral whole-spine radiographs with 90° of shoulder flexion. On the other hand, Horton et al. [6] reported that the 90° position was inferior to the fists on clavicles position for visualizing the vertebral landmarks. Although we are under the impression that the visualization of key vertebral landmarks with the clasped position is comparable to other arm positions, further studies are needed. However, the reliability for SVA is generally high, suggesting that the variability lies in the actual sagittal balance rather than measurement of the SVA [4, 6, 21].

In conclusion, for evaluation of sagittal spinal alignment for the lumbar region in adults, the clasped position is comparable to relaxed standing position and can be easily achieved without added equipment, with high reliability.

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