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Evaluation on Thoracic Trunk Shift and Coronal balance in Post-Operative Scoliosis Patients

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Thoracic trunk shift and Coronal balance are main features to be considered while planning treatment for scoliosis patients. Thoracic trunk shift refers to deviation of trunk from its normal position. Coronal balance refers to deviation of seventh cervical bone from sacrum in coronal plane. After undergoing scoliosis correction surgery, these two parameters are measured by surgeons using radiograph images to make sure the scoliosis curve progression is stopped and whether vertebral alignment is back to normal. Since the relationship between thoracic trunk shift and coronal balance in the post-operated scoliotic patients is questionable, this study is done to find the correlation between thoracic trunk shift and coronal balance in the thoracic scoliosis patients who underwent correction surgery at least a year before from the date of taking radiographs. Radiographs of 24 patients were collected. Statistical analysis was done using paired sample 't' test, with 'p' value of 0.05 as the level of significance. The mean millimetre measurement of thoracic trunk shift and coronal balance was found to be 27.62 mm and 10.50 mm. Results of our study showed that there is a 10.18% of relation in between the post thoracic trunk shift and coronal balance of those 24 patients.

Keywords: vertebral fusion, radiographs, balance, plumb line

I. INTRODUCTION

Scoliosis is a medical condition in which the spine is abnormally twisted and curved. Globally scoliosis is the most common musculoskeletal disorder affecting the children ranging from 2-3%. When examining the scoliosis patients from posterior (back) view, spine looks 'C' shaped or 'S' shaped. Treatment to the scoliosis depends upon factors like Cobb angle and age. It can be treated by either cast, brace or surgery. Casting is provided for the age group between 0-3 years, bracing is provided for the children and surgery is performed if the cobb angle is more than 40 degrees. During surgery, surgeons fuse the vertebrae causing scoliosis curve, using metal implants. Since the alignment of vertebrae is affected in scoliosis, the Center of Gravity (CoG) and Line of Gravity (LoG) are also affected in the scoliosis patients. In an anatomical standing posture, the CoG and LoG lies anterior to sacrum bone (S2). Whereas, in scoliosis pa-

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tients, the CoG and LoG is altered or deviated according to the severity of scoliosis. The level of deviation can be roughly understood by measuring the Coronal balance, Sagittal balance, Thoracic trunk shift, Thoracolumbar and Lumbar sagittal alignment.

A study done by Damavandi *et al.* (2013) on head and trunk mass and centre of mass position estimations in able bodied and scoliotic girls concluded that the pre-operative scoliotic girls had greater pelvic forward tilt and trunk inclination when compared with normal subjects. Whereas, another study done by Jae Yong Park (Park *et al.*, 2013) on the effect of scoliosis angle on centre of gravity sway found that the whole body balancing abilities in the pre-operative scoliosis patients is significantly different than the normal persons. This explains the importance of pelvic tilt, centre of gravity and trunk inclination in maintaining a proper posture. In scoliosis patients, since the trunk posture is altered or shifted to one side, it in turn provides more pressure to the lumbar region on the side of scoliosis curve (Mohankumar & Leong, 2014). Using image processing (Mohankumar & Leong, 2015; Leong & Than, 2014; Tung & Leong, 2013) a study conducted by Hajizadeh *et al.* (2013) on developing a 3D multibody model of the scoliotic spine with lateral bending motion for comparison of ribcage flexibility concluded that the load at lumbar joints in scoliosis model were higher when compared with the normal.

Even after treating the scoliosis surgically, due to the sudden upright posture caused because of stretching the scoliosis curve during surgery, patients feel a disturbance in their balance. A study by de Abreu *et al.* (2012) on the influence of surgical treatment of adolescent idiopathic scoliosis on postural control supports this theory. They concluded that the scoliosis patients have a large centre of pressure oscillation when compared with the age matched healthy adults. Even after surgery, oscillation is decreased on the initial 90 days. But later, it remained larger than before surgery. During scoliosis correction, surgeons correct the scoliosis angle by using implants, bone graft and manual pressure. Some claim that most of the curve is reduced because of the manual pressure and on the other hand, some claim its due to the vertebral fusion and metal implants. Recently, a study done by Trobisch *et al.* (2011) on postoperative trunk shift in Lenke 1 and 2 curves concluded that the coronal balance does not correlate with thoracic trunk shift. The postoperative trunk shift is common after surgery for adolescent idiopathic scoliosis. But it occurs only in 13.6% of patients and 65% occurs as an iatrogenic (caused by surgeon). If the curve is corrected only by manual pressure, implants can take over the vertebral fusion. Then, the need for fusing the vertebrae will be a questionable debate. Human spine consists of 33 vertebrae which are linked to each other through facets and ligaments. If the abnormal curve (scoliosis) leads to an altered coronal balance, sagit-

tal balance, thoracic trunk shift, thoracolumbar, and lumbar sagittal alignment, then after treating the scoliosis, these parameters must return back to normal. Hence, in order to validate this, in this study, we find the thoracic trunk shift (TTS) and coronal balance (CB) between the pre and post operated scoliosis patients. The objective of this study is to compare and find the relation between TTS and CB of pre and post-operated scoliosis using the radiographs acquired at least one year after their surgery (it takes 8 to 10 months for a complete fusion).

O'Connell *et al.* (2007) conducted a study on disc strain in axial compression using cadaver model, nonmagnetic compression frame, commercial software and magnetic resonance. Jamshidnejad and Arjmand (2015) conducted a study on spinal loads after posterior lumbar surgery. They used a three dimensional, multi-joint, musculoskeletal model and simulation to find the loads. Amin *et al.* (2016) did a study on six degree of freedom loading sequence on compressive properties of human lumbar spine using cadaver and hexapod robot testing system. Dreischarf *et al.* (2013) carried out a study on finding compressive force in the lumbar spine from intradiscal pressure measurements using a finite element model created using CT scan images. In 2013, Skrzypiec *et al.* (2013) used cadaver and servo-hydraulic testing machine to find the shear load sharing in degenerated human lumbar spine. These techniques are time consuming and need some sophisticated instruments to carry out the study. As mentioned above, most of the studies were done using cadaver and computer assisted software's. Whereas, in a real-life situation, whenever a patient comes to a physician for his/her low back pain, there is no time for the physician to create a 3D model of the spine or to perform finite element analysis, to understand the severity of the pain, balance shift and complexity of the spinal load. There is a need for the physicians and orthopaedic surgeons to have a non-invasive, easy method to comprehend the load distribution. In this paper, we use radiographs (trunk) to calculate the thoracic trunk shift and coronal balance in post-operative scoliosis patients.

II. MATERIALS AND METHODS

Sampling method followed was a non-probability convenient sampling. The study design was observational cross sectional study.

A. Data Collection

Data collection was done at Government General Hospital, Chennai, India. Proper consent was obtained from the radiology department before collecting data. Pre and post-operative radiographs of the 24 thoracic scoliosis patients between the age group 10 to 25 years who underwent scoliosis correction surgery were obtained. Since the fusion process between the vertebrae takes at least ten months to completely

fuse, we obtained the radiographs of scoliosis patients who underwent correction surgery at least 1 year before from the date of data collection. Baseline assessment were done. The thoracic shift and coronal balance was measured in radiographs. Sample of 3 patient's data are provided below.

Table 1. Patient details

Gender	Age	TTS Pre	TTS Post	CB Pre	CB Post
F	16	28 mm	16 mm	10 mm	3 mm
F	20	51 mm	22 mm	12 mm	2 mm
M	15	31 mm	9 mm	19 mm	4 mm

B. Evaluation of Thoracic Trunk Shift

Thoracic shift is measured by first identifying the apical thoracic vertebra (the most deviated vertebra). Through the centre of that vertebra, a horizontal line AB is drawn touching the boundary of the ribs on either sides. Midpoint of the line AB is calculated as point C and a vertical line, perpendicular to the line AB is drawn. Then, the centre sacral vertical line (CSVL) is drawn from the midpoint of the S1 upward and parallel to the sides of the radiograph. Now, distance between the perpendicular line through C and CSVL is measured in millimetres (Figure 1). This measurement refers to the thoracic trunk shift.

C. Evaluation of Coronal Balance

Coronal balance is measured by first identifying the C7 bone. From the centre of C7, a vertical line is drawn downward parallel to the sides of the radiograph (in other words, Plumb line). Then, the CSVL is drawn upwards. The distance between the C7 plumb line and CSVL is measured as coronal balance (Figure 2). It is measured in millimetres.

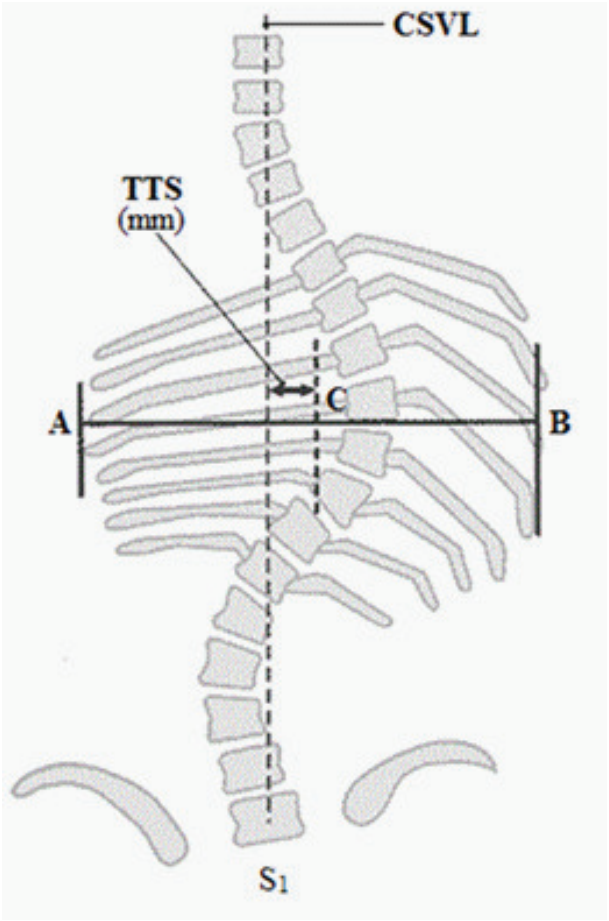

Figure 1. Thoracic Trunk Shift

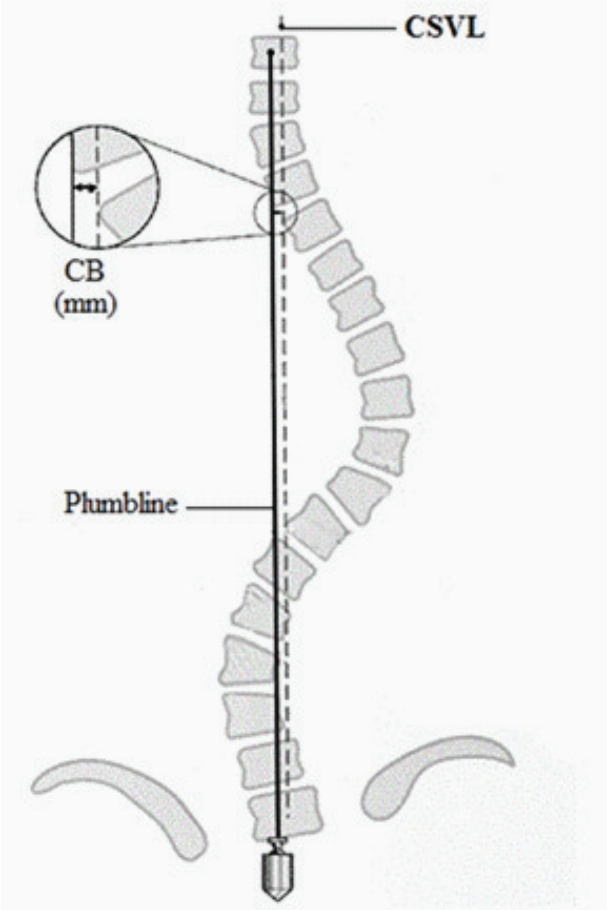

Figure 2. Coronal Balance

III. RESULTS

Out of 24 samples, 7 were males and 17 were females. Statistical analysis was done using paired sample 't' test, with 'p' value set as 0.05 as the level of significance. The mean TTS of the pre and post-operated scoliosis patients was 42.45 mm and 14.83 mm. The standard deviation was ±10.362 and ±5.189. Whereas, the mean CB of the pre and post-operated scoliosis patients was 14.75 mm and 4.25 mm. The standard deviation was ±4.120 and ±1.359.

Between the pre and post TTS, mean was 27.62 mm, standard deviation was ±7.441 with the t value of 18.187. While, the mean between the pre and post CB was 10.50 mm, standard deviation was ±3.844, with the t value of 13.379. The results of the paired sample test of both the TTS and CB pre and post-operated scoliosis patients showed that there is a significant level of decrease with the p value lesser than 0.05. The mean decrease was 27.62 in TTS and 10.50 in CB, with the 95% confidence interval. Hence, we reject the null hypothesis. There is a significant difference in the TTS and CB between the pre-operative and post-operative scoliosis patients.

Table 2. Results

Variables	Mean	SD	'*t*' value	'*p*' value
TTS Pre	42.45	10.36		
TTS Post	14.83	5.18		
TTS Pre & Post	27.62	7.44	18.18	.000
CB Pre	14.75	4.12		
CB Post	4.25	1.35		
CB Pre & Post	10.50	3.84	13.37	.000

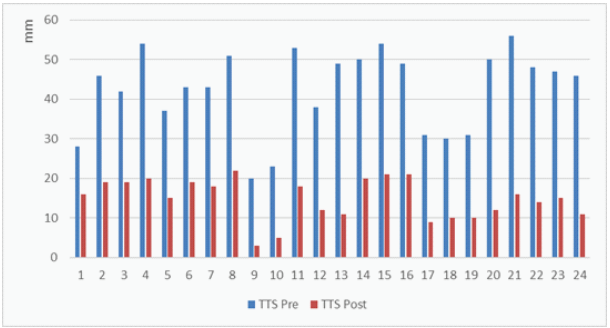

Figure 3. Pre and post-operative thoracic trunk shift

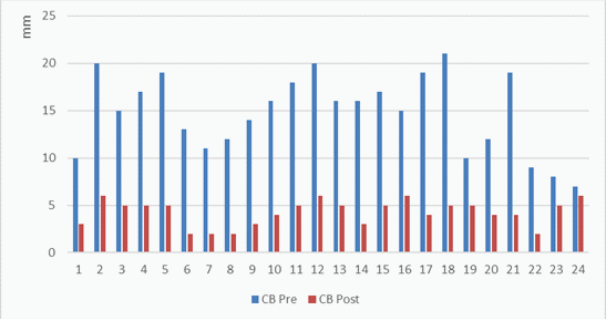

Figure 4. Pre and post-operative coronal balance

IV. DISCUSSION

A study done by Richards *et al.* (2005) on assessment of trunk balance in thoracic scoliosis concluded that if the coronal balance and thoracic apical vertebral translation values are known, then the lateral trunk shift can be reliably estimated. In this study, we directly measure the thoracic trunk shift and coronal balance of the post-operated thoracic scoliosis patients. A study by Karami *et al.* (2016) on the assessment of coronal radiographic parameters of the spine in the treatment of adolescent idiopathic scoliosis concluded that precise attention to the coronal balance in pre-operative is vital in prevention of post-operative decompensation. During the scoliosis correction surgery, surgeons perform osteotomy, place bone grafts in the course of scoliosis curve and fuse the vertebrae together. With the help of metal implants, bone graft and bone regeneration, curve correction occurs promptly. Another study by Ameri *et al.* (2014) on natural history of coronal balance after spinal fusion in adolescent idiopathic scoliosis revealed that the first 12 months after posterior spinal fusion is the spontaneous improvement period for coronal balance. Following that period of time is less likely. In contrast, a study by Siderakis *et al.* (2013) on analysis of coronal balance and last level of arthrodesis in Lenke type 5 idiopathic scoliosis concluded that the general average Apical Vertebral Translation Lumbar (AVTL) was greater in the patients whose coronal balance did not improve.

In our study, we could not able to get the patients Lenke type, as they underwent scoliosis correction surgery during the period of 2011 to 2014, only the patient's details, Cobb angle measurement, radiographs were available. Hence, such information (Lenke type) was not available at the time of data collection. But, it was evident that patients Cobb angle, TTS and CB were significantly reduced between the pre and post-operated patients. We also tried the correlation between pre-operative TTS & CB and post-operative TTS & CB, but the results were not significant and not even had a fair correlation between them. The percentage difference between the mean of pre & post TTS and pre & post CB was 89.82%, showing that there is a 10.18% of similarity in the relationship between TTS and CB. Since the vertebrae is different after surgery, i.e. fused vertebrae with implants and bone graft, a finite element analysis should be done to find its mechanical strength. Hence, simultaneous with this study, we also try to cre-

ate a 3D mesh model of the fused vertebrae (Mohankumar & Leong, 20152015) using signal and image processing (Fahmi & Leong, 2012).

Because of bone healing occurring along with vertebral fusion, most of the scoliosis correction takes place within the first 12 months itself. A finite element study can provide an in depth understanding of the mechanical strength of fused scoliotic vertebrae and its response to the real-life scenarios like bending, twisting and shear force. The results of our study clearly show that there is a significant decrease in the thoracic trunk shift and coronal balance between the pre and post-operative thoracic scoliosis patients and 10.18% of relation between the thoracic trunk shift and coronal balance among those 28 patients. The results of our study provide added advantage to the known knowledge of physiotherapists and occupational therapists in treating the patients who underwent scoliosis correction via mobilising and bringing them back to the normal lifestyle.

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