Crossing the Cervicothoracic Junction During Posterior Cervical Decompression and Fusion: Is It Necessary?

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BACKGROUND: Posterior cervical fusion (PCF) is performed to treat cervical myelopathy, radiculopathy, and/or deformity. Constructs ending at the cervicothoracic junction (CTJ) may lead to higher rates of adjacent segment disease, and much debate exists regarding crossing the CTJ due to paucity of data in the literature.

OBJECTIVE: To determine whether extension of PCF constructs across the CTJ decreases incidence of adjacent segment disease and need for revision surgery.

METHODS: A single-center retrospective case series of patients undergoing multilevel PCFs since 2011 with at least 6-mo follow-up was conducted. Outcomes were analyzed and compared based on caudal extent of instrumentation via multivariate regression.

RESULTS: A total of 149 patients underwent PCF, with a mean follow-up of 18.9 mo. A total of 15 (10.1%) revisions were performed, 7 (4.7%) of which were related to the construct. Five (8.3%) revisions were performed for constructs ending at C6, 1 (5.3%) at C7, 1 (2.6%) at T1, and none (0%) at T2 ($P = .035$). Mean procedure duration was 215 min at C6, 214 min at C7, 239 min at T1, and 343 min at T2 ($P = .001$). Mean estimated blood loss was 224 mL at C6, 178 mL at C7, 308 mL at T1, and 575 mL at T2 ($P = .001$). There was no difference in length of stay, disposition, surgical site infection, or radiographic parameters.

CONCLUSION: Extension of PCFs across the CTJ leads to lower early revision rates, but also to increased procedure duration and estimated blood loss. As such, decisions regarding caudal extent of instrumentation must weigh the risk of pseudarthrosis against that of longer procedures with higher blood loss.

KEY WORDS: Adjacent segment disease, Cervicothoracic junction, Posterior cervical fusion, Revision surgery

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Posterior cervical instrumentation and fusion is commonly performed for patients with cervical myelopathy, radiculopathy, or deformity. A significant portion of these cases require instrumentation caudally to C6 or C7. The prevalence of clinical adjacent segment disease (ASD) after cervical fusion is quoted from 11.0% to 38.1%,[1] giving rise to a situation whereby recent literature has debated prophylactic extension to T1 or below in an effort to avoid accelerated breakdown at the cervicothoracic junction (CTJ).[2-5]

ABBREVIATIONS: ASD, adjacent segment disease; **BMI,** body mass index; **CTJ,** cervicothoracic junction; **EBL,** estimated blood loss; **LOS,** length of hospital stay; **PCF,** posterior cervical fusion; **SSI,** surgical site infection; **STROBE,** Strengthening the Reporting of Observational Studies in Epidemiology; **SVA,** sagittal vertical axis

The hypothesis behind this extension is based on the unique set of biomechanical forces and constraints imposed at the CTJ. As reported by Schroeder et al,[4] the subaxial cervical spine provides up to 20° of combined flexion/extension, 10° of lateral bending, and 5° to 7° of rotation per level. This mobility is in stark contrast to the structurally rigid thoracic spine, which permits <5° of flexion/extension and lateral bending per level. The CTJ is also a transition point between the lordosis of the cervical spine and the kyphosis of the thoracic spine.[4,6] It is postulated that postinstrumentation ASD occurs secondary to a larger force/moment arm on a given joint, in addition to limited segmental flexibility adjacent to said joint. The substantial difference between mobility in the cervical and thoracic spine may amplify rates of ASD at the CTJ when multilevel cervical constructs are terminated in the lower cervical spine.[4,6,7]

Although the extension of posterior cervical instrumentation across the CTJ may reduce the rate of CTJ ASD compared to constructs ending in the cervical spine, this must be balanced against theorized increased operative risks. Despite the vast number of these surgeries performed, there remains a paucity of literature investigating this subject with limited evidence to guide surgeons. The goal of this study is to analyze the need for revision surgery based on caudal extent of multilevel posterior cervical instrumentation, in addition to evaluation of several perioperative, outcome, and radiographic measures.

METHODS

A single-center retrospective review (case series) of all multilevel (3 or more levels) posterior cervical fusions (PCFs) done by 5 spine fellowship trained attending neurosurgeons since the implementation of our institution's electronic medical record in June 2011 was performed. All patients were 18 yr of age or older and had at least 6 mo of follow-up. Patients were excluded if age was less than 18 yr, follow-up was less than 6 mo, or if surgery was performed due to trauma or underlying malignancy or infection. Caudal level of instrumentation was selected based on each surgeon's judgment and determination of the amount of degenerative disease at C7-T1 based on degree of facet arthropathy and canal and foraminal stenosis. Extension across the CTJ was favored in cases involving kyphotic deformities or presence of degenerative disease at the CTJ. If stopping short of the CTJ, care was taken not to disrupt the facets and interspinous ligaments. When extension to the thoracic spine was performed, instrumentation at the C7 segment was skipped in most cases due to proximity of the screw heads at C7 and T1. If the construct ended at C7, lateral mass screws were placed using the "down and out" technique. Single diameter rods were used in all cases. Demographic, perioperative, outcome, and radiographic data were collected. The primary outcome was need for revision surgery due to factors related to the initial surgery, namely pseudarthrosis, ASD, or hardware failure. Duration of procedure, estimated blood loss (EBL), length of hospital stay (LOS), disposition (home vs rehabilitation), and incidence of surgical site infection (SSI) were also tracked as secondary endpoints. Furthermore, postoperative cervical spine parameters—cervical lordosis, cervical sagittal vertical axis (SVA), and T1 slope—were measured by 2 neuroradiologists for patients who had imaging available. Figure outlines the study patient population and selection process.

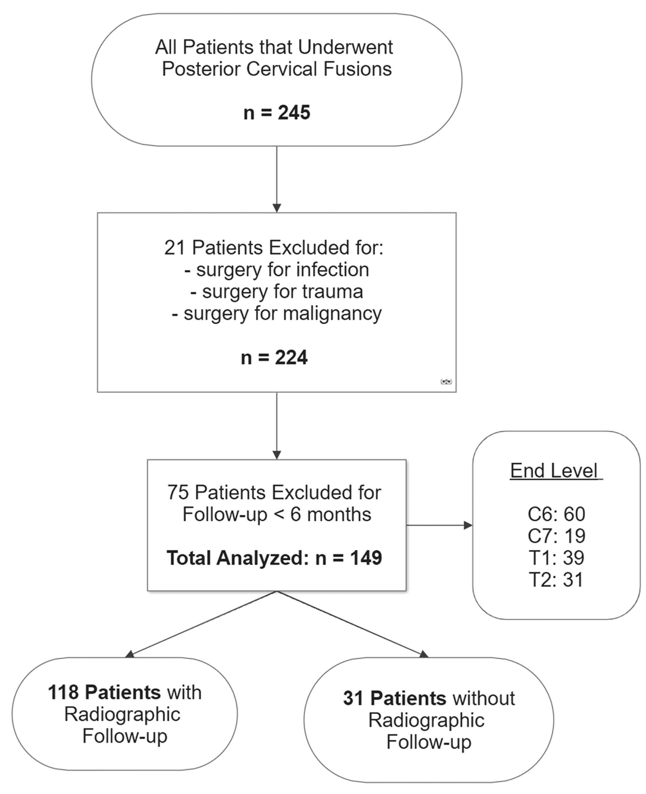

FIGURE. *Patient study population: inclusion and exclusion criteria, number of patients per end level, and number of patients with and without radiographic follow-up.*

Statistical Analysis

After demographic data were collected from the electronic medical record, patients were divided into groups based on end level of the construct: C6, C7, T1, or T2, as well as combined cervical (C6 or C7) or thoracic (T1 or T2) end level groups to compare to other studies in the literature. Groups were compared for significant differences in demographics using the Kruskal-Wallis equality of populations test for continuous variables and the Fisher exact test for categorical variables. Next, a multivariate regression analysis was performed using the individual end levels, in which the independent variables were age, gender, body mass index (BMI), prior or concurrent anterior fusion, attending surgeon performing the operation, and end level (primary variable), and the dependent variables were need for revision (binary, primary outcome), duration of procedure, EBL, LOS, disposition (binary), and SSI (binary). Probit regression analysis was used for binary variables, including need for revision surgery, disposition, and SSI. The radiographic parameters—cervical lordosis, cervical SVA, and T1 slope—were compared between groups based on end level of the construct using the Kruskal-Wallis test, and then compared based on need for revision using the Mann-Whitney test. Statistical analyses were performed using Stata (StataCorp, College Station, Texas) and Prism (GraphPad, San Diego, California), with a prospectively determined P-value of $<.05$ taken to indicate significant difference for all analyses.

Study Design and Ethics

This study adheres to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines. This study was approved by our institution's Institutional Review Board (Georgetown University IRB: STUDY00000556) and did not require patient consent due to the retrospective nature of the analysis.

TABLE 1. Demographic Data

End level	C6	C7	T1	T2	C6 + C7	T1 + T2	Total	*P* value
n	60	19	39	31	79	70	149	
Age	63.5 (57.0-69.3)	68.0 (59.0-71.5)	64.0 (56.0-72.0)	66.0 (59.5-71.5)	65.0 (57.5-70.0)	65.5 (56.5-71.8)	65.0 (57.0-71.0)	.692
Male gender	71.7%	47.4%	51.3%	29.0%	65.8%	41.4%	54.4%	**.001**
Female gender	28.3%	52.6%	48.7%	71.0%	34.2%	58.6%	45.6%	
BMI	29.8 (24.5-32.7)	28.0 (24.3-33.0)	27.5 (24.0-31.8)	28.7 (24.9-33.0)	29.8 (24.4-32.8)	28.0 (24.3-32.6)	28.1 (24.3-32.8)	.899
Anterior fusion	11.7%	10.5%	7.7%	32.3%	11.4%	18.6%	15.4%	**.034**
Follow-up duration	15.0 (9.7-28.7)	17.0 (11.4-22.8)	11.4 (7.1-21.5)	12.4 (7.8-17.6)	15.4 (10.2-28.6)	12.1 (7.1-20.1)	13.0 (7.9-22.9)	.076
Attending surgeon								.137

Median (interquartile range). Bold values indicate statistical significance.

TABLE 2. Included Revisions

Initial surgery	Reason for revision	Revision surgery
C3-6 decompression and instrumented fusion	Caudal adjacent segment disease and kyphotic deformity	C3-T2 extension of fusion
C3-6 decompression and instrumented fusion	C6-7 dynamic instability and stenosis	C2-T2 extension of fusion
C2-6 decompression and instrumented fusion	C1-2 dynamic instability and C6-T1 adjacent segment disease	O-T2 extension of fusion
C2-6 decompression and instrumented fusion	C6-7 adjacent segment disease	C6-7 anterior cervical discectomy and fusion
C3-6 decompression and instrumented fusion	C5-6 recurrent stenosis	C5-6 anterior cervical discectomy and fusion
C3-7 decompression and instrumented fusion	C7-T1 kyphotic deformity	C7 pedicle subtraction osteotomy and C3-T4 extension of fusion
C3-7 decompression and C3-T1 instrumented fusion	C2-3 and T1-2 adjacent segment disease	C2-T2 extension of fusion

RESULTS

Demographic Analysis

A total of 149 patients underwent multilevel PCF and met inclusion and exclusion criteria, with a mean follow-up duration of 18.9 mo (range 6.0-79.4 mo). A total of 60 (40.3%) constructs ended at C6, 19 (12.8%) ended at C7, 39 (26.2%) ended at T1, and 31 (20.8%) ended at T2. When combining groups, 79 (53.0%) constructs ended in the cervical spine and 70 (47.0%) constructs ended in the thoracic spine. Kruskal-Wallis and Fisher exact tests showed no differences in age, BMI, follow-up duration, or attending surgeon between groups. There were, however, differences in gender and presence of anterior fusion. There were more males (71.7%) in the constructs ending at the C6 group and more females (71.0%) in the T2 group ($P = .001$). Constructs ending at T2 had more prior or concurrent anterior fusions (32.3%) than the other groups ($P = .034$). Demographic data are listed in Table 1.

Primary Outcome

A total of 15 total revision surgeries were performed, giving an initial revision rate of 10.1%. However, only 7 (4.7%) of these revisions were related to pseudarthrosis, ASD, or hardware failure, and they are listed in more detail in Table 2. Excluded reasons for revision are listed in Table 3. Of note, one excluded revision involved misplacement of a T1 screw. While screw misplacement is certainly a complication of longer constructs bridging the CTJ, we believe that it is more of a technical error and does not reflect the long-term stability of these constructs in relation to the CTJ, and, as such, it was excluded. Five (8.3%) revisions were performed for constructs ending at C6, 1 (5.3%) at C7, 1 (2.6%) at T1, and none (0%) at T2 ($P = .035$) (Table 4). A multivariate regression was then performed. End level was the only variable to have an independent effect on revision rate ($P = .035$), while age ($P = .556$), gender ($P = .137$), BMI ($P = .668$), presence of anterior fusion ($P = .581$), and attending surgeon ($P = .058$) did not. Results of the multivariate regression analysis are listed in Table 5.

Secondary Outcomes

The multivariate regression also included multiple secondary outcomes as dependent variables: duration of procedure, EBL, LOS, disposition, and SSI. End level had a significant effect on duration of procedure and EBL but not on LOS, disposition,

TABLE 3. Excluded Revisions

Initial surgery	Reason for revision
C3-6 decompression and instrumented fusion	Proximal junctional kyphosis at T3 related to prior thoracolumbar fusion
C2-6 decompression and instrumented fusion	Wound dehiscence
C3-7 decompression and C3-T1 instrumented fusion	Misplaced T1 screw
C3-T2 decompression and instrumented fusion	Epidural fluid collection
C3-C7 decompression and C2-T2 instrumented fusion	C5-6 foraminal stenosis with C5 palsy
C3-C7 decompression and C2-T2 instrumented fusion	Residual canal stenosis
C3-C7 decompression and C2-T2 instrumented fusion	Retained surgical drain
C2-T2 decompression and fusion	Retained surgical drain

TABLE 4. Revision Rates

End level	Revisions	Revision rate
C6	5	8.3%
C7	1	5.3%
T1	1	2.6%
T2	0	0.0%
C6 + C7	6	7.6%
T1 + T2	1	1.4%
	$P=$ **.035**	

Bold value indicate statistical significance.

or SSI. Mean procedure duration was 215 ± 10 min at C6, 214 ± 19 min at C7, 239 ± 11 min at T1, and 343 ± 20 min at T2 ($P = .001$). Mean EBL was 224 ± 20 mL at C6, 178 ± 22 mL at C7, 308 ± 38 mL at T1, and 575 ± 98 mL at T2 ($P = .001$). Procedure duration was missing for 4 of 149 patients, and EBL was missing for 21 of 149 patients. Mean LOS was 9.4 ± 1.4 d at C6, 6.3 ± 1.1 d at C7, 4.9 ± 0.5 d at T1, and 12.0 ± 2.2 d at T2 ($P = .966$). In terms of disposition, 38.3% of patients with constructs ending at C6 were discharged to a rehabilitation facility, 15.8% for C7, 23.1% for T1, and 35.5% for T2 ($P = .581$). The incidence of SSI was 6.7% at C6, 0.0% at C7, 0.0% at T1, and 6.5% at T2 ($P = .423$). Secondary outcomes are listed in Table 6.

TABLE 5. Multivariate Regression Analysis (*P*-values)

	Age	Gender	BMI	Anterior fusion	Attending surgeon	End level
Revision rate	.566 (−.015)	.137 (−1.03)	.668 (.018)	.581 (.402)	.058 (.503)	**.035** (−.662)
Duration of procedure	.578 (−.399)	.105 (25.13)	.173 (1.45)	.617 (1.50)	**.001** (25.60)	**.001** (34.43)
Estimated blood loss	.780 (.744)	.057 (102.5)	.053 (7.00)	.320 (74.04)	**.002** (77.66)	**.001** (99.46)
Hospital stay	.917 (−.008)	.222 (2.05)	.622 (.056)	**.031** (4.97)	.192 (.891)	.966 (.029)
Disposition	**.032** (.033)	.239 (.404)	.897 (.003)	.904 (.057)	.416 (.109)	.581 (−.076)
Surgical site infection	.518 (.019)	.462 (.455)	.479 (−.034)	.180 (.944)	.458 (.172)	.423 (−.190)

P-value (coefficient estimate for probit regression for binary variables or regression for continuous variables). Bold values indicate statistical significance.

TABLE 6. Secondary Outcomes

	C6	C7	T1	T2	C6 + C7	T1 + T2	Total	*P* value
Duration of procedure (min)	207 (146-277)	245 (145-270)	256 (174-285)	330 (279-366)	213 (146-272)	283 (224-335)	255 (169-303)	**.001**
Estimated blood loss (mL)	200 (150-250)	150 (100-200)	200 (150-400)	400 (225-663)	200 (100-250)	300 (200-500)	200 (150-400)	**.001**
Hospital stay (d)	6.2 (4.0-10.3)	5.0 (3.1-6.0)	4.0 (3.1-5.2)	8.2 (5.0-13.4)	6.0 (3.9-9.3)	5.0 (3.4-8.5)	5.2 (3.8-8.8)	.966
Disposition (% Rehab)	38.3%	15.8%	23.1%	35.5%	32.9%	28.6%	30.9%	.581
Surgical site infection (%)	6.7%	0.0%	0.0%	6.5%	5.1%	2.9%	4.0%	.423

Median (interquartile range). Bold values indicate statistical significance.

TABLE 7. Radiographic Parameters (*P*-values)

	Cervical lordosis	Cervical SVA	T1 slope
C6 vs C7 vs T1 vs T2	.857	.249	.533
Revision vs nonrevision	.352	.584	.754

Radiographic Outcomes

Finally, 118 of the 149 total patients had postoperative radiographs available for review. When comparing groups based on end level of the construct, there was no statistically significant difference in cervical lordosis ($P = .587$), cervical SVA ($P = .249$), or T1 slope ($P = .533$). When comparing the revision and nonrevision groups, there was also no difference in cervical lordosis ($P = .352$), cervical SVA ($P = .584$), or T1 slope ($P = .754$). Radiographic parameters are listed in Table 7.

DISCUSSION

Many surgeons favor extending PCF constructs across the CTJ due to the unique biomechanical forces in this area of the spine. The transition from the mobile, lordotic cervical spine to the rigid, kyphotic thoracic spine generates significant force at this segment.[4,7-10] Surgery near the CTJ can be destabilizing for several reasons. Instrumentation (and fusion) terminating in this region may impart an even larger moment arm at this already stressed spinal segment. Eliminating segmental motion via fusion leads to increased forces on adjacent segments, a concept validated by cadaveric studies demonstrating increased intradiscal pressure at adjacent levels.[11] Posterior approaches are more disruptive of the posterior tension band, including muscle dissection, laminectomies, and violation of ligamentous structures and facets, which further contributes to destabilization of the CTJ.[7,12] They also lack anterior column support and provide less restoration of cervical lordosis compared to anterior approaches.[4] Furthermore, anatomic challenges in this region include altering vertebral size and morphology, relative spinal mobility, and change in concavity between the cervical and thoracic spine.[13]

Any combination of these biomechanical factors may manifest as ASD. In a systematic review, Lawrence et al[1] reported the prevalence of clinically evident ASD to range from 11% to 12% at 5 yr, 16% to 38% at 10 yr, and 33% at 17 yr, with an annual incidence of 2.9% per year. They showed that factors contributing to the development of ASD included age > 60 yr, fusing adjacent to C5-C6 or C6-C7 levels, pre-existing disc herniation, and dural compression secondary to spinal stenosis.[1] Given the proclivity for construct failure at the CTJ, surgeons proposed bridging the junction into the more rigid thoracic spine.[12] These constructs may result in less of an increase in intradiscal pressure and stress at the CTJ due to the inherent stability the thoracic spine obtains from the sternum and ribs.[11] Extension to the thoracic spine also provides a greater surface area for fusion and uses larger screws, which allow for more stable fixation for fusion.[5] While the majority of patients who require revision surgery improve postoperatively, the complication risk for these revision surgeries has been reported to be as high as 27%.[14] Bridging the CTJ during the index case may limit the need for revision surgery and exposing patients to such high complication risks.

Interpretation of Results

The objective of this study was to determine if extension of PCF constructs across the CTJ led to a decreased incidence of ASD necessitating revision surgery. A total of 149 patients were divided into 4 groups based on the caudal end level of their constructs: C6, C7, T1, or T2. There were no differences between groups in age, BMI, follow-up duration, or attending surgeon performing the operation. However, there were more males (71.7%) in the C6 group and more females (71.0%) in the T2 group, likely due to greater concern for osteopenia/osteoporosis in the female population. Constructs ending at T2 also had more prior or concurrent anterior fusions (32.3%) as, biomechanically, longer constructs may more often require anterior column support.

Overall, the results of our multivariate regression are statistically significant in favor of bridging the CTJ. The revision rates were 8.3% for constructs ending at C6, 5.3% at C7, 2.6% at T1, and 0% at T2 ($P = .035$). When combining the C6 and C7 groups into a cervical group and the T1 and T2 groups into a thoracic group, the revision rates were 7.6% and 1.4%, respectively. End level was the only independent variable to have a significant effect on revision rate; age ($P = .566$), gender ($P = .137$), BMI ($P = .668$), presence of an anterior fusion ($P = .581$), and attending surgeon ($P = .058$) did not. We consider these early revision rates due to the relatively short duration of follow-up.

The multivariate regression also included several secondary outcome measures. End level had a statistically significant effect on procedure duration ($P = .001$) and EBL ($P = .001$) but not LOS ($P = .966$), disposition ($P = .581$), or SSI ($P = .423$). Attending surgeon had a significant effect on duration of procedure and EBL, possibly due to individual operative technique, experience, and/or level of resident physician involvement. The presence of prior/concurrent anterior fusion led to significantly longer LOS, which is expected when undergoing more extensive surgical intervention. Age had a significant effect on disposition, as older patients can be expected to require inpatient rehabilitation more frequently than younger patients. Interestingly, there was a larger increase in both mean procedure duration (239-343 min) and mean EBL (308-575 mL) when comparing ending constructs at T1 vs T2, implying that T1 may be the optimal end level when taking revision rate, procedure duration, and EBL into consideration.

Our study also included radiographic parameters for 118 of the 149 total patients, with no difference in cervical lordosis, cervical SVA, or T1 slope based on end level or need for revision. However, these were immediate postoperative radiographs, which may not

TABLE 8. Literature Review

Study	Shroeder et al, 2016[4]	Osterhoff et al, 2017[3]	Truumees et al, 2018[5]	Kennamer et al, 2018[2]	Present study
n	219	74	177	221	149
Mean follow-up	49.8	37	24	50.7	18.9
Cervical revision rate	35.3%	31.0%	8.9%	9.1%	7.6%
Thoracic revision rate	18.3%	6.3%	5.5%	17.8%	1.4%
Total revision rate	27.8%	25.7%	7.5%	10.9%	4.7%

be as informative as long-term follow-up radiographs in making definitive conclusions.

Literature Review, Comparison, and Generalizability

Although the unique biomechanical forces at the CTJ are well described, there remains a paucity of literature that investigates crossing the CTJ during PCF. When reviewing the literature, only 4 retrospective clinical studies were identified: 2 of which recommend crossing the CTJ and 2 found no difference in outcomes (Table 8).[2-5] Schroeder et al[4] present 219 patients with a mean follow-up of 49.8 mo in which the revision rates for constructs ending at C7 were 35.3%, 18.3% at T1, and 40.0% at T2-T4, for an overall revision rate of 27.8% ($P = .008$). Their multivariate regression showed that constructs ending at C7 (odds ratio: 2.29, 95% CI 1.13-4.61, $P = .02$) and Charlson Comorbidity Index (odds ratio: 1.37, 95% CI 1.01-1.87, $P = .045$) were variables that independently predicted need for revision surgery, and they recommended extension of PCF constructs to T1. Osterhoff et al[3] present 74 patients with mean follow-up of 37 mo in which the revision rates for constructs ending at C7 were 31.0% and 6.3% for T1 or T2 ($P = .038$), and they recommend bridging the CTJ to T1 or T2. Truumees et al[5] present a multicenter series of 177 patients with a minimum follow-up of 24 mo in which the revision rate for constructs ending in the cervical spine was 8.9% and 5.5% for constructs ending in the thoracic spine ($P > .05$). EBL for the thoracic group was significantly higher (578.9 ± 518.5 mL vs 367.7 ± 308.6 mL, $P < .05$). Duration of procedure (266.9 ± 144.2 min vs 248.9 ± 133.8 min) and LOS (5.6 ± 3.7 days vs 4.94 ± 3 days) were comparatively higher for the thoracic group but not statistically significant ($P > .05$). Rate of pseudarthrosis was higher in the cervical group (21.2%) than the thoracic group (10.96%) ($P < .05$). Based on these findings, they recommend crossing the CTJ in smokers or other patients at increased risk for pseudarthrosis while avoiding it in medically frail patients. Kennamer et al[2] present 221 patients with a mean follow-up of 50.7 mo in which the revision rate for constructs ending at C6 was 5.6%, 10.0% at C7, 19.5% at T1, and 0% at T2 ($P = .74$). Radiographic follow-up was available for 177 patients, which identified a statistically significant relationship between revision rate and increasing SVA ($P = .002$) and higher T1 slope ($P = .04$). As such, they suggest that end level may be less important than cervical SVA and T1 slope for predicting ASD and need for revision.

In comparison to the other published studies, our series had the lowest revision rate (4.7% overall), which may be a result of our relatively short follow-up duration (mean: 18.9 mo). We analyzed outcomes based on specific end level, including C6, C7, T1, and T2, which was performed only in Kennamer et al,[2] and also included combination cervical and thoracic groups. Schroeder et al[4] and Osterhoff et al[3] failed to include constructs ending at C6, which often constitute a significant proportion of PCFs performed. Importantly, we excluded patients involved in trauma or with underlying malignancy or infection, which was not done with Osterhoff et al,[3] as well as revisions not related to the construct or ASD, which was not done with Schroeder et al[4] or Truumees et al.[5] Instead, we included SSI as a secondary outcome in our multivariate regression in order to capture that data. Furthermore, we included several secondary outcomes—duration of procedure, EBL, LOS, disposition, and SSI—which was only accomplished by Truumees et al.[5] Overall, our results are congruent with those of Schroeder et al[4] and Osterhoff et al[3] in recommending bridging the CTJ when performing PCFs. These results contribute significantly to this topic due to the conflicting conclusions of the prior studies and highlight the need for larger prospective studies and/or registries of pooled data to achieve more conclusive results. Furthermore, these results can be generalized to the degenerative cervical spine disease population.

Limitations and Future Directions

There are several limitations to this study. The first of which is its retrospective nature, which can be affected by surgeon bias. Larger prospective studies are needed for more conclusive results. Our mean follow-up duration was 18.9 mo, with a minimum of 6 mo, which may not be sufficient time to allow for ASD to occur, thus underestimating its incidence. This likely led to our relatively low revision rate of 4.7%, which may not capture revisions that occur later on postoperatively. The mean follow-up duration of 18.9 mo was also incongruous with the long range of follow-up (79.4 mo maximum) and can introduce some bias to our analysis. This may be due to the patients undergoing revisions having longer overall follow-up as part of having multiple surgeries. Furthermore, there were significant differences between groups in gender and presence of anterior fusion, which may affect the validity of the multivariate regression. Moreover, our study lacks long-term radiographic follow-up. Recent studies highlight the importance of radiographic parameters, particularly the relationship between T1 slope minus cervical lordosis and cervical SVA.[15] As such, they should be included in future studies investigating outcomes of PCF.

CONCLUSION

There are unique biomechanical forces at play at the CTJ that need to be considered when performing PCFs. Our study demonstrates that extension of PCF constructs across the CTJ leads to statistically significantly lower early revision rates, but also leads to a statistically significant increase in procedure duration and EBL. Given these findings, decisions regarding the caudal extent of PCF constructs must weigh the risk of ASD, pseudarthrosis, and hardware failure against the risk of longer procedures with higher blood loss on an individual case-by-case basis. Longer clinical and radiographic follow-up are necessary to make more definitive conclusions.

Disclosures

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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