Journal of Spine
ISSN: 2165-7939

Brodano et al., J Spine 2015, 4:6
DOI: 10.4172/2165-7939.1000269

Research Article Open Access

Adult Scoliosis: A Retrospective Analysis of the Correlation between Radiological Parameters and Clinical Outcomes

Giovanni Barbanti Brodano*, Lisa Babbi, Marco Girolami, Alessandro Gasbarrini, Stefano Bandiera, Silvia Terzi, Riccardo Ghermandi, Cristiana Griffoni and Stefano Boriani

Department of Oncological and Degenerative Spine Surgery, Istituto Ortopedico Rizzoli, Bologna, Italy

Abstract

Background: According to current literature, surgical management of Adult Scoliosis (AS) can benefit selected patients, especially when concurrent sagittal deformities are balanced.

This retrospective study analyzes this hypothesis by matching clinical and radiological results after AS surgical correction in selected cases. The study also analyzes the possible correlation between mechanical failure events and residual postoperative sagittal imbalance.

Materials and Methods: 12 patients, average aged 57 years, underwent AS surgical correction. Today, these patients have a follow up range from 24 months to 71 months (average 53.6 months).

Values related to scoliotic curve, lordosis, kyphosis and pelvic parameters (Pelvic Incidence, PI; Pelvic tilt, PT; Sacral Slope, SS; Sagittal Vertical Axis, SVA) were measured and registered pre-operatively and post-operatively.

Patients were examined at 3, 6, and 12 months after surgery and then every year through outpatient visits, where the degree of patient satisfaction was evaluated. Patients also received before the surgery and at 3, 6, 12 months follow up auto-administered validated questionnaires (Visual Analog Score, Oswestry Disability Index, Quality of Life) for the evaluation of clinical outcomes. Regarding patients' responses to these questionnaires we have a follow up range of 3-20 months (average 8.4 months). Mechanical failure complications were also registered during the entire follow up period.

Results: Radiological results: scoliosis was corrected on average 27°; kyphosis changed in 10 patients, by an average increase of 11.33° in 6 patients and by an average reduction of 12.7° in 4 cases. The average correction of lordosis, compared to an ideal reference value, was 61.94% (41.89 – 86.42%). A pathological pelvic retroversion (PT>20°) affected 10 patients out of 12. After surgery this compensation vanished in 3 patients while it remained >20° in 7. Postoperative plumb line analysis showed that only five patients had a balanced postoperative profile.

Clinical results: Improvement of clinical conditions and patient's satisfaction were obtained in 9 out of 12 patients.

Mechanical Failure: in our series, 4 patients (33%) experienced hardware failure.

Statistical analysis was performed using Kendall's correlation test and Pearson's correlation test.

Conclusions: This retrospective study evaluates medium and long term adult scoliosis surgical results, by matching clinical outcomes and postoperative balance. The complete rescue of physiological balance was demonstrated to reduce disability in all cases except one; according to our experience, also a partial reduction of the deformity could improve the clinical patient's condition, especially in cases where deformity and disability were severe before the surgery. Statistically analysis showed a correlation between kyphosis changes following surgery and clinical outcomes trend.

Despite the small sample size, we also observed that residual imbalance favored early mechanical hardware failure, confirming the trend reported in the literature.

Keywords: Adult scoliosis; Surgical correction; Sagittal parameters; Clinical outcomes; Mechanical hardware failure

Background

In the seventies Vanderpool points out that the prevalence of scoliosis in people above 50 years was about 6% [1]. Later on other Authors have estimated the prevalence of scoliosis on routine chest radiographs in intravenous pyelogram to range from 1.4 to 9% [2-4]. Although nowadays the prevalence of scoliosis in the adult population has been reported as ranging from 2% to 32%, recent studies targeting elderly volunteers showed a prevalence of more than 60% [3-8]. Considering an increasing aging population and increasing attention to quality of life issues, adult scoliosis is becoming a considerable health care concern. Aside from the aesthetic considerations of scoliosis in the adult, significant pain and disability can develop [5]. Indeed, pain and disability determine the treatment choice for AS patients, as coronal plane Cobb angle guides decision making in adolescent idiopathic scoliosis (AIS). For these reasons the request of surgical procedures for AS is increasing despite high risk rates, difficult goal achievement, perioperative complications and high mechanical failure rate, making the surgical treatment of these complex patients still challenging.

Clinical and radiological evaluation of adult deformities can rule

***Corresponding author:** Giovanni Barbanti Brodano, Department of Oncological and Degenerative Spine Surgery, Istituto Ortopedico Rizzoli, Via G.C. Pupilli 1, 40136 Bologna, Italy, Tel: +39 051 636 6705; E-mail: giovanni@barbantibrodano.com

Received November 05, 2015; **Accepted** December 10, 2015; **Published** December 12, 2015

Citation: Barbanti Brodano G, Babbi L, Girolami M, Gasbarrini A, Bandiera S, et al. (2015) Adult Scoliosis: A Retrospective Analysis of the Correlation between Radiological Parameters and Clinical Outcomes. J Spine 4: 269.doi:10.4172/2165-7939.1000269

out the specific features of each patient to identify the drivers of pain and disability and the compensatory mechanisms.

In order to understand and correct the deformity, it is priority the radiographic evaluation of deformity in sagittal plane rather than in coronal plane and to restore physiological spino-pelvic parameters is the subsequent goal.

In this retrospective study we analysed the clinical and radiological results after surgical correction, in a series of patients affected by AS.

The aim of this study was to evaluate the relationship between the deformity correction and the activities of daily living and the quality of life. Sagittal balance, lumbar lordosis, PT and PI has been compared with postoperative changes in pain and disability.

The second endpoint was to investigate the trend of mechanical complications in comparison to deformities correction. The hypothesis was that poor deformity correction leads more frequently to early mechanical failure than sagittal balance achievement.

Methods

In this retrospective analysis we evaluated 12 selected patients suffering from Adult Scoliosis (AS); all the deformities were treated surgically from December 2009 to August 2013.

These 12 patients were selected from an open group of 30 patients affected by AD. Inclusion criteria were: 18 years old or older patients, diagnosis of AS as a consequence of Adolescent Scoliosis of the Adult (ASA) or De novo Degenerative Scoliosis (DDS) [6,7] minimum 6 months conservative treatment failure; radiographic studies were antero-posterior and lateral free-standing X-ray including the C7-pelvis range; preoperative and postoperative clinical questionnaires completion; minimum 3 months follow up. All patients were treated by the same surgical team. Patient's general data are reported in Table 1. Today, these patients have a follow up range from 24 months to 71 months (average 53.6 months).

Patients with neuromuscular disease, trauma, spinal infections, ankylosing spondylitis, or tumors were not included in this study. Previous surgery hasn't been considered as exclusion criteria.

The final selected group was composed by 12 patients, 3 males and 9 females average aged 57.3 years.

Six months conservative treatment failure was one of the key points for surgery admission: local heat, non-narcotic analgesics and bracing aid were useful to improve symptoms but they didn't prevent curve progression. Corticosteroid injections in the form of nerve root blocks, facet injections and epidural steroid injections were also executed because of considerable value in the arsenal of conservative management [8].

Code	Patient	Age	Sex	Previous Surgery	Scoliosis Type	Main Curve
1	C.P.	70	F	NO	ASA	T-L
2	D.F.C.	59	F	YES	DDS	L
3	D.F.A	55	F	YES	DDS	NCC
4	D.S.S.A.	42	F	YES	DDS	L
5	M.M.	60	F	NO	DDS	L
6	Ma.L.	49	F	NO	DDS	L
7	Me.L.	56	F	NO	DDS	L
8	M.O.	72	F	YES	DDS	L
9	P.L.	59	F	NO	DDS	NCC
10	R.C.	57	M	NO	ASA	T-L
11	R.E.	66	M	NO	DDS	NCC
12	V.M.	40	M	NO	DDS	NCC

Abbreviations: ASA: Adolescent Scoliosis of the Adult; DDS: De novo Degenerative Scoliosis; T-L: thoraco-lumbar; L: lumbar; NCC: No Coronal Curve

Table 1: Demographic data of the patients and preoperative characterization.

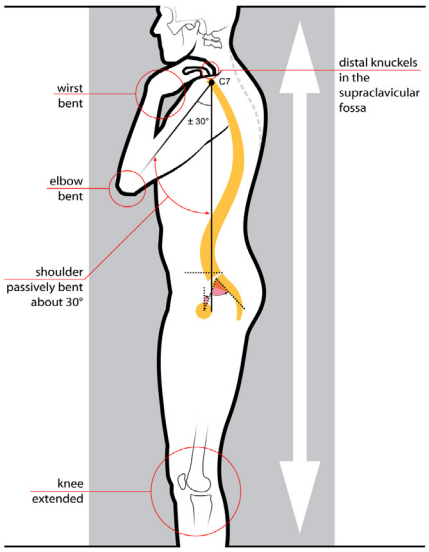

Figure 1: Clavicle position assumed by the patient during X-ray analysis performed for measurements with Surgimap Spine software. In this position the patient is standing and fully flexes the elbows with the hands in a relaxed fist, wrists flexed, placing the proximal interphalangeal (PIP) joints comfortable up into the supraclavicular fossae, thus passively flexing the humerus forward. Hands are centered in the fossae, midway between the suprasternal notch and acromion. This comfortable position allows good visualization of C7, T2 and T12 landmarks. The radiogram finally should include the skull, odontoid, hip and femur.

Radiological evaluation

Preoperative and postoperative panoramic standing radiographs from each patient were evaluated through Surgimap Spine Imaging Software (www.surgimap.com, provided by Nemaris Inc., New York, NY) [9]. This is free software integrating spine-related measurements and tools for surgical planning in combination with data from the published literature; it also offers a graphical method for the surgical planning of osteotomies.

For measurements with Surgimap Spine software all the images should include the whole spine on the AP plane, the spine and the pelvis in the sagittal projection. During X-ray all patients were standing in the clavicular position [10], looking straight ahead with elbows bent and knuckles in the supraclavicular fossa bilaterally (Figure 1).

As a retrospective study, one of the most restrict parameter in the patient selective process was preoperative and postoperative eligible imaging recruitment: in most cases the standing X-ray was not suitable for pelvic parameters evaluation with Surgimap Spine software and this finally became an important exclusion criteria. The 12 patients included in this study had preoperative and postoperative free-standing antero-posterior and lateral radiographs of the spine including C7-pelvis gap and femoral heads.

From standing antero-posterior radiographs the scoliotic curve (structured and not) was determined. In 6 cases (50%) the main curve was lumbar, in 4 cases (33%) the main curve was <30° and classified as No coronal curve (NCC) and in 2 cases (12.5%) the curve was thoraco-lumbar (Double curve) (Table 1).

From lateral radiographs C7 plumb line, thoracic kyphosis, lumbar

lordosis, PI, PT and SS were analyzed [11]. According to Schwab adult scoliosis classification [5], we considered patients with SVA (C7 plumb line – sacrum distance) between 0 and 5 cm as balanced; viceversa if SVA was >5 cm or <0 cm the patient was considered forward and backward imbalanced, respectively.

All preoperative and postoperative radiographical spino-pelvic parameters were collected as described by Schwab [12] and are reported in Table 2.

The average preoperative main curve was 36.9° (6°-76°). The average kyphosis was 29.2° (2°-70°); the average lumbar lordosis was 36.5° (15°-56°); the average PI was 62.8 (37°-84) and the average PT was 30.1° (14°-53°).

In five patients SVA was >4 cm, indicating sagittal imbalance.

Four patients of the whole group underwent previous spinal surgery (Table 1) with 2-5 levels lumbar posterolateral fusion; in all cases deformity and pain worsened after the primary surgery.

All the surgical procedures were performed by the same team with a posterior approach and the deformity correction was achieved through posterolateral fusion in 5 cases, circumferential arthrodesis with interbody cages in 7 cases (Transforaminal Lumbar Interbody Fusion, TLIF, in 6 cases and Posterior Lumbar Interbody Fusion, PLIF, in 1 case). In 7 cases iliac screws were implanted (Table 3).

Clinical Evaluation

In order to objectify preoperative and postoperative clinical conditions of each cases, we submitted patients to worldwide approved clinical tests as Visual Analogue Scale (VAS), Oswestry Disability Index (ODI) [13] and Quality of Life test (EQ-5D) preoperatively and at 3, 6, 12 months during follow up. The average follow up was 8.4 months (range 3-20 months).

Concerning preoperative clinical evaluation, average VAS value was 8.75 (7-10), average ODI was 54.7 (30-94), average QoL was 30.9 (10-70) (Table 4).

During follow up visits, starting from one year after surgery, patient's satisfaction was evaluated and 9 of 12 patients were generally satisfied with the results even at long term follow up.

Results

Postoperative radiological evaluation through Surgimap software was made with both immediate postoperative and follow up panoramic standing radiographs.

Surgical aims were to reduce the frontal deformity and to restore the sagittal balance. We used the Cobb method to evaluate the postoperative frontal deformity on standing antero-posterior (AP) radiographs and SVA, lordosis and PT values to estimate the postoperative sagittal conditions on latero-lateral (LL) radiographs.

Lordosis and PT values were not reported as an absolute value but as relative results: we overlapped the planned ideal results, obtained by pre-surgical planning, with the postoperative actual results. We calculated the best correction for each patient and compared these values with the current ones obtained after surgical correction; the final percentage values represent a comparison between the expected and current results (Table 2).

Preoperative planning was based on the theoretical physiological values of lordosis and PT for each patient. Through the application

Code	Cobb angle °		Lordosis °		LL-post/ LL- ideal (%)	Kyphosis °		Kyphosis post-Kyphosis pre	PI°		PT°		PT-post/ PT-ideal (%)	SS°		SVA		Mechanical complications	FU (months)
	pre	post	pre	post		pre	post		pre	post	pre	post		pre	post	pre	post		
1	35	3	53	33	67.3	33	29	-4	59	61	29	26	-33.3	29	34	iB	iB	yes	3
2	37.71	25.42	49	32	48.7	14	38	24	76	76	29	40	37.9	47	35	iB	iB	yes	5
3	6	2	15	38	79.2	5	11	6	58	59	33	25	-61.5	25	34	iB	BAL	no	6
4	76		24	28	103.7	13	22	9	37	21	27	7	-285.7	10	13	BAL	iB	no	3
5	46	6,78	27	30	48.4	14	38	24	72	49	43	18	-108.7	28	30	iB	iB	no	6
6	43	3,48	51	27	61.7	28	35	7	54	48	14	23	64.3	39	25	BAL	BAL	no	20
7	45.58	10.34	47	39	86.4	70	55	-15	55	48	23	22	-33.3	32	25	BAL	BAL	no	12
8	38	28	32	42	76.36	33	33	0	65	50	37	25	-70.6	27	24	BAL	BAL	yes	14
9	23	16	56	30	46.2	29	21	-8	75	61	29	31	6.9	45	30	BAL	iB	yes	3
10	45.55	15.32	21	28	77.8	45	45	0	46	65	16	27	-275.0	29	38	BAL	BAL	no	6
11	27.54	15	26	33	52.4	2	23	21	73	55	28	18	-125.0	44	36	BAL	iB	no	16
12	19	13	23	31	41.9	63.8	40	-23.8	84	53	53	30	-69.7	30	23	iB	iB	no	7

Table 2: Preoperative and postoperative values of different radiological parameters detected in 12 patients affected by adult scoliosis.

Patient	Arthodesis Area	Surgical Access	Surgical Technique
1	T3- S1	posterior	TLIF L3-L4, L4-L5, L5-S1
2	T4-ILIUM	posterior	postero-lateral
3	L1- ILIUM	posterior	PLIF L4-L5, L5-S1
4	L2-L5	posterior	TLIF L3-L4, L4-L5
5	T8-ILIUM	posterior	TLIF L5-S1
6	T8- ILIUM	posterior	TLIF L4-L5, L5-S1
7	T4-L4	posterior	postero-lateral
8	T4-ILIUM	posterior	postero-lateral
9	T10- S1	posterior	TLIF L2-L3, L3-L4
10	T8- ILIUM	posterior	postero-lateral
11	T10- ILIUM	posterior	TLIF L2-L3, L5-S1
12	T4-L1	posterior	postero-lateral

Table 3: Description of the surgical procedures performed for AS correction.

Code	VAS		IQR*	IQR-VAS %	ODI		IQR*	IQR-ODI%	EQ-5D		IQR*	EQvar %	FU (months)
	pre	post			pre	post			pre	post			
1	8	7	-1	-12.5	48	64	16	30.8	60	30	-30	-50.0	3
2	10	3	-7	-70.0	66	30	-36	-54.5	10	80	70	77.8	5
3	9	4	-5	-55.6	46	18	-28	-60.9	20	85	65	81.3	6
4	9	2	-7	-77.8	30	30	0	0	70	80	10	33.3	3
5	10	2	-8	-80.0	94	34	-60	-63.8	10	50	40	44.4	6
6	9	6	-3	-33.3	38	24	-14	-36.8	20	60	40	50.0	20
7	8	1	-7	-87.5	46	14	-32	-69.6	40	80	40	66.7	12
8	10	8	-2	-20.0	76	52	-24	-31.6	20	20	0	0	14
9	8	8	0	0	60	62	2	5.0	30	10	-20	-66.7	3
10	8	5	-3	-37.5	56	40	-16	-28.6	10	70	60	66.7	6
11	9	1	-8	-88.9								0	16
12	7	5	-2	-28.6	42	26	-16	-38.1	50	80	30	60.0	7

Table 4: Preoperative and postoperative clinical outcomes evaluated through auto-administered questionnaires.

of the formula L (lordosis) >PI-10 we found the ideal lordosis score; according to the literature, the PT ideal value should be <20° in all patients [14-16].

Scoliosis

Scoliotic deformity reduction was calculated on AP radiographs through the Cobb method with an average gap of 27° from a preoperative average value of 36.9° (6°-76°) to a postoperative average value of 12.6° (2°-28°) (Table 2).

Thoracic Kyphosis

Postoperative kyphosis score changed in 10 patients out of 12. In 6 of these 10 cases, it increased of 15.2° (range +6°-+24°). In the remaining 4 cases it decreased of 12.7° (range -4° -23.8°).

Postoperative kyphosis resulted to be in the physiological range [17] (11°-40°) in 11 cases (included a case with final 45°). In one case from a preoperative hyperkyphosis of 70° we obtained a postoperative 55° kyphosis. In 2 patients kyphosis didn't change after deformity correction (Table 2).

Lumbar Lordosis

Ten cases out of 12 patients showed preoperative hypolordosis compared to the ideal value on the basis of personal PI (PI-LL<10°) [18]. The perfect overlap between the postoperative lordosis and the planning value was achieved in 1 patient: in other words, only 1 of 12 cases had a 100% correction of the sagittal deformity. In the remaining cases indeed, the lumbar lordosis correction was partial: 65.8% (range 41.9 -103.7%) was the average correction compared to the expected value (Table 2).

Pelvic Tilt

A pathological pelvic retroversion (PT>20°) affected 10 patients out of 12 (Table 2).

After surgery this compensation vanished in 3 patients (patients 4, 5, 11 presented postoperative PT<20°) while it was maintained >20° in 7 (patients 1, 2, 3, 7, 8, 9, 12).

Nevertheless, 5 of these 7 patients (patients 1, 3, 7, 8, 12) presented a postoperative reduced PT value showing an average PT correction (approach to physiological PT<20°) of 53.7% (range -33.3 -70.6%).

In remaining 2 of these 7 cases (patient 2, 9) postoperative PT value worsened by increasing respectively of 11° and 2°.

In 2 patients (patient 6, 10) a physiological preoperative PT<20°, worsened to 23° pathological postoperative PT (patient 6) and to 27° (patient 10) (Table 2).

Sagittal Balance

The postoperative plumb line analysis showed 6 forward imbalanced patients with SVA>5 cm (Table 2: IB); only 1 patient was considered backward unbalanced with negative SVA (Table 2: IB). Five patients showed a balanced postoperative profile with SVA between 0 and 5 cm.

Clinical Results

Patients underwent clinical tests during follow up at 3, 6, 12 months after surgery. The mean follow up period regarding clinical tests was 8.4 months (range 3-20 months). Data in Table 4 refer to the last available follow up, because clinical tests were not completed by patients in each visit. Anyway, at each visit patients' satisfaction level was investigated.

Our results show improving of clinical conditions and satisfaction for the treatment in 9 of 12 patients in terms of higher quality of life and lower pain score, although in 2 cases disability increased.

The mean VAS score reduction was 4.8 in 11 cases showing general pain reduction; in 1 patient VAS score was unchanged.

ODI score decreased on average of 28.3 points in 8 patients, it was unchanged in 1 patient and it increased by an average of 9 points in 2 patients.

EQ-5D data showed improvement of quality of life with an average increase of 44.3 in 8 patients; in 1 patient it was unchanged while it worsened on average of 25 points in 2 patients.

We analyzed possible statistical correlation between clinical outcomes (VAS, ODI, EQ-5D) and improvement of different spino-pelvic parameters. We observed a statistical correlation between the VAS score variation and the percentage ratio "postoperative kyphosis/ preoperative kyphosis", confirmed by Kendall correlation (based on non-gaussian hypothesis) and Pearson correlation (based on Gaussian hypothesis) (Figure 2, Table 5A and 5B).

No statistical correlations were detected between VAS, ODI and EQ-5D clinical outcomes and other spino-pelvic parameters.

Mechanical failure

In our series, 4 patients (33%) experienced mechanical failure. In 3 cases we had screws loosening and in 1 case rods break (Table 2).

Discussion

Conservative Treatment

Results from recent studies [2,3] have demonstrated the superiority of surgery compared with conservative care regarding back and leg pain, leading to a generally favourable risk/benefit ratio for AS surgery, even in older patients [19]. Currently, a lack of consensus exists on the most efficacious conservative treatment for adult degenerative scoliosis; however, in our opinion a strong conservative attempt is mandatory before decision for surgery in all AS patients. The initial treatment of patients with back pain and scoliosis should not differ from the treatment of patients with mechanical back pain without deformity. A physical therapy program should be instituted to improve aerobic capacity, strengthen muscles, and improve flexibility and joint motion. Local heat, non-narcotic analgesics and bracing may help the patient in the improvement of symptoms but do not prevent curve progression. Corticosteroid injections in the form of nerve root blocks, facet injections and epidural steroid injections may be of considerable value in the arsenal of conservative management [8]. Only after the failure of a minimum 6 months conservative treatment, if disability and pain scores haven't decreased, the surgical option will be considered and discussed with the patient [20].

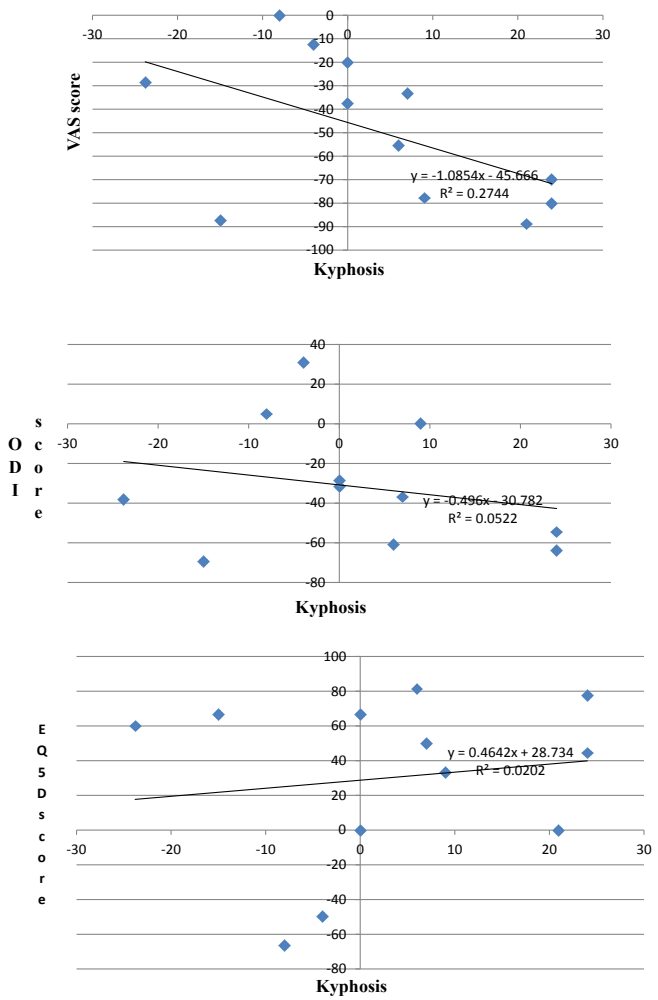

Figure 2: Analysis of statistical correlation between clinical outcomes (VAS, ODI, EQ-5D) and improvement of different spino-pelvic parameters. We observed a statistical correlation between the VAS score (pain) and the percentage ratio "postoperative kyphosis/ preoperative kyphosis", confirmed by Kendall correlation (based on non-gaussian hypothesis) and Pearson correlation (based on Gaussian hypothesis).

Imaging

The surgical treatment of AD requires a correct radio graphical evaluation, with the full length AP and LL views being the keystone for the imaging of these patients.

In our study, as a retrospective study, eligible radiograms were the most severe selective inclusion criterion, reducing our series from 40 to final 12 patients.

There are different opinions between physicians concerning the "best" position for a patient when taking a standing lateral 36" radiograph, while the AP view has been less debated. For LL view the techniques proposed include putting the arms straight out in front of the patient (parallel with the floor) with support or unsupported. Other techniques include partially flexing the arms out front, or folding the hands in the supraclavicular fossa.

According to Horton [10], the position we propose is the clavicle position where the patient fully flexes the elbows with the hands in a relaxed fist, wrists flexed, placing the proximal interphalangeal (PIP) joints comfortable up into the supraclavicular fossa, thus passively flexing the humerus forward (Figure 1). Hands are centered in the fossae, midway between the suprasternal notch and acromion. This comfortable position allows good visualization of C7, T2 and T12 landmarks. The radiogram finally should include the skull, odontoid, hip and femur.

Postoperative radiological parameters and disability score comparison

Glassman and co-workers [21,22], such as most of the recent literature, demonstrated the fundamental relationship between sagittal

Group	Code	IQR-VAS%	IQR-ODI%	IQR-QoL%	LL-POST/ LL-IDEAL (%)	Kyphosis post-Kyphosis pre (°)	PT-POST/ PT-IDEAL (%)	SVA post-op	Mechanical complications	FU (months)
	3	-55.6	-60.9	65	81.3	6	-61.5	BAL	no	6
	6	-33.3	-36.8	50	61.7	7	64.3	BAL	no	20
A	7	-87.5	-69.6	66.7	86.4	-15	-33.3	BAL	no	12
	10	-37.5	-28.6	66.7	77.8	0	-275	BAL	no	6
	1	-12.5	30.8	-50	67.3	-4	-33.3	iBa	yes	3
B	4	-77.8	0	33.3	103.7	9	-285.7	iBp	no	3
	9	0	5	-66.7	46.2	-8	6.9	iBa	yes	3
	2	-70	-54.5	77.8	48.7	24	37.9	iBa	yes	5
C	5	-80	-63.8	44.4	48.4	24	-108.7	iBa	no	6
	11	-88.9			52.4	21	-125	iBa	no	16
	12	-28.6	-38.1	60	41,9	-23.8	-69.7	iBa	no	7

Table 5: Matching of radiographical and clinical outcomes after AS surgical treatment.

Kendall's Correlation		LL-POST/ LL-IDEAL	PT- POST (correction obtained)	Kyphosis-POST/ Kyphosis-PRE	PT- POST
VASvar %	Correlation coefficient tau	-0.242	0.260	**-0.462**	**0.462**
	Sig. (2-tails)	0.273	0.243	**0.039**	**0.039**
	N	12	12	12	12
ODIvar%	Correlation coefficient tau	0.018	-0.110	0.167	0.183
	Sig. (2-tails)	0.938	0.639	0.481	0.435
	N	11	11	11	11
QoLvar%	Correlation coefficient tau	0.185	0.047	0.125	0.094
	Sig. (2-tails)	0.408	0.836	0.580	0.678
	N	12	12	12	12

Table 6: p-values for Kendall's Correlation (A) and Pearson's Correlation (B) for radiographic and clinical parameters.

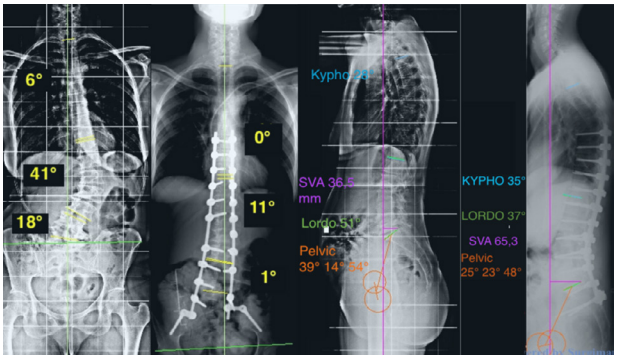

Figure 3: Pre-operative and post-operative antero-posterior and latero-lateral radiographs of a representative patient from Group A, showing a neutral global alignment after surgery (SVA 0-5 cm) which corresponds to decreased post-operative disability and pain scores (good clinical outcomes).

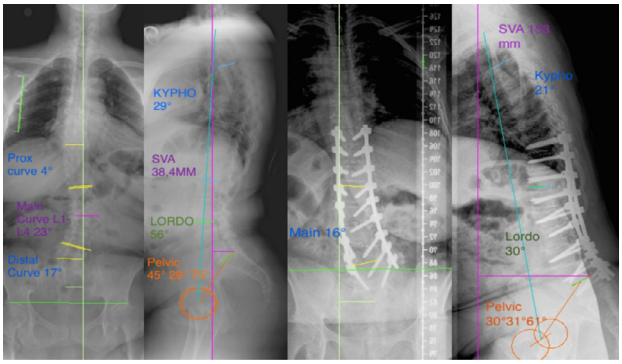

Figure 4: Pre-operative and post-operative antero-posterior and latero-lateral radiographs of a representative patient from Group B, showing postoperative sagittal imbalance which corresponds to worsened clinical outcomes.

alignment and clinical outcomes in adult scoliosis. Our evidence-based experience suggested that physiological postoperative sagittal alignment sometimes does not always guarantee patient's satisfaction.

To critically analyze our results in adult scoliosis surgical treatment we decided to match radiological and clinical outcomes in a retrospective study. We collected some surprisingly data, which are not in agreement with the modern literature.

The primary end point of our retrospective study was to validate the hypothesis, commonly and internationally accepted, that disability significantly decreases after balance restoration. The secondary end point was to evaluate hardware failure events in relation to the final sagittal alignment, according to the hypothesis that postoperative physiological balance should preserve hardware from premature failure, while postoperative imbalance is the main cause of screw loosening, rod break, junctional syndrome and, in general, mechanical complications [23-25].

On the basis of published correlations between SVA and patient reported clinical outcomes, thresholds of postoperative SVA were used to subdivide the sample depending on final sagittal balance: neutral global alignment group (patients with a postoperative SVA between 0 and 5 cm) with 5 patients and anterior or posterior global alignment group (patients with a postoperative SVA more than 5 cm or negative) with 7 patients.

Clinical data were recorded and patients divided depending on the improvement or the worsening of clinical tests results.

Radiological and clinical outcomes were finally matched and we obtained 3 final groups of patients which are described and analysed separately here, even if these groups have not a statistical relevance due to the small size.

Group A: neutral global alignment (SVA 0-5 cm) corresponds to decreased disability and pain scores. This group includes 4 patients with an average decrease of VAS and ODI of -4.5 and -22.5 and an average increase of EQ-5D of 51.2. 76% of the ideal lordosis was reached in this group of patients, average postoperative PT was 24.2° and average final kyphosis was 36.5°. The personal satisfaction of patients, despite the incomplete radiological outcomes, should be considered analysing the global outcomes of group A [15,26,27]. In particular, not all patients reached the ideal lordosis value but all experienced an improved daily ability (Table 6 and Figure 3).

Group B: postoperative sagittal imbalance corresponds to worst clinical tests results. 3 patients (1, 4 and 9) showed these characteristics. Among them, in 2 cases we faced to anterior sagittal imbalance with SVA >5 cm and average lordosis at 56.2% of the theoric value. 33% of the planned PT was obtained in patient 1, while in patient 9 a pathological postoperative PT (27°), from a preoperative physiological value (16°), and was detected, demonstrating a pelvic retroversion. Patient number 4 showed a posterior imbalance with an excess lordotic value compared to the ideal one. From a preoperative PT of 27° we obtained a postoperative physiological value of 7° and also kyphosis improved moderately from 7° to 22° (Table 6 and Figure 4).

All patients complained worsening of their clinical conditions and this worsening appeared from auto-administered tests: ODI increased by 9 points on average, EQ-5D decreased by 20 points on average and, differently, VAS improved by 4 points on average.

Group C: all patients with a certain inconsistency between radiological and clinical outcomes were gathered in group C. In 4 cases (patients 2, 5, 11 and 12) postoperative anterior imbalance matches

with improvement of clinical outcomes. Average lordosis correction was 47.8% compared to the ideal value. Average PT, from a preoperative value of 38.2° switched to a postoperative value of 27.5°; in no case we obtained pelvic tilt restoration at physiological value and in one case it worsened from 29° to 43° postoperatively. No pathological kyphosis occurred in this group of patients. Differently from radiological results, clinical outcomes improved with VAS and ODI average reduction of 6.25 and 37.7 respectively, and EQ-5D average increase of 46.6 (Table 6).

Patient number 8, belonging to Group C, showed the opposite situation with a decrease of clinical tests scores, despite a physiological postoperative balance. It was a second surgery in a 72 years old woman affected by junctional syndrome after posterolateral L3-S1 arthrodesis. New surgery consisted on L3 PSO and T4-ilium stabilization. Normal kyphosis and balance, reduced PT (from 37° to 25°) and 76.4% lordosis correction obtained, didn't correspond to clinical outcomes with a worsening of VAS (-2), ODI (-24) and EQ-5D (unchanged during 14 months follow up).

Late operative site pain (LOSP) of no apparent cause after idiopathic scoliosis correction has been discussed [28]. LOSP is described as a residual pain over the surgical scar and the periscapular area. Hypothetical origins are nonunion, skin-deep hardware, aspecific soft tissue inflammation. LOSP is considered as a current cause of reoperation and, according to Scott, it is an indication for implant removal.

Adogwa et al. [29] investigated the role of baseline depression after spine second surgery in the elderly. Affective disorders such as depression have been shown to influence patient-reported outcomes and self-interpretation of health status. The Authors conclude that independently of surgical effectiveness, baseline depression influences the patient's satisfaction and it should be considered as a potential confounder especially in this group of elderly people.

Clinical outcomes are still unclear in this patient at 14 months FU.

Patient number 2 presented with junctional syndrome, flat back and hardware failure after posterolateral lumbo-sacral artrhodesis. Poor clinical preoperative status was underlined by tests (VAS, ODI, QoL respectively 10, 66, 10). In this case second surgery was considered mandatory and patient underwent T4-ilium posterolateral fusion. Although surgical outcome wasn't brilliant and didn't reach the ideal correction, disc and hardware failure pain disappeared. Postoperative balance was not completely restored but improved and clinical tests showed the new postoperative status improvement compared to the previous one.

One the other hand, even if the subjective clinical condition was satisfying, at 5 months FU patient experienced hardware loosening that was documented during radiological screening.

Patients 5 and 11 have high PI (72° e 73°). Accordingly to Roussouly and Pinheiro-Franco [30] an individual with a high value of PI, when in sagittal imbalance, has higher possibilities of retroversion and he is able to increase widely the posterior offset between the sacrum and the femoral heads in the sagittal plane. This mechanism may help to restore the position of C7 plumb line behind the femoral heads, as in cases of progressive kyphosis. However, this large retroverted pelvis is limited by hip joint extension, which prevents the achievement of the maximum PT, with SS equal to 0°. This is the reason why, after reaching maximal retroversion, the spino-pelvic complex performs the next method of balance correction, which is flexing the knees to tilt the femoral shaft. Both patients presented lumbar hypolordosis or kyphosis, thoracic hypokyphosis, inferior limb compensation showing a final not favorable and painful situation.

Insufficient surgical correction with residual anterior imbalance was performed in both patients but a more economical position and reset knee flexion and hip extension was reached. This is a plausible explanation of the improving quality of life and function tests results. At 6 and 16 months FU patients didn't show any hardware failure.

Patient 12 is a 40 years old male presenting with thoraco-lumbar iperekyphosis, hypolordosis, hips iperextension and knees flexion despite an high PI value (84°). Sagittal aligment was anteriorly dislocated and clinical tests demonstrated a low quality of life. After lumbar pedicle subtraction osteotomy (PSO) and thoraco-sacral posterolateral arthrodesis, residual anterior imbalance with underestimated lordosis and pathological PT did not match with substantial increased quality of life.

No mechanical failure at 7 months of follow up was noted.

Few hypotheses in favor of the improved quality of life are: the young age and alleged favorable biological tissue reactivity; a clinical and radiological preoperative poor condition that benefited from surgical partial reduction. Until today we can't objectively justify the high clinical results the patient experienced.

Statistical analysis highlighted a significant correlation between the VAS score (pain) and the percentage ratio "postoperative kyphosis/ preoperative kyphosis", confirmed by Kendall correlation (based on non-gaussian hypothesis) and Pearson correlation (based on Gaussian hypothesis).

No other statistical correlations were detected between VAS, ODI and Quality of life clinical outcomes and spino-pelvic parameters in these series of patients.

Clinical results and mechanical failure comparison

A percentage of 33% of patients, 4 over a total of 12, experienced hardware failure: one case of broken rods and 3 cases of alisteresys (Figure 5). Three of these, 75%, showed a postoperative residual imbalance.

Generally speaking, 5 patients over 12 showed postoperative imbalance; 42% of these had mechanical failure at an average FU period of 6 months (range 3-13).

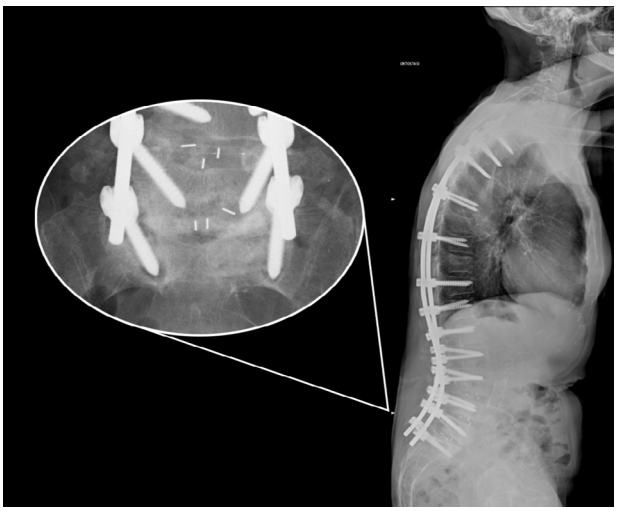

Figure 5: Post-operative radiographs of a patient showing alisteresis of sacral screws, associated to sagittal imbalance.

Differently, at an average 10 months FU, only 20% (1 case over 5) of balanced patients experienced mechanical failure.

Several papers reported in the literature analyzed complications in posterior fusion and instrumentation for adult scoliosis [31-35].

Charosky et al. [31] identified reoperation risks factor on surgically treated adult scoliosis in patients aged 50 years or older. Overall complication rate was 39%, and 26% of the patients were reoperated for mechanical or neurological complications. Risk factors include number of instrumented vertebra, fusion to the sacrum, PSO, and preoperative pelvic tilt of 26° or more. There is a 44% risk of a second surgery in the 6-years-period after the primary procedure.

In a review analysing 111 patients Schwab et al. [32] underlined how a postoperative 40-95 mm SVA exposed the hardware to a greater rate of failure at a minimum 1 year FU then patients with postoperative physiological (<4 mm) PT.

Our results, with the limitation of the small sample size, confirmed the view that a correct postoperative balance is protective towards implants failure, thus reducing mechanical complications.

Conclusion

Concerning the first aim of our study, we observed a correlation between clinical outcomes and radiological parameters after the surgical treatment of adult scoliosis only for 7 of 12 patients: 4 patients reported a restoration of the sagittal balance after surgery corresponding to good clinical outcomes (decreased disability and pain scores); 3 patients reported post-operative sagittal imbalance associated with worsening of clinical conditions. However, 5 of 12 patients didn't show any positive or negative correlations between clinical outcomes and radiological parameters, indicating that sagittal restoration is not always a driver for clinical improvement, but clinical improvement after surgery can be also achieved without sagittal balance. Overall the data indicate that 9 of 12 patients are satisfied with results achieved.

Concerning the second aim of this study, the occurrence of mechanical complications at different follow up periods resulted to be associated with poor sagittal balance restoration after surgery, as attended.

Considering the limited number of patients analyzed, the results discussed here should be confirmed through a larger prospective study, in order to evaluate which parameters could be relevant to obtain benefits from a demanding surgery such that required for the correction of adult scoliosis.

Competing Interests

Authors don't have any financial or non-financial competing interests to declare.

Acknowledgements

The Authors are grateful to Dr. Elettra Pignotti for statistical analysis of the data and to Carlo Piovani for pictures and radiographical images elaboration.

References

1. Vanderpool DW, James JI, Wynne-Davies R (1969) Scoliosis in the elderly. J Bone Joint Surg Am 51: 446-455.
2. Kostuik JP, Bentivoglio J (1981) The incidence of low-back pain in adult scoliosis. Spine (Phila Pa 1976) 6: 268-273.
3. Pérennou D, Marcelli C, Hérisson C, Simon L (1994) Adult lumbar scoliosis. Epidemiologic aspects in a low-back pain population. Spine (Phila Pa 1976) 19: 123-128.
4. Witt I, Vestergaard A, Rosenklint A (1984) A comparative analysis of x-ray findings of the lumbar spine in patients with and without lumbar pain. Spine (Phila Pa 1976) 9: 298-300.
5. Schwab F, Farcy JP, Bridwell K, Berven S, Glassman S, et al. (2006) A clinical impact classification of scoliosis in the adult. Spine (Phila Pa 1976) 31: 2109-2114.
6. Aebi M (2005) The adult scoliosis. Eur Spine J 14: 925-948.
7. Schwab F, Ungar B, Blondel B, Buchowski J, Coe J (2015) Scoliosis Research Society-Schwab adult spinal deformity classification: a validation study. Spine (Phila Pa 1976) 37: 1077-1082.
8. Bradford DS, Tay BK, Hu SS (1999) Adult scoliosis: surgical indications, operative management, complications, and outcomes. Spine (Phila Pa 1976) 24: 2617-2629.
9. Akbar M, Terran J, Ames CP, Lafage V, Schwab F (2013) Use of Surgimap Spine in sagittal plane analysis, osteotomy planning, and correction calculation. Neurosurg Clin N Am 24: 163-172.
10. Horton WC, Brown CW, Bridwell KH, Glassman SD, Suk SI, et al. (2005) Is there an optimal patient stance for obtaining a lateral 36" radiograph? A critical comparison of three techniques. Spine (Phila Pa 1976) 30: 427-433.
11. O'Brien MF, Kuklo TR, Blanke KM, Lenke LG (2005) Radiographic Measurement Manual. Medtronic Sofamor Danek USA, 1-110.
12. Schwab FJ, Blondel B, Bess S, Hostin R, Shaffrey CI, et al. (2013) Radiographical spinopelvic parameters and disability in the setting of adult spinal deformity: a prospective multicenter analysis. Spine (Phila Pa 1976) 38: E803-812.
13. Fairbank JC, Pynsent PB (2000) The Oswestry Disability Index. Spine (Phila Pa 1976) 25: 2940-2952.
14. Duval-Beaupère G, Schmidt C, Cosson P (1992) A Barycentremetric study of the sagittal shape of spine and pelvis: the conditions required for an economic standing position. Ann Biomed Eng 20: 451-462.
15. Lafage V, Schwab F, Patel A, Hawkinson N, Farcy JP (2009) Pelvic tilt and truncal inclination: two key radiographic parameters in the setting of adults with spinal deformity. Spine (Phila Pa 1976) 34: E599-606.
16. Schwab F, Patel A, Ungar B, Farcy JP, Lafage V (2010) Adult spinal deformity-postoperative standing imbalance: how much can you tolerate? An overview of key parameters in assessing alignment and planning corrective surgery. Spine (Phila Pa 1976) 35(25): 2224-2231.
17. Bernhardt M, Bridwell KH (1989) Segmental analysis of the sagittal plane alignment of the normal thoracic and lumbar spines and thoracolumbar junction. Spine (Phila Pa 1976). 14: 717-721.
18. Schwab F, Lafage V, Patel A, Farcy JP (2009) Sagittal plane considerations and the pelvis in the adult patient. Spine (Phila Pa 1976) 34: 1828-1833.
19. Blondel B, Schwab F, Bess S, Ames C, Mummaneni PV, et al. (2013) Posterior global malalignment after osteotomy for sagittal plane deformity: it happens and here is why. Spine (Phila Pa 1976) 38: E394-401.
20. Bess S, Boachie-Adjei O, Burton D, Cunningham M, Shaffrey C, et al. (2009) Pain and disability determine treatment modality for older patients with adult scoliosis, while deformity guides treatment for younger patients. Spine (Phila Pa 1976) 34: 2186-2190.
21. Glassman SD, Berven S, Bridwell K, Horton W, Dimar JR (2005) Correlation of radiographic parameters and clinical symptoms in adult scoliosis. Spine (Phila Pa 1976) 30: 682-688.
22. Glassman SD, Bridwell K, Dimar JR, Horton W, Berven S, et al. (2005) The impact of positive sagittal balance in adult spinal deformity. Spine (Phila Pa 1976) 30: 2024-2029.
23. Kim YJ, Bridwell KH, Lenke LG, Rhim S, Cheh G (2006) Pseudarthrosis in long adult spinal deformity instrumentation and fusion to the sacrum: prevalence and risk factor analysis of 144 cases. Spine (Phila Pa 1976) 31: 2329-2336.
24. Kim YJ, Bridwell KH, Lenke LG, Rhim S, Cheh G (2006) Sagittal thoracic decompensation following long adult lumbar spinal instrumentation and fusion to L5 or S1: causes, prevalence, and risk factor analysis. Spine (Phila Pa 1976) 31: 2359-2366.
25. Berjano P, Bassani R, Casero G, Sinigaglia A, Cecchinato R, et al. (2013) Failures and revisions in surgery for sagittal imbalance: analysis of factors influencing failure. Eur Spine J 22 Suppl 6: S853-858.

26. Smith JS, Sansur CA, Donaldson WF 3rd, Perra JH, Mudiyam R, et al. (2011) Short-term morbidity and mortality associated with correction of thoracolumbar fixed sagittal plane deformity: a report from the Scoliosis Research Society Morbidity and Mortality Committee. Spine (Phila Pa 1976) 36: 958-964.

27. Daubs MD, Lenke LG, Cheh G, Stobbs G, Bridwell KH (2007) Adult spinal deformity surgery: complications and outcomes in patients over age 60. Spine (Phila Pa 1976) 32: 2238-2244.

28. Cook S, Asher M, Lai SM, Shobe J (2000) Reoperation after primary posterior instrumentation and fusion for idiopathic scoliosis. Toward defining late operative site pain of unknown cause. Spine (Phila Pa 1976) 25: 463-468.

29. Adogwa O, Carr K, Fatemi P, Verla T, Gazcon G, et al. (2014) Psychosocial factors and surgical outcomes: are elderly depressed patients less satisfied with surgery? Spine (Phila Pa 1976) 39: 1614-1619.

30. Roussouly P, Pinheiro-Franco JL (2011) Biomechanical analysis of the spino-pelvic organization and adaptation in pathology. Eur Spine J 20 Suppl 5: 609-618.

31. Charosky S, Guigui P, Blamoutier A, Roussouly P, Chopin D; Study Group on Scoliosis (2012) Complications and risk factors of primary adult scoliosis surgery: a multicenter study of 306 patients. Spine (Phila Pa 1976) 37: 693-700.

32. Schwab F, Lafage V, Farcy JP, Bridwell K, Glassman S, et al. (2007) Surgical rates and operative outcome analysis in thoracolumbar and lumbar major adult scoliosis: application of the new adult deformity classification. Spine (Phila Pa 1976) 32: 2723-2730.

33. Cho KJ, Suk SI, Park SR, Kim JH, Kim SS, et al. (2007) Complications in posterior fusion and instrumentation for degenerative lumbar scoliosis. Spine (Phila Pa 1976) 32: 2232-2237.

34. Zimmerman RM, Mohamed AS, Skolasky RL, Robinson MD, Kebaish KM (2010) Functional outcomes and complications after primary spinal surgery for scoliosis in adults aged forty years or older: a prospective study with minimum two-year follow-up. Spine (Phila Pa 1976) 35: 1861-1866.

35. Smith JS, Shaffrey CI, Glassman SD, Berven SH, Schwab FJ, et al. (2011) Risk-benefit assessment of surgery for adult scoliosis: an analysis based on patient age. Spine (Phila Pa 1976) 36: 817-824.