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Posterior Spinal Fusion with Rib Resection Allows for Improved Deformity Correction as well as Patient Satisfaction

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Abstract

Study Design Retrospective Cohort Study

Objective This study aimed to compared radiographic and clinical outcomes in Adolescent Idiopathic Scoliosis (AIS) patients undergoing posterior spinal fusion (PSF) with and without thoracoplasty.

Summary of Background Data Scoliosis is a three-dimensional deformity. As a result, patients often have an associated rib cage deformity, with clinical and aesthetic implications. Direct vertebral rotation (DVR) allows for some reduction of the rib hump; however, the deformed ribs remain deformed. Rib resection has been utilized to further reduce the rib hump, however there are concerns of increased pain, operative time, and blood loss.

Methods Retrospective review of 400 AIS patients undergoing PSF between 2018–2023. Patients were stratified based on those who underwent rib resectioning (RR) and those who did not (Non-Rib Resection, N-RR). Radiographic, surgical, and clinical outcomes were compared. Clinical outcomes were collected utilizing SRS-22 and our institution's activity questionnaire, validated via "test-retest" method. All data is presented as medians, IQR, frequencies, and percents. Fisher's Exact, Chi-squared, and Wilcoxon rank-sum tests were used.

Results 153 patients were in the RR group, 247 were in the N-RR. Preoperative rib hump was not statistically significant between the two groups ($p=0.49$). Final rib hump was 16.3 mm in RR patients and 29.8 mm in N-RR ($p<0.001$). RR had 60.5% rib hump correction; N-RR had 30.4% correction ($p<0.001$). Patient reported self-image ($p=0.02$) and mental health ($p=0.01$) scores had significantly improved in RR. No differences in 90-day complication rates ($p=0.19$) or self-reported return to activities ($p>0.05$).

Conclusion Rib resectioned patients had approximately double the amount of rib hump correction at 60.5%, compared to those who did not undergo rib resectioning at 30.4%, with no increase in the rate of complications. RR patients had improved self-reported self-image and mental health scores, with no difference in timing for return to activities.

Key Points

1. Rib resectioning allows for a significant reduction in radiographic rib hump.
2. Rib resectioning improves self-reported self-image and mental health scores according to the SRS-22 questionnaire.
3. There were no differences observed in complication rates, including respiratory complications between rib resectioning patients and those who did not undergo rib resectioning.

Introduction

Scoliosis, characterized by lateral curvature and vertebral rotation, also leads to rib cage abnormalities that impact clinical outcomes and body image.[1]Thoracoplasty is an adjunctive surgical procedure aimed at addressing rib deformity, usually performed alongside scoliosis correction surgery to improve posterior chest wall and functional results.[2] However, the addition of thoracoplasty introduces surgical complexity to corrective spinal fusion and leads to increased pain, operative time, and blood loss.[1,3–6]

In 1995, Lenke et al demonstrated a temporary reduction in pulmonary function test (PFT) values in idiopathic scoliosis patients undergoing posterior spinal fusion with segmental spinal instrumentation and a concomitant thoracoplasty.[7] Albeit the PFT values returned to baseline at about 2 years, this led to criticism and hesitation to perform thoracoplasty.[7] Further, Lee et al introduced the concept of direct vertebral rotation (DVR). [8] This is achieved with segmental instrumentation, such as pedicle screws. After DVR, the rib hump is less prominent, so routine thoracoplasty was deemed unnecessary. In 2008, Suk et al reported his experience with thoracoplasty and noted patients who underwent thoracoplasty (whether with or without

DVR) had superior rib hump correction and self-reported self-image scores.[2] Since then, thoracoplasty is slowly becoming increasingly used. Although pedicle screws address the deformity in all three planes and the rib deformity often decreases, it still remains prominent and a concern to the teenage patient and family. The ribs and chest wall that get deformed because of the vertebral rotation in scoliosis remain deformed after scoliosis correction, while scoliosis correction 'repositions' the rib prominence it does not directly address it.

In certain patients, this residual rib hump gives rise to body image issues and occasionally pain as well. Adolescents are particularly sensitive to their self-image because they are in their formative years, and the altered appearance of their trunk from rib deformity can significantly affect their self-esteem.[1,9–11] Thoracoplasty can be attractive to these patients and families as the rib deformity is often the primary motive for many to seek treatment in the first place.[2,12,13] At this institution, the possibility of thoracoplasty is discussed at the preoperative appointment but a final decision is made intraoperatively after assessing the residual rib hump following scoliosis correction.

This is the analysis of outcomes of scoliosis patients that have undergone rib resectioning concurrently with their spinal fusion and its impact on patient's function and outcomes, as well as associated complications.

Methods

This is an IRB-approved, retrospective chart review of pediatric patients (<18 years) with adolescent idiopathic scoliosis (AIS) from a single institution who had undergone a posterior spinal fusion (PSF) between 2018 and 2023. 400 patients were divided into two groups: those who had thoracoplasty/rib resectioning (Rib Resection Group, n=153) and those who did not

(Non-Rib Resection Group, n=247). Patients with neuromuscular or syndromic scoliosis were excluded. Revision procedures were excluded.

Demographic characteristics included age, sex, and BMI. Radiographic measurements included preoperative and postoperative Cobb angles, cobb correction, levels fused, fixation points, preoperative and final rib hump (mm), and rib index. Rib hump was defined as the vertical distance from the apex of the most prominent convex rib hump to the apex of the concave rib at the same level, according to Suk et al.[2] Surgical data included estimated blood loss (EBL), allogenic transfusion rate, operative time, narcotic refill rate, out of bed (OOB), 90-day complications, respiratory complications, VAS scores at rest and activity, length of stay (LOS), total opioid consumption, and grand total opioid consumption (the sum of the total hospital stay opioid consumption and the patient's initial take-home opioid prescription). At most recent follow-up, patients completed both the Scoliosis Research Society 22 (SRS-22) questionnaire, assessing the following: pain, function, self-image, mental health, and satisfaction, and the institution's activity questionnaire. For the activity questionnaire, patients are asked to self-assess their activity levels on a 1-10 Likert scale. Patients were also asked involvement of preoperative activities and months to return to preoperative activities. This scale was developed due to a lack of standard activity questionnaires and validated through the "test-retest" method with a minimum of three weeks between each response. Kappa coefficients (κ) and intraclass correlation coefficients (ICC) were calculated to determine agreement between questionnaire responses *(Tables 1a and 1b).*

Surgical Procedure

The providers determine the need for thoracoplasty based on preoperative physical "push-prone" examination, where the patient is lying prone and the surgeon pushes on the rib

prominence to see if the ribs level out, parental/patient concerns, and intraoperative assessment. The thoracoplasty procedure is performed in the periapical region where the ribs are most prominent. The thoracodorsal fascia is incised to expose the prominent ribs subperiosteally, using Cobb elevator, Alexander rib stripper, and Doyen retractors. 3-5 ribs are resected, depending on the extent of rib hump deformity and the surgeon's discretion.

The ribs are exposed subperiosteally utilizing a small Cobb elevator. The ventral portion of the rib periosteum is elevated with the Cobb elevator. An AM8 burr is used to burr down on the rib with the Cobb elevator protecting the lungs anteriorly. Once the rib is completely cracked down in a controlled manner, the distal rib is elevated with the help of a Kocher. Further dissection is done with the Alexander rib stripper or a Doyen to dissect the ventral periosteum/pleura away. Following this, a rib cutter is introduced, and 1-2 inches is resected. This process is repeated as many times as needed based on the number of ribs to be resected. Following this, Valsalva maneuver is carried out twice with the pressure raised to 40 mmHg to ensure there are no pleural leaks.

Statistical Analysis

Continuous variables are presented as median and interquartile ranges (25^{th}-75^{th}) and analyzed using Wilcoxon rank-sum tests. Categorical variables are presented as frequencies and percentages and analyzed using Chi-squared test or Fisher's exact tests. An independent biostatistician performed all statistical analyses using SAS software version 9.4 (SAS Institute Inc., Cary, NC). All p-values were two-tailed, with $p<0.05$ considered significant.

Results

Demographic and Radiographic Data

This study had a total of 400 patients. 153 patients were in Rib Resectioning (RR) group, and 247 patients were in Non-Rib Resectioning (N-RR) group. There were no demographic differences between the groups ($p>0.05$).

In the RR group, median preoperative rib hump was 43.1 mm, final rib hump was 16.3 mm, and rib hump correction was 60.5%. In the N-RR group, median preoperative rib hump was 43.5 mm ($p=0.49$), final rib hump was 29.8 mm ($p<0.001$), and rib hump correction was 30.4% ($p<0.001$). Levels fused were significantly higher in RR patients at a median and interquartile range of 12.0 (11.0, 13.0) levels compared to 12.0 (10.0, 12.0) levels in N-RR ($p=0.04$). 69.7% of RR patients have 12 or more levels fused, compared to 56.0% N-RR patients ($p=0.01$). Fixation points were also significantly higher in RR ($p<0.001$). *(Table 2).*

Surgical Data

RR had 500.0 mL EBL, significantly higher than 400.0 mL in N-RR group ($p=0.02$). 37 (24.2%) RR patients had more transfusions than 37 (15.0%) N-RR patients ($p=0.02$). Operative time in the RR group was 252.0 minutes and the N-RR group was 245.0 minutes ($p=0.78$). No differences in maximum VAS pain scores ($p>0.05$). Both groups had a median LOS of 4.0 days ($p=0.31$). RR patients consumed a grand total of 218.5 mg of opioids, significantly more than 183.2 mg in N-RR ($p<0.001$). 16 (10.5%) RR patients requested a narcotic refill, compared to 16 (6.5%) N-RR patients ($p=0.15$).

Complications

The RR group had 6 (3.9%) complications: 3 patients developed a surgical site infection (SSI), one patient developed superior mesenteric artery (SMA) syndrome, one patient developed atelectasis and required nasal cannula, and one patient experienced pleural effusion, which

required a chest tube to be placed. There were 2 (1.3%) respiratory complications in this group: pleural effusion and atelectasis requiring nasal cannula. The N-RR group had 4 (1.6%) complications (p=0.19): one SSI, one case of spontaneous perforated bowel from impacted stool, one patient who developed atelectasis and required nasal cannula, one patient who visited the ER for tachycardia, fever, and respiratory distress. There was 1 (0.40%) respiratory complication: atelectasis that required nasal cannula (p=0.56). *(Table 3).*

SRS-22

71 patients in the RR group and 73 patients in the N-RR group completed the SRS-22 questionnaire. RR patients had significantly higher self-image (4.8 vs 4.6, p=0.02) and mental health scores (4.8 vs 4.4, p=0.01) when compared to the N-RR group. No other differences in survey results were observed. *(Table 4).*

Activity Questionnaire

85 RR patients and 124 N-RR patients completed the activity questionnaire. There were no reported differences in return to sports (p=0.87), running (p=1.0), or carrying a backpack (p=0.39). There were no differences in time to return to sports (p=0.49), running (p=0.78), or carrying a backpack (p=0.62). 77.4% of RR patients participated in physical therapy (PT) after surgery, compared to 67.1% of N-RR patients (p=0.17). *(Table 5).*

Discussion

This study aimed to investigate the functional and clinical outcomes of thoracoplasty on AIS patients who underwent PSF. There were four main findings in this study: patients that undergo rib resectioning a) have a greater reduction in their rib hump b) have better self-image

and mental health values according to SRS-22 c) rib resectioning does not impact time to return to running, sports, or physical therapy participation, and d) both the patients who underwent rib resectioning and those that did not experienced similar rates of complications, including respiratory complications.

Rib Hump Difference

Radiographically, rib resectioning reduces the rib hump by 60.5%, this is double what is observed in the patients who did not undergo rib resectioning, who experienced only a 30.4% reduction in their rib hump. This improvement is seen across all aspects of the rib deformity assessment including final rib hump, rib hump correction, and final rib index. Suk et al. in 2008, also found a significant rib hump correction, a 57% reduction in the rib deformity in those who underwent a thoracoplasty procedure.[2] Suk et al's study investigated the outcomes of patients who underwent spinal fusion with both thoracoplasty and direct vertebral rotation (T-DVR), those with thoracoplasty without DVR (T+N-DVR), and those with no thoracoplasty (N-T).[2] T-DVR had the best rib hump and angle correction with 70% correction, T+N-DVR had 57% correction, and N-T had the least correction at 35% .[2] Min et al conducted a study with 21 AIS patients who underwent thoracoplasty.[10] Their findings showed patients had a 40% improvement in radiographic rib hump and a 44% improvement in their clinical rib hump.[10] Geissele et al found that in 50 thoracic scoliosis patients who underwent thoracoplasty, the mean reduction in rib prominence was 71% in the thoracoplasty group, compared to 17% in the control group (26 randomly selected age and instrumentation-matched scoliosis patients).[11] They found that regardless of the instrumentation used (CD, Harrington, or Luque) thoracoplasty generates a significant difference between preoperative rib prominence and follow-up rib prominence across each group; this difference was not seen in the control group.[11]

Patient-Reported Outcomes

Body image is extremely important in the formation of one's confidence and self-satisfaction.[2,10,11] Adolescents are especially vulnerable to negative thoughts regarding self-image, which can significantly impact their mental state and health.[14,15] It was observed that compared to N-RR patients, RR patients had significantly better self-image and mental health scores. Sherman et al, Duray et al, and Suk et al all found that rib-resected patients had improved self-image scores.[1,2,16] Min et al reported no significant difference in any reported SRS parameter which included self-image, however this was in a small sample size of only 21 patients.[10]

Rib resectioning does not affect time to return to running, sports, carrying a backpack, or participation in physical therapy. In a 2007 analysis of 254 PSF patients, Newton et al found that while PSF by itself resulted in clinically significant improvements in PFT values such as FVC (forced vital capacity), TLC (total lung capacity), and FEV1 (forced expiratory volume) on average, both an open anterior approach and a thoracoplasty adjunct correlated with lower average patient PFTs.[5] They noted that the addition of thoracoplasty to a posterior surgical approach significantly increased the likelihood of patients experiencing a decrease of at least 15% in their predicted PFT values two years after surgery, with 29% of patients affected compared to 11% who underwent the N-RR procedure.[5] Similarly, recent systematic reviews and meta-analyses by Kumar et al and Turner et al found that certain PFT values during a minimum 2-year follow-up period were reportedly lower for patients who underwent PSF with thoracoplasty.[13,17] The present study did not conduct PFTs as it is not standard of care, instead return to sports and exercise was utilized as a clinical surrogate of pulmonary function. Participation in athletic activities shows some relation to superior PFTs. Dugral et al evaluated pulmonary function in university students with a mean age of 19.37 years.[18] They reported that

FEV1 and FVC values were higher in those who exercised, specifically in females who exercised when compared to sedentary females.[18] Further, Lazovic et al and Durmic et al have shown that endurance athletes have shown greater performance in FEV1 and FVC values.[19,20] The present patient's self-reported activity outcomes demonstrate that even if there was an observed reduction in PFTs, there is no functional effect since return to athletic activities such as running and sports, including competitive sports, was not significantly different between the two groups.

Other Perioperative Outcomes

However, slight increased blood loss (500.0 mL vs. 400.0 mL) was observed, as well as higher transfusion rates in the RR group, both of which were significant. These results may be secondary to the more levels fused in the RR group, although the median is 12.0 levels in both groups the IQR is 11.0-13.0 levels, compared to 10.0-12.0 levels in the N-RR group. Further, 69.7% of RR patients had 12 or more levels fused, compared to only 56.0% in the N-RR group, which was significantly lower (p=0.01). Notably, this difference did not seem to impact operative time. It also did not appear to affect maximum VAS pain scores, both at rest and activity, however this was likely because patients in the RR consumed more pain medication to account for their increased pain which is seen in a higher grand total opioid consumption with RR patients. Sherman et al observed no increase in opiate consumption, VAS scores, or length of hospitalization in their study on 46 AIS patients who underwent PSF with thoracoplasty when compared to those that did not receive thoracoplasty.[1] In the present study, although a 19.2% increase (35.3 mg) in the grand total opioid consumption in RR patients was observed, their opioid consumption is still substantially lower than opioid consumption results that have been previously reported in patients who were receiving PCA.[21]

No significant difference was observed in days to OOB, LOS, or 90-day complications. 90-day respiratory complications were isolated and analyzed as well, which showed no significant difference. The RR group had 6 (3.9%) and the N-RR group had 4 (1.6%) complications within 90 days. Between the groups, a total of three patients who experienced respiratory complications was found. 1.3% of RR patients, compared to 0.4% of N-RR patients experienced a respiratory complication. A thoracoplasty procedure's proximity to the pleura causes concern over potential damage and respiratory complications such as pleural effusions.[22] Duray et al noted an increase in pleural effusions in the thoracoplasty group (63%); similarly, Sherman et al saw 4.3% pleural effusions, while Min et al noted 9.5% experienced pleural effusion.[1,2,10,16,22] In the present study, one patient in RR had a pleural effusion (0.65%) and one had atelectasis. The pleural effusion required placement of a chest tube. There were no pleural effusions in the N-RR group.

Limitations

Future studies could contribute to a better consensus on the impact of thoracoplasty on lung physiology. With regards to the positive effects of thoracoplasty on self-image and mental health, the complexity of assessing mental health and self-image outcomes may not be well captured in limited Likert-type scale survey.

Conclusion

Rib resection patients had better correction of their rib deformity, with a 60.5% decrease in their rib hump compared to only a 30.4% in the non-rib resectioned patients, this was without an increase in the rate of complications. Finally, rib resectioned patients had better SRS-22

outcomes in terms of self-image and mental health, and there was no difference in timing for return to sports and similar activities.

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Table 1a. Activity Questionnaire Validation Results for Categorical Variables. Kappa Coefficient ranges from 0.0 to 1.0, closer to 1.0 indicates better reliability.

	Kappa (95% C.I.)
Preop sports	0.92 (0.76, 1.0)
Physical Therapy	0.78 (0.49, 1.0)
Return to sports	0.83 (0.50, 1.0)
Return to gym	0.62 (0.15, 1.0)
Return to backpack	1.0 (1.0, 1.0)
Return to running	1.0 (1.0, 1.0)

Table 1b. Activity Questionnaire Validation Results for Continuous Variables. Intraclass Correlation Coefficient ranges from 0.0 to 1.0, closer to 1.0 indicates better reliability.

	ICC (95% C.I.)
Preop activity	0.78 (0.62, 0.95)
Postop activity	0.87 (0.77, 0.97)

Table 2. Comparison of demographic and radiographic variables between AIS patients that underwent rib resectioning and those that did not. Data is presented as averages and 95% confidence intervals. Statistical values with $p < 0.05$ are considered statistically significant and bolded.

	RR (n=153)	**N-RR (n=247)**	**P**
Age (years)	15.0 (13.5, 17.0)	15.3 (13.9, 16.9)	0.57
BMI (kg^2/m)	21.4 (19.3, 25.1)	21.1 (19.1, 25.7)	0.71
Female, n(%)	109 (71.2%)	173 (70.0%)	0.80
Preop Cobb (°)	54.9 (48.3, 66.2)	54.0 (50.1, 60.0)	0.56
Postop Cobb (°)	17.4 (9.2, 22.4)	17.0 (10.5, 22.0)	0.98
Cobb Correction (%)	71.4 (60.6, 80.0)	68.0 (61.3, 79.8)	0.49
PreOp Rib Hump (mm)	43.1 (34.1, 57.2)	43.5 (35.8, 49.3)	0.49
Final Rib Hump (mm)	16.3 (13.8, 22.4)	29.8 (25.1, 34.8)	**<0.001**
Rib Hump Correction, (%)	60.5 (51.7, 70.7)	30.4 (22.8, 40.2)	**<0.001**
PreOp Rib Index	2.7 (2.0, 3.7)	2.6 (2.0, 3.5)	0.36
Final Rib Index	2.1 (1.7, 2.6)	2.4 (1.7, 3.2)	**0.006**
Levels Fused	12.0 (11.0, 13.0)	12.0 (10.0, 12.0)	**0.04**
Levels fused ≥ 12, n (%)	85 (69.7%)	130 (56.0%)	**0.01**
Fixation Points	25.0 (24.0, 27.0)	24.0 (20.3, 25.0)	**< 0.001**

P-values were obtained from Wilcoxon-rank sum tests for continuous variables and chi-square or Fisher's exact tests for categorical variables.

Table 3. Comparison of hospital course and surgical outcomes between AIS patients that underwent rib resectioning and those that did not. Pain scores are only calculated for the first three days (POD 0 – POD 2). Data is presented as averages and 95% confidence intervals. Statistical values with $p < 0.05$ are considered statistically significant and bolded.

	RR (n=153)	**N-RR (n=247)**	**P**
EBL (mL)	500.0 (300.0, 700.0)	400.0 (300.0, 600.0)	**0.02**
Operative Time (mins)	252.0 (217.0, 294.0)	245.0 (217.0, 295.0)	0.78
Transfusion, n(%)	37 (24.2%)	37 (15.0%)	**0.02**
Max Pain Score at Activity			
POD 0	5.5 (3, 7)	5 (4, 8)	0.74
POD 1	6 (4, 8)	6 (4, 8)	0.61
POD 2	7 (5, 8)	6 (5, 7)	0.10
Overall	8 (6, 9)	7 (6, 8)	0.25
Max Pain Score at Rest			
POD 0	5 (4, 7)	5 (4, 7)	0.87
POD 1	6 (4, 8)	6 (4.5, 8)	0.42
POD 2	7 (5, 8)	7 (6, 8)	0.16
Overall	8 (5, 9)	8 (7, 9.5)	0.07
Narcotic refill (%)	16 (10.5%)	16 (6.5%)	0.15
Total Opioid Consumption	147.8 (112.5, 188.7)	128.7 (92.5, 169.8)	**0.002**
Grand Total Opioid Consumption	218.5 (161.5, 267.7)	183.2 (134.6, 239.4)	< **0.001**
OOB by POD 1 OOB after POD 1	135 (97.1%) 4 (2.9%)	224 (99.6%) 1 (0.4%)	0.07
LOS (days)	4.0 (3.0, 5.0)	4.0 (3.0, 4.5)	0.31
90-day complications, n (%)	6 (3.9%)	4 (1.6%)	0.19
Respiratory Complications, n(%)	2 (1.3%)	1 (0.4%)	0.56

P-values were obtained from Wilcoxon rank-sum tests for continuous variables and chi-square or Fisher's exact tests for categorical variables.

Table 4. Comparison of **SRS-22** results between AIS patients that underwent rib resectioning and those that did not. Data is presented as averages and 95% confidence intervals. Statistical values with $p < 0.05$ are considered statistically significant and bolded.

	RR (n=71)	**N-RR (n=73)**	**p-value**
Pain	4.6 (4.2, 5.0)	4.6 (4.0, 5.0)	0.48
Function	5.0 (4.4, 5.0)	4.8 (4.6, 5.0)	0.53
Self-image	4.8 (4.2, 5.0)	4.6 (4.0, 5.0)	**0.02**
Mental Health	4.8 (4.2, 5.0)	4.4 (4.0, 4.8)	**0.01**
Satisfaction	5.0 (4.5, 5.0)	5.0 (4.5, 5.0)	0.93

P-values were obtained from Wilcoxon rank-sum tests.

Table 5. Comparison of **activity questionnaire** results between AIS patients that underwent rib resectioning and those that did not. Data is presented as averages and 95% confidence intervals. Statistical values with $p < 0.05$ are considered statistically significant and bolded.

	RR (n=85)	**N-RR (n=124)**	**P**
Preop sports, n(%)	36/56 (64.3%)	47/86 (54.7%)	0.26
Of those who did preop sports, Return to sports, n(%)	25/36 (69.4%)	27/47 (57.4%)	0.26
Total return to sports	41/ 53 (77.4%)	51/67 (76.1%)	0.87
Time to sports (months)	3.0 (2.0, 6.0)	3.5 (2.0, 12.0)	0.49
Return to running, n(%)	55/59 (93.2%)	72/78 (92.3%)	1.0
Time to running (months)	3.0 (2.0, 6.0)	3.0 (1.5, 4.5)	0.78
Return to backpack, n(%)	59/60 (98.3%)	75/79 (94.9%)	0.39
Time to backpack (months)	2.0 (1.5, 4.0)	2.0 (1.3, 3.0)	0.62
Participated in physical therapy (PT), n(%)	48/62 (77.4%)	55/82 (67.1%)	0.17

P-values were obtained from Wilcoxon rank-sum tests for continuous variables and chi-square or Fisher's exact tests for categorical variables.