Temporal progression and spatial distribution of "normal" prevertebral soft tissue swelling following central corpectomy for cervical spondylotic myelopathy

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Abstract

Objective: To document the temporal progression and spatial distribution of prevertebral soft tissue swelling (PSTS) after central corpectomy (CC) and to determine the variables affecting its severity. **Background:** The natural attributes of PSTS following CC for cervical spondylotic myelopathy (CSM) have not been characterized in literature. **Materials and Methods:** PSTS was measured at the C2 level and midpoint of the operated segment on lateral radiographs of the cervical spine taken pre-operatively and post-operatively (day 0, day 3/4, day 5 and day 6/7) in 93 patients with CSM undergoing one to three level uninstrumented CC. Patient's age, weight, Nurick's grade, number of corpectomy levels and intubation time were correlated with the PSTS. **Results:** Proportionately, the swelling was maximal at the C2 level rather than at the level of CC, on all days, irrespective of the level of surgery. At the C2 level, the increase in PSTS was maximum by day 3/4 ($P = 0.0001$), whereas at the CC level, the PSTS continued to increase till day 5 ($P = 0.0001$). PSTS was higher in patients undergoing a three-level CC and in those with inclusion of C4 in the CC ($P = 0.002$). **Conclusion:** Patients undergoing CC are at risk for upper airway obstruction mainly at the C2 level in the first 3 days after surgery due to the PSTS. Those undergoing three-level CC, or having inclusion of C4 in the CC, have a greater degree of PSTS and have a higher risk of post-operative airway obstruction.

Key words: *Airway, cervical spine, cervical spondylosis, corpectomy, prevertebral soft tissue*

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Introduction

Prevertebral soft tissue swelling (PSTS) is an expected consequence of anterior cervical spine surgery. However, there are only few reports in literature on the temporal profile and location of the swelling.[1-3] All reports of post-operative PSTS have been in patients undergoing anterior cervical discectomy and fusion (ACDF). There has been no published study of the temporal course or spatial distribution of PSTS following central corpectomy (CC) for cervical spondylotic myelopathy (CSM). Furthermore, there is little information on the factors predicting PSTS following anterior cervical surgery.

The aim of this study was to determine the natural course

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of PSTS after uninstrumented single or multi-level CC, to determine the location of maximum swelling and to analyze factors that lead to an increase in PSTS. As the aim of the study was to determine the natural course of PSTS, only those patients who had no post-operative airway complications were included in the study.

Materials and Methods

Patients

In this retrospective study, all patients undergoing CC for CSM or ossified posterior longitudinal ligament (OPLL) from August 2005 to March 2010, who had serial post-operative lateral cervical radiographs from the first to the seventh post-operative days, were included. All patients (n = 93) had a pre-operative lateral cervical spine radiograph, day 0 (post-operative on the day of surgery) and post-operative day 3 or day 4 radiographs. In addition, at least one more x-ray was done on post-operative day 5 (n = 66) or day 6/7 (n = 57). Twenty-eight patients had x-rays done both on day 5 and day 6 or 7. None of the patients included in the study had airway complications requiring therapeutic intervention.

Surgery

All patients undergoing CC had features of cervical myelopathy. All patients underwent uninstrumented CC (single or multilevel) with autologous strut grafting. The surgical technique has been detailed in previous publications.[4,5] Iliac crest grafts were used for single and two level procedures and fibula was used for three level procedures. A lateral X-ray of the neck was obtained during the immediate post-operative period. After proper position of the graft was ensured, the patient was mobilized in the immediate post-operative period with a Philadelphia collar.

PSTS measurements

The anteroposterior (AP) thickness of the prevertebral soft tissue was measured using a PACS digital measuring tool (Pathspeed Web Release 8.1; GE Health Systems, USA). C2 level was chosen to represent the part of the cervical spine that was relatively uninvolved by the surgical dissection. On all radiographs, a line was drawn along the inferior border of the C2 vertebra, and the line was extended till the posterior border of the air shadow. The distance from the anteroinferior border of the C2 vertebra till the posterior border of the air shadow along the above line was measured as the PSTS at the C2 level [Figure 1]. At the level of surgery, a line was drawn from the anteroinferior border of the superior vertebra to the anterosuperior border of the inferior vertebra above and below the vertebral segments to be removed, on the pre-operative radiograph. The distance from the midpoint of this line to the posterior margin of the tracheal air shadow was taken as the PSTS at the level of the CC [Figure 1]. Following surgery, the measurement was repeated as described above. If part of the graft was projecting anterior to the line, it was also included in the PSTS measurements [Figure 2]. The measurements were performed independently by two of the authors, and any variations in the measurements were then settled by a joint reading of the radiographs by the two authors. The mean PSTS was calculated at the C2 and CC levels on day 0, day 3/4, day 5 and day 6/7. The post-operative change in PSTS from the pre-operative values was also expressed as a percentage change using the formula: (Post op value - pre op value / pre op value) x 100.

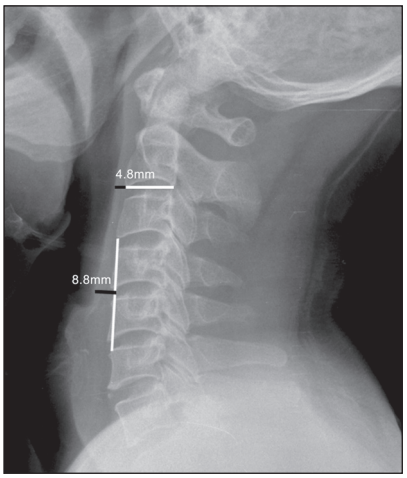

Figure 1: Lateral radiograph of the cervical spine showing the method used to measure the prevertebral soft tissue swelling at the C2 and at the proposed operative level

Variables studied

The following variables were studied for their influence on the severity of PSTS: inclusion of C4 level in the CC, number of corpectomy levels (1, 2, 3), age (≤50 years vs. >50 years), sex, body weight (≤65 kg vs. >65 kg), severity of myelopathy (Nurick's grade 1–3 vs. grades 4 and 5) and intubation time (≤4 h vs. >4 h).

Statistical methods

Data was entered in Excel software (Microsoft, Seattle, WA, USA) and analyzed using the SPSS statistical software package [SPSS version 11.5 (SPSS Inc., Chicago, IL, USA)]. Mean and standard deviations were computed for continuous variables. A univariate analysis with one variable at a time and all hypothesized variables at a time as multivariate analysis was carried out. Significance was determined at the 5% level.

Results

There were 86 men and 7 women. The mean age was 52.4 years (range: 34–71 years). A single-level CC was performed in 42 patients (C4 in 2, C5 in 18, C6 in 21 and C7 in 1). Two-level CC was performed in 45 patients at

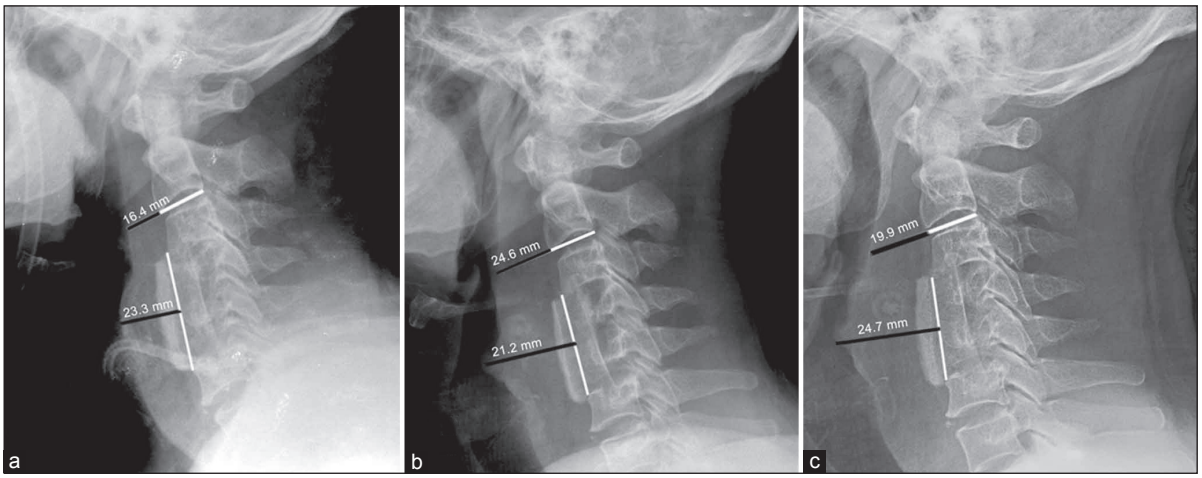

Figure 2: Serial lateral radiographs of the same patient shown in Figure 1 showing the progression of the prevertebral soft tissue swelling (PSTS) at the C2 and central corpectomy (CC) level: (a) day 0, (b) day 3 and (c) day 5. Note the increase in PSTS at the C2 by day 3 and decrease by day 5. The PSTS at the CC level has also increased by day 3, but measures slightly more at day 5

Table 1: Mean soft tissue measurements (mm) on pre-operative and post-operative radiographs

Level	Pre-op. Mean (range)	Day 0 Mean (range)	Day 3 or 4 Mean (range)	Day 5 Mean (range)	>Day 5 Mean (range)
C2	5.4 (2.5–11)	11.9 (4–29.6)	17.3 (5.8–36.9)	14.8 (5.4–35.4)	13.2 (4.4–31.5)
Graft	14.9 (4.4–21.6)	21.7 (12.8–31.2)	26.4 (16–36)	26.3 (15.2–34.7)	25.3 (13.6–31.5)

the following levels: C4–C5 in 18, C5–C6 in 26 and C6–C7 in 1. 6 patients underwent three-level CC (all C4–C6).

Temporal progression

There was significant increase in the PSTS from day 0 to day 6/7 at the C2 and CC levels (P = 0.0001, Wilcoxon signed ranks tests). At the C2 level, the increase in PSTS reached its maximum by day 3/4 (P = 0.0001), following which it decreased but had not returned to the pre-operative level by post-operative days 5–7 [Table 1 and Figure 2]. The PSTS at the CC level increased by day 3/4 and continued to increase minimally (by an additional 5%) till day 5 (P = 0.0001), following which it started decreasing [Table 1 and Figure 2].

Location of PSTS

The mean change of the PSTS from the pre-operative value, at the C2 level, was 6.4 mm and 11.9 mm, at day 0 and day 3/4, respectively. The mean changes at the CC level at the same intervals of time were similar, 6.8 mm and 11.5 mm. The percentage changes, however, were significantly higher at the C2 level when compared with the CC level [Figure 3]. At the C2 level, the increase in the PSTS was 127.3% and 236.9% on day 0 and day 3/4 respectively. The percentage change at the CC level was 69.5% and 95% at the same time intervals. The maximum percentage change in swelling was always noted at the C2 level as compared with the CC level at all time points of measurements (P = 0.0001). This observation was seen in all patients regardless of the number of levels of CC (P = 0.005, Kruskal-Wallis test).

Variables affecting PSTS

The effect of different variables on the change in PSTS was studied at day 3/4 as the PSTS was maximal at the C2 level on day 3/4 and, at the CC level, 95% of the increase in PSTS had occurred by this time [Figure 3]. The effect of the variables on the percentage change in PSTS at the C2 and CC levels is summarized in Tables 2 and 3 and Figure 4. Multivariate analysis showed that patients who underwent a three level CC or who had a CC including C4 body had a significantly higher increase in PSTS at the C2 level. There was no statistical correlation between age, weight, sex, Nurick's grade (severity of myelopathy) and duration of surgery and the severity of PSTS.

Discussion

Quantifying PSTS

Different methods have been used to quantify PSTS.[1-3] Andrew and Sidhu[1] measured PSTS across all cervical vertebrae from C2 till the T1 level. One measurement was made at C2 and three measurements were made per cervical vertebra in the subaxial spine at the level of the superior end plate, mid body and inferior end plate. Sanfilipo *et al.*[2] made all measurements at the inferior end plate of the cervical vertebrae. Suk *et al.*[3] made measurements of PSTS on the line parallel to the upper

Table 2: Univariate analysis for variables on the percentage change in PSTS at the C2 and graft levels on day 3/4

Variable	Percentage change in PSTS at C2 level Mean (range)	*P* value	Percentage change in PSTS at graft level Mean (range)	*P* value
No. of levels of CC				
1 (n = 42)	148.5 (5.3–494.4)	0.002	87 (21.1–296.6)	0.49
2 (n = 45)	247.7 (40.7–631.6)		105.4 (15.3–540.9)	
3 (n = 6)	444.5 (149.4–908.8)		72.2 (31.5–92.6)	
Inclusion of C4 in CC				
Yes (n = 26)	355.4 (138.8–908.8)		147.4 (31.2–540.9)	
No (n = 67)	190.2 (5.3–631.6)	0.0001	74.4 (15.3–296.6)	0.0001
Age (years)				
≤50 (n = 44, mean = 45.1)	215.1 (5.3–494.4)	0.23	109.5 (25.1–492)	0.54
>50 (n = 49, mean = 59)	256.9 (16.7–908.8)		108.0 (29.4–354.5)	
Gender				
Male (n = 86)	233.5 (5.3–908.8)	0.34	92.3 (15.3–540.9)	0.08
Female (n = 7)	277.9 (72.7–413.3)		128.7 (39.6–296.6)	
Body weight (kg)				
≤65 (n = 53, mean = 57.5)	225.2 (16.7–908.8)	0.56	104.4 (19.6–540.9)	0.24
>65 (n = 37, mean = 71.6)	246.1 (5.3–631.6)		82.3 (15.3–381.1)	
Pre-opNurick grade				
1–3 (n = 50)	215.2 (5.3–908.8)	0.17	89.1 (15.3–540.9)	
4,5 (n = 43)	262.7 (40.7–631.6)		102.2 (22.8–402)	0.46
Duration of surgery				
≤4 h (n = 50, mean = 3.7)	237.7 (5.3–908.8)		96.3 (21.1–402)	
>4 h (n = 40, mean = 4.8)	228.5 (40.7–631.6)	0.79	94.3 (15.3–540.9)	0.91

Table 3: Multivariate analysis for variables on the percentage change in PSTS at the C2 and graft levels on day 3/4

Variable	C2 level Std coefficient Beta (95%confidence interval)	*P* value	Graft level Std coefficient Beta (95%confidence interval)	*P* value
No. of levels of CC				
1 (n = 42)	0.194	0.15	-0.342	0.01
2 (n = 45)	(-20.1 to 129.3)		(-83.4 to -9.7)	
3 (n = 6)				
Inclusion of C4 level				
Yes (n = 26)	-0.343	0.006	-0.548	0.0001
No (n = 67)	(-221.9 to -39.0)		(-145.6 to -55.4)	
Age (years)				
≤50 (n = 44, mean = 45.1)	0.009	0.93	0.022	0.83
>50 (n = 49, mean = 59)	(-65.4 to 71.1)		(-30.1 to 37.1)	
Gender				
Male (n = 86)	-0.133	0.19	-0.084	0.41
Female (n = 7)	(-205.8 to 41.7)		(-86.1 to 35.9)	
Body weight (kg)				
≤65 (*n* = 53, mean = 57.5)	0.149	0.13	-0.095	0.34
>65 (*n* = 37, mean = 71.6)	(-16 to 117)		(-48.3 to 17.2)	
Pre-op. Nurick grade				
1–3 (*n* = 50)	0.2	0.05	-0.094	0.36
4, 5 (*n* = 43)	(-0.5 to 134.8)		(-18.1 to 48.6)	
Duration of surgery				
≤4 h (*n* = 50, mean = 3.7)	-0.129	0.23	0.116	0.30
>4 h (*n* = 40, mean = 4.8)	(-116.2 to 29.3)		(-17.1 to 54.6)	

end plate from the mid point of the anterior surface of each vertebral body to the posterior border of the air shadow. On post-operative radiographs, we could not visualize the mid point of the vertebral body inferior to the level of the CC in all the cases, and hence decided to restrict our measurements to the mid point of the level of CC. We also felt that having a measurement at each vertebral level would not be clinically significant. Instead, we speculated that with just two measurements at appropriate levels (lower border of C2 body and at the mid point of the CC), trends in the temporal progression and spatial distribution of the PSTS would be evident. We chose the PSTS at the lower border of the C2 body to represent a part of the neck that was relatively uninvolved in the surgical dissection. Previous reports in patients undergoing ACDF have suggested that the PSTS is maximal at the C3 or C4 level and that it might have been appropriate to include measurements at this

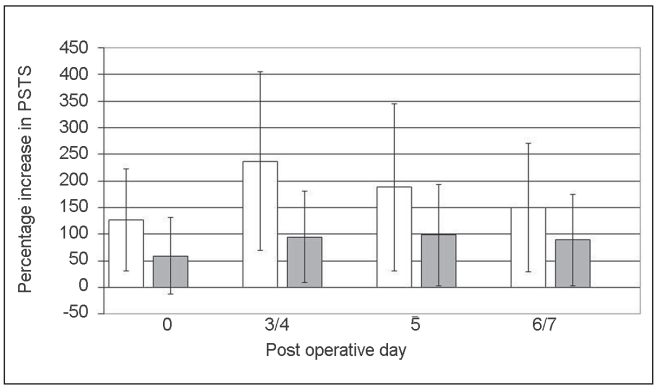

Figure 3: Bar graph showing the mean increase in prevertebral soft tissue swelling (PSTS) at C2 (white bars) and central corpectomy (CC) levels (grey bars) on different post-operative days. Note the more rapid increase and reduction in the PSTS at the C2 level compared with the CC level

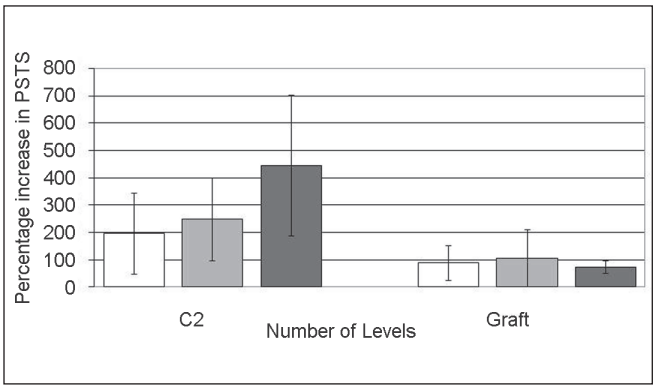

Figure 4: Bar graph comparing the increase in prevertebral soft tissue swelling on post-operative day 3/4 in patients undergoing 1, 2 and 3 level central corpectomy (CC) at C2 and CC levels. (1 level CC – white bar, 2 level CC – light grey bar, 3 level CC – dark grey bar)

level. But, because some of our patients had undergone a corpectomy including the C4 body, using C3 or C4 level measurements would not have counted as measurements in a region remote from the surgical dissection.

Several authors have measured PSTS in the cervical region in non-operated individuals and have found a wide variation from person to person. Penning *et al.*[6] found that the PSTS ranged between 1 and 5 mm at the C2 lower border and 11 and 20 mm at the C6 level. We also observed a wide patient-to-patient variation in the pre-operative PSTS [Table 1]. Because of the wide variation in absolute values, we decided to quantify the percentage change in PSTS in addition to reporting absolute values, as this would better clarify the spatial distribution of the swelling after surgery. Andrew and Sidhu[1] also reported on the percentage changes in addition to the absolute values.

Andrew and Sidhu[1] and Sanfilippo *et al.*[2] measured the PSTS on radiograph films, whereas Suk *et al.*[3] used the PACS measuring tool similar to the technique used by us. Hence, the absolute measurements of the PSTS from the different studies cannot be compared, although the percentage changes in the PSTS can be compared.

Location of PSTS

Although there has been some variability in the studies regarding the location of the maximal PSTS following ACDF, all studies showed that the swelling was higher at the C2–C4 levels rather than at the site of the surgery. Andrew and Sidhu[1] found that the percent change in the PSTS was maximal at the lower border of the C3 body. Suk *et al.*[3] documented that the swelling was maximum at the C2–C3 levels. They also noted more severe PSTS in fusions above the C5 level. The latter finding is not surprising, as fusions above the C5 level would have involved dissection at the levels most prone to swelling, namely the C3 and the C4 levels. Our results showed that the maximum percentage change in the PSTS was noted at the C2 level and not at the CC level irrespective of the level of surgery [Figure 3]. We calculated the percentage change in the PSTS from the absolute measurements presented by Sanfilippo *et al.*[2] in their patients undergoing ACDF. At 2 weeks after ACDF, the maximal increase in the post-operative PSTS was at the C4 lower border (60% change as compared with 45% at C3, 47% at C5 and 33% at C6 levels). They did not report the levels of surgery, but it can be safely presumed that most patients would have undergone surgery at the C5/6 or C6/7 disc levels rather than at the C4/5 level. It was also interesting to note from their data that the 2-week post-operative measurements at the C2 level had shown only a 27% change. This indicates that although the PSTS is maximal at the C2 level in the early post-operative period, the resolution of the PSTS at this level is also more rapid than at the lower levels, as demonstrated in our results [Figure 3]. It is likely that once the patient is erect most of the time and spends less time recumbent, the edema at the C2–C3 levels settles rapidly.

From the studies in patients with ACDF and our study in patients undergoing CC, it appears that the airway at the level of the oropharynx (opposite C2–C3) is maximally at risk for compromise following anterior cervical surgery rather than at the level of the surgery.

Multiple studies[7-9] in patients with sleep apnea syndrome have revealed that upper airway obstruction occurs at the retropharyngeal or retroglossal level, which extends from opposite the C1 to C2–C3 level. This retropharyngeal space lies between the prevertebral fascia posteriorly and the buccopharyngeal fascia anteriorly. It is filled with loose areolar tissue and is closed above by the base of the skull and on each side by the carotid sheath.[10] The size of the upper airway structures, tongue, soft palate, parapharyngeal fat

pads, lateral pharyngeal walls and mandible are crucial determinants of upper airway calibre. Patients who have thick lateral pharyngeal walls encroach on the pharyngeal lumen, which in turn leads to reduction in the lateral airway diameter. Also, during sleep, there is a reduction in the tone of the upper airway dilator muscles, which results in a decrease in airway size and an increase in upper airway resistance.[7-9]

Andrew and Sidhu[1] speculated that the reasons for the maximal change in the PSTS at the C2–C4 levels was because of the greater availability of potential space in the retropharyngeal tissues at these levels as compared with the more tightly packed anatomy at the C5–C7 levels. We speculate that the recumbent position adopted by the patients in the immediate post-operative period could be another cause for the accumulation of tissue fluids in the oropharynx and nasopharynx. The lordotic curvature of the cervical spine might also cause drainage of fluids in the direction of the upper cervical spine from the higher levels of the mid cervical spine. Because the airway at the CC level (typically at C4–C6 levels) is more rigid due to the laryngeal and tracheal cartilages, it is less prone to obstruction. Therefore, patients undergoing CC are more prone to develop obstruction at the oropharyngeal level and not at the airway below that level.

Temporal progression

The temporal profile of PSTS after ACDF has been documented in the literature.[1-3] Suk *et al* [3] concluded that the PSTS increased markedly after surgery on the second and third days, after which it subsided. Our results concur with the findings of Suk *et al*.[3] PSTS increased from the immediate post-operative period and reached its maximum on the third or fourth day at the C2 level ($P = 0.0001$), following which it reduced. At the CC level, 95% of the PSTS had occurred by day 3/4, and only an additional 5% of increase in PSTS occurred at day 5 ($P = 0.0001$), following which it reduced. At both the levels, it did not decline to the pre-operative values at days 6/7. Since airway obstruction in the post-operative period is more likely determined by the space available at the C2 level, it is evident that patients undergoing anterior cervical surgery in general and CC in particular are at maximal risk for developing airway obstruction in the first 3 days after surgery and are unlikely to develop this complication after that. Sanfilippo *et al*.[2] noted that it takes close to 6 weeks for complete dissipation of the PSTS.

Causes and risk factors for PSTS

The main cause of PSTS after anterior cervical surgery is tissue edema. Other causes are post-operative hematoma, cerebrospinal fluid leak and graft or plate dislodgement.[1,2,9,11] As we used a wound drain in all our patients, a hematoma was unlikely to be the cause of the swelling. A corpectomy leaves an increased surface area of bleeding cancellous bone, which contributes to local edema and local lymphatic obstruction.[12] Extensive tissue dissection above C4 often underneath the mandible requires forceful retraction, further adding to the tissue and pharyngeal trauma in these patients.[13] Severe idiopathic angioedema has also been reported after anterior cervical surgery.[14] Multiple risk factors have been proposed for increase in PSTS after anterior cervical surgery. They include obesity, operative time greater than 10 h, a second ACDF operation, blood transfusions >300 ml, advanced age (>65 years of age), presence of a cerebrospinal fluid fistula and a severe degree of myelopathy (Nurick's Grade 4–5).[11,13] Sagi *et al*.[13] also found that prolonged intubation time (>5 h), exposure of >4 vertebral bodies or exposure above the C4 level had a significant correlation with the development of an airway complication. Although these authors suggested that surgery above C4 level leads to more edema, it is evident from our study and previous reports that even in those undergoing surgery at lower levels, the swelling is maximal above the C4 level. Smoking and pre-existing pulmonary disease (chronic obstructive pulmonary disease or asthma) have been reported to be additional risk factors. Our results showed that the variables that were predictive of the increased change in PSTS was the number of levels of corpectomy and inclusion of C4 in the CC ($P = 0.0001$). Age, sex, mean body weight, severity of myelopathy (Nurick's grade) and intubation time did not influence the change in PSTS at the C2 level. Although the intubation time did not correlate with the severity of PSTS in our study, a possible reason could be the overall short duration of surgery in our patients. Even in the group with >4 h of intubation time, the mean intubation time was only 4.8 h. This does not seem to be significantly different from the mean intubation time of 3.7 h in the group with intubation time of <4 h.

Conclusion

PSTS after CC is maximal at the level of C2 rather than at the CC level, irrespective of the level of surgery. PSTS is maximal at day 3/4 at C2 level and at day 5 at the CC level. Patients undergoing CC should be carefully watched for respiratory insufficiency till the third or fourth post-operative day, and special attention should be paid to patients who are at higher risk for developing more severe PSTS.

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