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DEFORMITY

Upper Thoracic *Versus* Lower Thoracic Upper Instrumented Vertebrae Endpoints Have Similar Outcomes and Complications in Adult Scoliosis

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Study Design. Retrospective review—multicenter database.

Objective. The purpose of this study was to compare the upper thoracic (UT) and lower thoracic (LT) upper instrumented vertebrae (UIV) in long fusions to the sacrum for adult scoliosis.

Summary of Background Data. The optimal UIV for stopping long fusions to the sacrum/pelvis are controversial. Although a UT endpoint may lead to greater operative times, blood loss, and higher rates of pseudarthrosis, the risk for the development of proximal junctional kyphosis and need for revision surgery is likely lower.

Methods. Retrospective analysis of a prospective database of patients with adult spinal deformity, Patients were selected on the basis of fusions to the sacrum/pelvis with UIV of T1–T6 (UT group) and those with a UIV of T9–L1 (LT group). Demographic data, operative details, and radiographical outcomes with Scoliosis Research Society scores, and Oswestry Disability Index outcomes were collected, as well as complication data were compared. The Fisher exact *T* tests were used for statistical analysis.

Results. A total of 198 patients (UT = 91, LT = 107) with a mean age of 61.6 were followed for an average of 2.5 years. Demographic variables were similar between the groups except for larger numbers of females in the UT group and a slightly higher body mass index in the LT group. Preoperatively, the UT group demonstrated significantly more lumbar scoliosis, thoracic scoliosis, and thoracolumbar kyphosis. The UT group demonstrated a larger number of fused segments length of stay and longer operative times. There was slightly larger volume of blood loss in the UT group.

The total number of complications and number of revision surgical procedures were similar between the groups. The UT group had a higher percentage of patients with 2 or more complications. Both groups had similar proximal junctional kyphosis angles and number of cases requiring revision for proximal junctional kyphosis. Scoliosis Research Society and Oswestry Disability Index outcomes were similar between the groups.

Conclusion. The UT and LT groups had similar outcomes. The UT group may have a higher rate of total complications, but major complications requiring return to the operative room were similar. The length of stay and operative times were higher in the UT group but may have been necessarily evidenced by the significantly higher coronal deformity and greater thoracolumbar kyphosis in the UT group.

Key words: spinal deformity, long fusion, complication, outcomes, proximal junctional kyphosis.

Level of Evidence: 4

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While performing long fusions to the sacrum and pelvis for adult deformities, the ideal proximal stopping point is not always clear. Although the relative indications for upper thoracic (UT) stopping points (T2–T4) include thoracolumbar kyphosis (TLK), large coronal curves in the thoracic spine, coronal and/or sagittal imbalance, and osteoporosis, whereas lower thoracic (LT) points (T10–T12) are generally used for those curves that are well balanced.[1–3] LT stopping point can mean shorter operative times, lower pseudarthrosis rates, lower rate of complications, and lower implant costs than UT stopping points.[1,4] Although LT stopping points

might be a better option for some patients with adult spinal deformities, LT fusions may result in higher rates of proximal junctional kyphosis (PJK) necessitating revision surgery.[5–7] Determining the criteria for LT *versus* UT stopping points is controversial with conflicting literature on the topic.[1–8]

The purpose of this study was to examine the differences between those patients with adult spinal deformities who underwent long fusions to the sacrum/pelvis with UT *versus* LT upper instrumented vertebrae (UIV) evaluating potential differences between the groups with respect to the demographics, radiographical and clinical outcomes as well as the type and rate of complications. We hypothesized that UT *versus* LT stopping points for long fusions to the sacrum will have (1) similar radiographical and clinical outcomes and (2) similar rates of complications.

MATERIALS AND METHODS

This is a retrospective review of a prospective multicenter database on patients with adult spinal deformities who underwent long fusions (≥5 levels) to the sacrum/pelvis for their deformities.

Inclusion criteria for the multicenter database were age of patients more than 18 years with one of the following criteria: a scoliosis measuring 20° or more, or a sagittal vertical axis (SVA) of more than 5 cm, or a pelvic tilt of more than 25°, or a thoracic kyphosis of more than 60°. Patients in the UT stopping point group were those who had a UIV between T1 and T6, whereas those who were in the LT stopping point group were those with UIVs between T9 and L1. Revision and primary cases were included. Exclusion criteria were patients with scoliosis due to neuromuscular, congenital, trauma, or paralytic etiologies. In addition, patients with incomplete radiographical data were excluded. There were a total of 356 patients in the database, 242 were eligible for the study and 198 (80%) had complete radiographical data to be included for the analysis in the study.

Demographic information collected included age, sex, primary or revision surgery status, body mass index, Charlson Comorbidity Index, and smoking status. Radiographical parameters collected were lumbar scoliosis, thoracic scoliosis, C7 plumb line, PJK angle, cervical lordosis, thoracic kyphosis, TLK, lumbar lordosis, and SVA. PJK angle was defined as the sagittal Cobb angle between the UIV and the UIV + 2. All radiographical parameters were collected at baseline, 1-year, and 2-year time points. Clinical outcomes were assessed by use of the Oswestry Disability Index and the Scoliosis Research Society Questionnaire (SRS score). Clinical outcome scores were also collected at baseline, 1-year, and 2-year time points and composite scores were reported to control for subjective variability in patient-reported questionnaires.

Operative details assessed included the number of fused segments, length of stay (LOS), estimated blood loss, and operative time (OR time). We also assessed the percentage of cases that underwent osteotomies, decompressions, and anterior interbody use between the groups in an attempt to control for cofounding variables causing differences in the operative details. Intraoperative monitoring data were also collected for somatosensory evoked potentials or motor evoked potential differences.

Complications were collected and compared between cohorts including infectious, neurological, cardiopulmonary, vascular, gastrointestinal, operative, renal, wound, radiographical, and death. The total number of complications was tallied and the percentage of major and minor complications as well as the total number of complications requiring revision surgery was assessed.

Statistical analysis was performed by using the Fischer exact *T* test between the cohorts. We performed a Bonferroni correction to correct for multiple hypotheses testing from 1 dataset and therefore, a $P < 0.025$ was considered to be significant.

RESULTS

Of the 354 patients in the database, a total of 198 patients (UT = 91, LT = 107) met inclusion for the study with an average follow-up of 2.5 years (range, 2.0–3.2 yr) Demographic variables were similar between the groups except for larger numbers of females in the UT group (86% *vs*. 65%, $P < 0.01$) and a slightly higher body mass index in the LT group (28.7 *vs*. 26.9 kg/m^2, $P = 0.02$) (Table 1). Preoperatively, the UT group demonstrated significantly more lumbar scoliosis (53.6°*vs*. 33.2°, $P < 0.01$), thoracic scoliosis (41.6°*vs*. 31.7°, $P = 0.01$) and TLK (17.9°*vs*. 8.9°, $P = <0.01$) (Table 2).

The UT group demonstrated a larger number of fused segments (15.4 *vs*. 8.2, $P < 0.01$), LOS (9.1 *vs*. 7.4 d, $P < 0.01$), and longer OR times (430 *vs*. 371 min, $P < 0.01$). There was slightly larger volume of blood loss (1947 *vs*. 1887 mL, $P = 0.08$) in the UT group despite the higher percentage of decompressions performed in the LT group (64% *vs*. 85%, $P < 0.01$) (Table 3).

The total number of major complications was similar between the groups (57% *vs*. 39%, $P = 0.20$) as well as those complications requiring revision surgery (15% *vs*. 22%, $P = 0.19$) (Table 4). Both groups had a similar percentage of

TABLE 1. Demographic Data Between the Upper Thoracic and Lower Thoracic Groups

Demographic	UT (n = 91)	LT (n = 107)	*P*
Age	60.9	62.0	0.45
Sex (female) (%)	86	65	<0.01
History of spine surgery (%)	47	53	0.44
Body mass index	26.9	28.7	0.02
Charlson Comorbidity Index	1.72	1.63	0.69
Smoker (%)	7	9	0.68
Follow-up (yr)	2.53	2.41	0.30

UT indicates upper thoracic; LT, lower thoracic.

TABLE 2. Radiographical Outcomes at 1-Year and 2-Year Time Points

Radiographical Details	UT (n = 91)	LT (n = 107)	*P*
Baseline alignment parameters			
Lumbar scoliosis (°)	53.6	33.2	<0.01
Thoracic scoliosis (°)	41.6	31.7	0.01
C7 plumb line (cm)	−3.8	5.2	0.22
PJK angle	1.7	5.5	<0.01
Cervical lordosis	10.9	10.1	0.74
Thoracic kyphosis	32.4	31.7	0.78
Thoracolumbar kyphosis	17.9	8.9	<0.01
Lumbar lordosis	35.3	36.5	0.67
Sagittal balance (mm)	8.2	7.3	0.38
Parameters at 1 yr			
Lumbar scoliosis (°)	25.2	18.2	<0.01
Thoracic scoliosis (°)	26.7	20.6	0.15
C7 plumb line (cm)	−4.2	−0.9	0.63
PJK angle	14.3	14.4	0.95
Cervical lordosis	11.4	8.6	0.34
Thoracic kyphosis	49.2	46.8	0.44
Thoracolumbar kyphosis	5.9	8.2	0.23
Lumbar lordosis	52.1	53.1	0.64
Sagittal balance (mm)	1.5	3.4	0.05
Parameters at 2 yr			
Lumbar scoliosis (°)	17.5	14.6	<0.01
Thoracic scoliosis (°)	25.6	18.4	0.19
C7 plumb line (cm)	−3.2	0.4	0.70
PJK angle	16.5	19.2	0.37
Cervical lordosis	11.0	8.9	0.60
Thoracic kyphosis	50.9	51.5	0.89
Thoracolumbar kyphosis	6.6	12.4	0.01
Lumbar lordosis	52.1	52.6	0.85
Sagittal balance (mm)	1.9	3.6	0.14

UT indicates upper thoracic; LT, lower thoracic, PJK, proximal junctional kyphosis.

TABLE 3. Operative Details Between Cohorts

Operative Details	UT (n = 91)	LT (n = 107)	*P*
No. of fused segments	15.4	8.2	<0.01
Length of stay	9.1	7.4	<0.01
Estimate blood loss (mL)	1947	1887	0.08
Operative time	430	371	<0.01
Decompressions (% of cases)	64	85	<0.01
Posterior column osteotomy (% of cases)	67	72	0.13
Average no. of osteotomies per case when performed	4.9	3.2	<0.01
Anterior interbody used (%)	29	21	0.20
Electromonitoring data (% use)	99	99	0.94
SSEP changes (%)	3	1	0.28
MEP changes (%)	6	1	0.09

UT indicates upper thoracic; LT, lower thoracic; PJK, proximal junctional kyphosis; SSEP, somatosensory evoked potential; MEP, motor evoked potential.

patients with 2 or more complications (55% *vs*. 43%, $P = 0.38$). Both groups had group had a similar PJK angle (19.2 *vs*. 16.5, $P = 0.37$) and cases requiring revision for PJK (3 *vs*. 2, $P = 0.45$) (Table 4).

SRS and Oswestry Disability Index outcomes were similar between the groups, although there was a difference in the composite appearance subscore at 1 year, it did not reach a minimal clinically significant difference. In addition, the total SRS score at 1-year and 2-year follow-up points was not different between the groups (Table 5). Interestingly, preoperative appearance and pain scores were lower in the LT group, although only the pain score reached minimal clinically significant difference (2.02 *vs*. 2.55; Table 5).

CONCLUSION

Our data suggest that the clinical and radiographical outcomes between patients who undergo fusions to the UT *versus* LT spine are not significantly different at 2-year follow-up. In addition, the rate of complications, although higher in the UT group (57% *vs*. 39%, $P = 0.20$), was also not significantly different. Interestingly, our results were very similar to a smaller study performed comparing UT *versus* LT UIVs in adult spinal deformity surgery.[1] In their study of 58 patients with an average 3-year follow-up, O'Shaughnessy *et al*[1] similarly concluded that there were no clinical or radiographical differences between the UT *versus* LT groups. Although they did find a higher prevalence of complications, pseudarthrosis, and revision surgery in the UT group, none of these differences reached statistical significance when compared with the LT group. In case of clinical outcomes, we noted less improvement in the SRS activity/function score in the UT group *versus* the LT group. This finding was not statistically significant. This is similar to O'Shaughnessy and colleagues who demonstrated no differences in comparing postoperative SRS scores between the groups (Table 5).

Our data suggest that radiographical parameters seemed to dictate the decision for choosing UT *versus* LT UIV stopping points. Those patients who had fusions extending into the UT

TABLE 4. Complication Data Between the Groups

Complications	UT (n = 91)	LT (n = 107)	*P*
Infection	6	3	0.22
Neurological	13	17	0.62
Cardiopulmonary	15	12	0.29
Vascular	0	0	N/A
Gastrointestinal	6	6	0.77
Operative	25	21	0.26
Renal	1	2	0.65
Wound	5	3	0.35
Radiographical	13	9	0.20
Mortality	1	0	0.32
Total no. of complications			
Major, no. (%)	52 (57)	42 (39)	0.20
Minor, no. (%)	59 (64)	58 (54)	0.59
Total complications requiring revision surgery at any time point after index operation (%)	15	22	0.19
Patients with ≥2 complications (%)	55	43	0.38
Pseudarthrosis requiring revision	2	1	0.25
PJK requiring revision	3	2	0.45

UT indicates upper thoracic; LT, lower thoracic; PJK, proximal junctional kyphosis.

TABLE 5. Health-Related Quality of Life Outcomes at 1-Year and 2-Year Time Points

HRQOL Scores	UT (n = 91)	LT (n = 107)	*P*
ODI baseline	44.2	48.1	0.14
Δ ODI @ 1 yr from baseline	−13.8	−17.4	0.19
Δ ODI @ 2 yr from baseline	−13.5	−13.7	0.96
SRS scores			
Activity baseline	2.88	2.64	0.05
Δ @ 1 yr from baseline	0.47	0.67	0.10
Δ @ 2 yr from baseline	0.54	0.73	0.25
Pain baseline	2.55	2.02	<0.01
Δ @ 1 yr from baseline	0.83	1.04	0.14
Δ @ 2 yr from baseline	0.76	0.79	0.89
Appearance	2.36	2.42	0.36
Δ @ 1 yr from baseline	1.42	1.03	0.01
Δ @ 2 yr from baseline	1.27	1.11	0.47
Mental	3.50	3.24	0.07
Δ @ 1 yr from baseline	0.42	0.40	0.86
Δ @ 2 yr from baseline	0.17	0.19	0.93
Satisfaction	2.82	2.53	0.06
Δ @ 1 yr from baseline	1.47	1.53	0.78
Δ @ 2 yr from baseline	1.23	1.51	0.37
Total	2.83	2.62	0.03
Total @ 1 yr	3.69	3.55	0.28
Total @ 2 yr	3.68	3.67	0.93

UT indicates upper thoracic; LT, lower thoracic; PJK, proximal junctional kyphosis; ODI, Oswestry Disability Index; HRQOL, health-related quality of life.

spine had larger coronal plane deformities in the thoracic and lumbar spine, as well as a greater magnitude of TLK. No significant differences were noted in SVA although the UT did have a slightly higher SVA at baseline.

As a result of a fusion extending into the UT spine, the patients in the UT group had longer OR times (~1 hr) despite having a lower percentage of cases requiring an osteotomy. It is possible that the larger average number of osteotomies performed, (4.9 *vs.* 3.2, $P < 0.01$) combined with the larger number of anterior interbody use and the higher prevalence of somatosensory evoked potential/motor evoked potential changes in the UT group partially explains the statistically significant difference noted in the OR time (Table 3). It was also noted that the LOS was 1.7 days higher in the UT group than in the LT group (Table 3). One might speculate that the higher LOS seen in this group is attributed to a larger number of total complications seen in this group (Table 4).

Similar to the O'Shaughnessy study, our UT group demonstrated a higher prevalence of complications than their LT counterparts. Similar to their study, we also did not see a statistically significant difference in complications between the groups. In contrast however, we noted that the rate of revision surgery was 15% in the UT group and 22% in the LT group, whereas the prior study showed a higher rate in the UT group. This may be due to the smaller cohort of 20 patients in their study, which can make a single event cause higher variations in the prevalence of complications.[1] We cannot make any definitive conclusions about pseudarthrosis between these groups because of the length of follow-up time needed to make such conclusions.[3] However, in the 2.5-year average follow-up of our study, we noted 2 pseudarthroses in the UT group and only 1 in the LT group necessitating revision surgery. Interestingly, we also noted a larger number of patients requiring revision surgery for PJK in the UT group than in the LT group (Table 4), despite the higher PJK angle noted in the LT group (Table 2), however, none of these differences were statistically significant between the groups.

Although we did not report our incidence of PJK, we thought it would be more clinically significant to report our data in raw format with PJK angles because there have been many well-done studies reporting the incidence of PJK to be between 20% and 40%.[5–7] PJK angles in our study were between 16° and 19° at 2-year follow-up, which suggests that our incidence is similar when using the traditional definition of PJK being more than 10°.[9] In our study, the PJK angle was not noted to be significantly different between the groups, although at 2 years, the LT group showed a higher PJK angle than the UT group, this difference failed to reach statistical significance (Table 2).

As hypothesized, UT *versus* LT UIV for long fusions to the sacrum/pelvis in adult deformity surgery has similar radiographical and clinical outcomes at an average of 2.5-year follow-up. The prevalence of complications was higher in the UT group; however, the prevalence of complications requiring revision surgery was higher in the LT group. Our data suggest that strong recommendations on using UT *versus* LT stopping points to patients is difficult to make at this time and is largely determined by the magnitude of the patient's deformity and sagittal balance at presentation. A UT UIV does not decrease rates of PJK and similarly, a LT UIV does not result in a lower number of complications requiring revision surgery although the overall number of complications might be less than UT UIVs.

➢ Key Points

- ❑ Clinical and radiographical outcomes at minimum 2-year follow-up are not different between those with long fusion with UT or LT UIV.
- ❑ The UT group had longer OR times and LOS and at baseline, had larger coronal and sagittal plane deformities.
- ❑ The prevalence of complications in the UT group was higher, but not statistically significant than that in the LT group.
- ❑ Proximal junctional kyphosis was similar between the groups.

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