Complications following central corpectomy in 468 consecutive patients with degenerative cervical spine disease

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OBJECTIVE This study was performed to describe the incidence and predictors of perioperative complications following central corpectomy (CC) in 468 consecutive patients with cervical spondylotic myelopathy (CSM) or ossification of the posterior longitudinal ligament (OPLL).

METHODS The authors performed a retrospective review of a cohort of patients who had undergone surgery for CSM (n = 338) or OPLL (n = 130) performed by a single surgeon over a 15-year period. All patients underwent uninstrumented CC with autologous iliac crest or fibular strut grafting. Preoperative clinical and imaging details were collected, and the type and incidence of complications were studied. Univariate and multivariate analyses were performed to establish risk factors for the development of perioperative complications.

RESULTS Overall, 12.4% of patients suffered at least 1 complication following CC. The incidence of major complications was as follows: C-5 radiculopathy, 1.3%; recurrent laryngeal nerve injury, 0.4%; dysphagia, 0.8%; surgical-site infection, 3.4%; and dural tear, 4.3%. There was 1 postoperative death (0.2%). On multivariate analysis, patients in whom the corpectomy involved the C-4 vertebral body (alone or as part of multilevel CC) were significantly more likely to suffer complications (p = 0.004). OPLL and skip corpectomy were risk factors for dural tear (p = 0.015 and p = 0.001, respectively). No factors were found to be significantly associated with postoperative C-5 palsy, dysphagia, or acute graft extrusion on univariate or multivariate analysis. Patients who underwent multilevel CC were predisposed to surgical-site infections, with a slight trend toward statistical significance (p = 0.094). The occurrence of a complication after surgery significantly increased the mean duration of postoperative hospital stay from 5.0 ± 2.3 days to 8.9 ± 6 days (p < 0.001).

CONCLUSIONS Complications following CC for CSM or OPLL are infrequent, but they significantly prolong hospital stay. The most frequent complication following CC is dural tear, for which a diagnosis of OPLL and a skip corpectomy are significant risk factors.

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KEY WORDS corpectomy; complications; dural tear; infections; C-5 palsy; dysphagia

CENTRAL corpectomy (CC), with or without instrumentation, provides excellent outcomes in patients with degenerative cervical myelopathy.^{9,13,18,21,36,38,58} However, CC can be a technically demanding procedure, and it may be complicated by dysphagia, recurrent laryngeal nerve injury, dural tear, nerve root palsy, wound infection, and graft displacement. Adverse events following cervical spine surgery contribute significantly to patient morbidity by leaving residual neurological deficits, prolong hospital stay, and markedly increase health care expenses.^{3,7,24,37,40,41,43,48,62}

Estimates of complication rates following CC for cervical spondylotic myelopathy (CSM) or ossification of the posterior longitudinal ligament (OPLL) have been limited by small cohort sizes or multiple surgeon involvement. Recent evidence has suggested that advanced age, a diagnosis of OPLL, long-level decompression and combined anterior-posterior approaches are associated with an increased risk of major complications following surgery for CSM or OPLL.⁶⁷ Most contemporary authors have studied complication rates following instrumented ventral decompression of the cervical spine. However, these conclusions cannot

ABBREVIATIONS CC = central corpectomy; CSM = cervical spondylotic myelopathy; LOS = length of stay; OPLL = ossification of the posterior longitudinal ligament; OR = odds ratio.

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be extrapolated to uninstrumented fusion for degenerative cervical spine disease, which does not suffer from hardware-related complications. To the best of our knowledge, no study has specifically examined preoperative variables that might help anticipate surgical morbidity following CC without instrumentation. Given this gap in the current literature, we sought to describe complications following CC without instrumented fusion and identify patient factors that predicted these complications.

Methods

All patients with CSM or OPLL were considered for CC unless the compression involved more than 3 vertebral bodies or extended behind the C-2 body. Between September 1991 and October 2007, 482 adult patients underwent CC at our institution, Christian Medical Center in Vellore, India. In all cases, the procedures were performed by the senior author (V.R.). Fourteen cases involving patients with primary nondegenerative pathology, such as cervical spine trauma, tuberculosis, tumor, or vertebral body dysplasia, were excluded from further analysis. All patients underwent a detailed clinical and radiological evaluation prior to surgery, and perioperative and postoperative patient details were maintained in a prospective database. The patients' functional status at baseline was recorded using the Nurick grading system.

Neutral and dynamic plain cervical spine radiographs were routinely obtained in all patients. MRI was performed preoperatively in 454 patients. In 14 patients who were operated on prior to 1995, either CT myelography or plain myelography was used. OPLL was diagnosed on the basis of MRI features and radiographs and confirmed intraoperatively. CT of the cervical spine was not performed routinely. Cervical spine curvature was classified by using a line drawn on a lateral radiograph, extending from the most posterior point on the inferior endplate of the C-2 vertebral body to a similar point on C-7. The spine was described as lordotic if all the vertebral bodies were anterior to this line and straight if the intervening vertebral bodies touched the line without crossing it. If the posterior cortical margins of the vertebral bodies extended beyond the line, the spine was classified as kyphotic.

Surgical Technique

Prophylactic antibiotics were administered for 24 hours after surgery. The protocol consisted of intravenous injection of 1 g of chloramphenicol at induction followed by 4 additional doses administered at 6-hour intervals. The surgical technique has been documented in previous publications.^{32,49,50} All patients underwent uninstrumented CC using autologous iliac (for 1- or 2-level procedures) or fibular (for 3-level procedures) strut grafts. The procedure is described here in brief. Neck extension was maintained intraoperatively with a rolled sheet placed under the shoulders. Traction was provided with Gardner-Wells tongs. The corpectomy width varied between 14 and 16 mm. After drilling the posterior cortical surface with the aid of an operating microscope, excision of the posterior longitudinal ligament was attempted in the majority of patients. In patients with a densely adherent OPLL or with

dural ossification, the ligament was thinned down and then detached ("floating-off technique"). The graft was inserted snugly between mortices drilled in the superior and inferior vertebral levels. On occasion, in the presence of additional ventral compression at a noncontiguous level, an isolated discectomy was also performed during the same procedure.

Operating times were noted from the surgeon's notes and were available for 90% of patients; the operating time ranged from 2 hours to 6 hours, with an average of approximately 3.5 hours. The duration of surgery diminished with increased surgeon experience in the later part of the series. A radiograph was obtained immediately after surgery to confirm correct placement of the graft. Prior to mobilization, all patients were prescribed a Philadelphia collar for continuous use for the first 3–6 months after surgery. Patients undergoing fibular grafting were mobilized at varying intervals after surgery ranging from immediately after surgery to 2 weeks after surgery.

Perioperative Complications

Complications of interest included dural tear with CSF leak, surgical-site infections, dysphagia and vocal hoarseness, graft displacement, and neurological deterioration. Complications were recorded during the period of hospital stay, and readmissions within 30 days of surgery were also noted. Unexpected medical complications were recorded as and when they occurred. C-5 palsy was defined as unilateral or bilateral upper-extremity weakness or dermatomal sensory loss or radicular pain in the absence of myelopathic signs. Infections were considered superficial if they did not extend deep to the muscular fascia and deep if they involved compartments below the fascia. Superficial infections were treated with antibiotics, while surgical debridement was reserved for deep infections. Postoperative length of stay (LOS) was documented from inpatient records.

Prognostic Variables

We attempted to identify clinical, radiological, and surgical risk factors for developing complications following CC. Each major complication was also separately evaluated for possible risk factors. Prognostic variables were categorized appropriately and included age at diagnosis (≥ 50 years vs < 50 years), sex, preoperative Nurick grade (poor [Grade 4 or 5] vs high [Grade 1, 2, or 3]), diabetes (present vs absent), symptom duration (≥ 1 year vs < 1 year), primary diagnosis (OPLL versus CSM), preoperative cervical alignment (kyphotic versus nonkyphotic), number of CC levels (2- or 3-level vs 1-level CC and 3-level versus 1- or 2-level CC), type of CC (skip vs contiguous). Because the operating time was less than 4 hours in the vast majority of our patients, and surgery lasting more than 4 hours has been found to be a risk factor for complications in most reported series, operating time was not considered in this analysis.^{5,52}

Statistical Analysis

Analysis was performed in consultation with a statistician. Data were entered into an electronic database and

analyzed with SPSS software (version 20.0, IBM Corp.). Descriptive statistics (mean and standard deviation for continuous variables and frequency and percentages for categorical variables) were calculated. Continuous and categorical variables were compared with the Student t-test and chi-square test, respectively. A univariate analysis was used to estimate the odds ratio (OR) and 95% confidence interval of each variable with respect to development of a particular complication. A stepwise logistic regression model was created using factors selected appropriately from the univariate analysis. Given the overall low incidence of complications, overfitting of the model was avoided by limiting the number of covariates; thus approximately 1 variable was included for every 10 events. Statistical significance was defined by a p value < 0.05.

Results

Clinical and operative details of the cohort are summarized in Table 1. The primary diagnosis was CSM in 330 patients (70.5%) and OPLL in 138 patients (29.5%). The cohort had an overwhelming male predominance, and 231 patients (49.4%) were 50 years of age or older at presentation. In 179 cases (38.2%), the patients' functional status was considered "poor" (Nurick Grade 4 or 5) prior to surgery. Sixteen patients had undergone prior attempts at cervical spine decompression (anterior approaches in 12 cases, posterior approaches in 4 cases). Preoperative neutral cervical spine radiographs were available for review in 398 cases and demonstrated a lordotic alignment in the majority. Most patients underwent a 2-level corpectomy, and segment most often operated on was C-5. Twenty-four patients underwent a 3-level procedure; including 2 patients who had undergone complete C-4, C-5, and C-6 corpectomies with partial removal of the C-3 and C-7 vertebral bodies as well. No patients underwent a true 4-level CC. Eighteen patients underwent "skip" corpectomies, with corpectomies being performed at C-4 and C-6 while the intervening C-5 vertebral body was preserved. Data on comorbid illnesses were available for review in 383 patients, approximately 6% of whom had been diagnosed with diabetes mellitus prior to surgery. Follow-up data were available in 381 patients; the mean follow-up period was 52.1 ± 40.2 months. Fusion rates were approximately 88%, studied at 1 year after surgery. However, this study was restricted in scope to the analysis of perioperative complications following CC.

Complications

Table 2 lists complications following CC, further stratified by the type of pathology. The most frequent complications were dural injury with cerebrospinal fluid (CSF) leak, surgical-site infections, graft extrusion, and C-5 palsy. Fifty-eight patients (12.4%) suffered at least 1 complication after surgery; 7 of these patients suffering more than 1 complication, but no patient suffering more than 3 complications.

Postoperative C-5 radiculopathy occurred in 6 patients overall. In 4 of these patients, the corpectomy had involved resection of the C-5 vertebral body. The remaining 2 patients had undergone a single-level C-6 CC and a C-4/C-6 skip CC, respectively.

TABLE 1. Baseline characteristics of the cohort (n = 468)

Characteristic	Value
Mean age at diagnosis (yrs)	48.6 ± 9.7
Sex	
Male	440 (94.0%)
Female	28 (6.0%)
Diabetes mellitus†	21 (5.5%)
Mean duration of symptom (mos)	21.3 ± 30.7
Mean preop Nurick grade	3.2 ± 1.0
Pathology	
CSM	330 (70.5%)
OPLL	138 (29.5%)
Preop sagittal alignment‡	
Lordotic	275 (69.1%)
Straight	93 (23.4%)
Kyphotic	30 (7.5%)
Number of operated segments	
1	155 (33.1%)
2	289 (61.8%)
3	24‡ (5.1%)
Skip corpectomies	18 (3.8%)
Levels included in corpectomy	
C-3	4
C-4	168
C-5	357
C-6	271
C-7	7

* Values represent numbers of patients or cases (%) unless otherwise indicated. Mean values are presented with standard deviations.

† Data on diabetes mellitus were available for only 383 patients and the percentage was calculated accordingly.

‡ Includes 2 patients who underwent partial corpectomies at the superior and inferior adjacent vertebral levels.

Dural tears, more common in patients with OPLL, were managed intraoperatively with a fascial onlay graft with an additional layer of gelatin sponge. Five patients (27.8%) undergoing skip CC developed dural tears; 3 of these 5 patients had OPLL. In all cases, a lumbar subarachnoid drain was inserted postoperatively, followed by restricted ambulation for 5–7 days.²⁷ No patient with dural tears developed meningitis, pseudomeningocele, or CSF fistula, and none required reoperation for dural repair. Recurrent laryngeal nerve injuries occurred in 2 patients who developed vocal hoarseness postoperatively.

Infections occurred in 3.4% of cases overall, and in more than half of these cases the infection occurred at the iliac crest graft site, although there was no statistically significant difference by site (neck incision vs graft site, p = 0.802). A bacterial isolate could be obtained from swab cultures in only 4 cases: coagulase-negative *Staphylococcus* in 2 cases, methicillin-sensitive *S. aureus* in 1 case, and *Escherichia coli* in 1 case. There were no deep infections; all infections responded well to antibiotic therapy without the need for surgical debridement.

One patient developed a hematoma at the iliac bone graft site that was drained via a bedside procedure. Graft displacement was seen in 8 cases overall and was associ-

TABLE 2. Complications following central corpectomy for CSM or OPLL*

Variable	Total (n = 468)	CSM (n = 330)	OPLL (n = 138)
Patients w/ any complication	58 (12.4%)	39 (11.8%)	19 (13.8%)
Patients w/			
No complications	410 (87.6%)	291 (88.2%)	119 (86.2%)
1 complication	51 (10.9%)	35 (10.6%)	16 (11.6%)
2 complications	7 (1.5%)	4 (1.2%)	3 (0.2%)
Approach related			
C-5 palsy	6 (1.3%)	4 (1.2%)	2 (1.4%)
Recurrent laryngeal nerve injury	2 (0.4%)	2 (0.6%)	0
Dysphagia	4 (0.9%)	4 (1.2%)	0
Dural tear w/ CSF leak	20 (4.3%)	8 (2.4%)	12 (8.7%)
Operated site hematoma	1 (0.2%)	1 (0.3%)	0
Graft related			
Graft extrusion	8 (1.7%)	6 (1.8%)	2 (1.4%)
Donor site hematoma	1 (0.2%)	1 (0.3%)	0
Donor site hernia	1 (0.2%)	1 (0.3%)	0
Surgical-site infections			
Total	16 (3.4%)	12 (3.6%)	4 (2.9%)
Neck	7 (1.5%)	4 (1.2%)	3 (2.2%)
Graft site	9 (1.9%)	8 (2.4%)	1 (0.7%)
Medical/anesthesia-related			
Respiratory failure/arrest	2 (0.4%)	0	2 (1.4%)
Pneumonia	2 (0.4%)	0	1 (0.7%)
Heart failure	1 (0.2%)	1 (0.3%)	0
Duodenal perforation w/ peritonitis & death	1 (0.2%)	1 (0.3%)	0

* Values are numbers of patients or complications (%).

ated with fracture of the graft in 2 patients. This complication was more frequent in the earlier part of the series. Five of these patients reported symptoms referable to graft migration: neck or shoulder pain in 3 cases, dysphagia in 1 case, and neurological deterioration in 1 case. In the other 3 patients, slippage was detected on routine postoperative radiographs performed to confirm graft position. Five of the 8 patients with graft displacement patients required a second operative procedure to reposition the graft. The 2 patients with fractured grafts were placed on bed rest for 6 weeks. The patient who had suffered neurological deterioration as a result of graft migration made a gradual recovery, improving from Nurick Grade 3 at baseline to Grade 2 at 6.5 years follow-up.

A 63-year-old patient developed acute neurological deterioration in the immediate postoperative period after a C5–6 corpectomy due to a local hematoma. He underwent an emergency surgical evacuation and made a gradual recovery after surgery. At his last follow-up visit, 10 months after surgery, he reported 25% improvement as compared with baseline.

Thus, overall, only 2 patients (0.4%) developed cord-related neurological deterioration.

The operative mortality rate was 0.2% (1 death in the 468 cases included in the analysis). The patient who died was a 71-year-old man, who had a preoperative Nurick grade of 4. He developed a duodenal perforation with peritonitis after a C-6 corpectomy and underwent emergency surgery but eventually died following complications related to the laparotomy.

Predictors of Complications

Patients undergoing a skip corpectomy ($p = 0.001$) or in whom the corpectomy involved the C-4 vertebral body (alone or as part of multilevel CC, $p = 0.004$) were significantly more likely to suffer any complications following CC on univariate analysis, as summarized in Table 3. On multivariate analysis, both these factors retained significance.

Factors significantly associated with dural tear on univariate analysis included age ≥ 50 years ($p = 0.026$), skip corpectomy ($p < 0.001$), OPLL ($p = 0.004$), and diabetes mellitus ($p = 0.029$), as shown in Table 4. On multivariate analysis using 3 covariates, OPLL ($p = 0.015$) and skip corpectomy ($p = 0.001$) remained significant risk factors for dural tear. No factors were found to be significantly associated with postoperative C-5 palsy, dysphagia, or acute graft extrusion on univariate or multivariate analysis. Patients with multilevel and skip CC were predisposed to surgical-site infections, with a slight trend toward significance ($p = 0.094$ and $p = 0.088$, respectively), as shown in Table 5. However, no factors were independently predictive of infection on logistic regression analysis.

Complications and LOS After Surgery

Data regarding LOS after CC could be retrieved in 379 patients. Overall, the mean LOS was 5.44 ± 3.33 days (range 2–25 days). In general, LOS was longer in patients with diabetes mellitus ($p = 0.042$), patients with OPLL ($p = 0.027$), and those who underwent multilevel ($p = 0.014$) or skip corpectomy ($p < 0.001$). The occurrence of any complication, quite predictably, was associated with a significant increase in the mean LOS (from 5.0 ± 2.3 days to 8.9 ± 6 days, $p < 0.001$). Patients who developed medical complications after surgery tended to have longer LOS than patients who suffered surgery-related complications ($p = 0.072$). LOS did not differ significantly when stratified by type of surgical complication ($p = 0.902$). Two patients required readmission for surgical infections that developed after discharge, and 1 patient was transferred to a cardiology service for further treatment of cardiac failure.

Discussion

Increased soft tissue exposure, bone resection, and operating times in CC have been variably associated with increased instrumentation and graft-related morbidity, in comparison with other ventral approaches, notably anterior cervical discectomy and fusion.^{33–35,65} However, in the hands of an experienced surgeon, CC can be performed safely and provides excellent ventral decompression in patients with both CSM and/or OPLL. To the best of our knowledge, this study presents complications rates in the largest cohort of patients undergoing CC published in the

TABLE 3. Univariate and multivariate analyses of risk factors associated with any complication (n = 58) following CC

Risk Factor	Univariate Analysis		Multivariate Analysis	
	OR (95% CI)	p Value	OR (95% CI)	p Value
Age $\geq$ 50 yrs	1.532 (0.877–2.674)	0.134*	1.152 (0.620–2.138)	0.655
Symptom duration $\geq$ 1 yr	1.323 (0.763–2.295)	0.319		
Preop Nurick grade of 4 or 5	0.977 (0.554–1.722)	0.936		
3-level corpectomy	0.630 (0.144–2.752)	0.539		
OPLL	1.191 (0.661–2.146)	0.560		
Skip corpectomy	5.208 (1.929–14.057)	0.001*	3.237 (1.076–9.736)	0.037
C-4 included in corpectomy	2.291 (1.304–34.025)	0.004*	1.815 (0.947–3.478)	0.072
C-5 included in corpectomy	0.974 (0.512–1.853)	0.936		
C-6 included in corpectomy	0.813 (0.468–1.413)	0.463		
Diabetes mellitus	2.259 (0.788–6.470)	0.129*	2.102 (0.695–6.359)	0.188
Previous cervical surgery	1.666 (0.460–6.031)	0.437		
Preop kyphosis	0.251 (0.033–1.895)	0.180		

* Factor inserted into the logistic regression model.

literature. Data from our cohort of 468 cases indicate that, overall, complications associated with this procedure were infrequent and comparable to those reported in the contemporary literature on CC with or without instrumented fusion. Furthermore, our cohort is notable for the absence of any hardware-related complications due to the lack of instrumented fusion.

Boakye et al.⁵ conducted a study on complications in 1560 patients treated at Veteran Affairs clinics over a 10-year period, demonstrating that age greater than 80 years, Type 1 diabetes mellitus, American Society of Anesthesiologists class greater than 3, and dependent functional status as predictors of complications following CC. Based on combined evidence from 60 citations, a recent review concluded that old age, longer operating time, and a 2-stage circumferential decompression were associated with increased perioperative complications.⁶⁷ Interestingly, among the numerous variables analyzed in our study, the execution of a skip corpectomy was found to be significantly associated with the risk of developing any complication after CC. Skip corpectomies are usually performed in the setting of extensive ventral compression, and the preservation of the C-5 vertebral body is believed to con-

fer greater stability and strength to the construct.^{4,10} The extensive exposure and the use of 2 graft constructs might be considered factors contributing to the higher complication rates in this group of patients. If these were the only factors, then patients undergoing 3-level CC should also be at higher risk for complications. Since 3-level CC was not seen as risk factor for higher rate of complications, the real reasons why patients undergoing skip corpectomies had a higher rate of complications remain unclear.

We report a relatively low rate of dysphagia compared with other studies reporting complication rates with CC.^{17,65} This may be a consequence of the shorter average duration of surgery (< 4 hours). More importantly, our definition of dysphagia led us to include only those patients who needed a nasogastric tube or parenteral feeding due to the dysphagia and not patients who only complained of pain during swallowing. Similarly, recurrent laryngeal nerve injury was only considered in dysphonic patients with laryngoscopic evidence of vocal cord palsy.

Dural Tear

CSF leaks due to dural tears contribute significantly to patient morbidity following CC, and could be associ-

TABLE 4. Univariate and multivariate analyses of risk factors associated with dural tear (n = 20) following CC

Risk Factor	Univariate Analysis		Multivariate Analysis	
	OR (95% CI)	p Value	OR (95% CI)	p Value
Age $\geq$ 50 yrs	3.222 (1.152–9.016)	0.026*	2.541 (0.879–7.346)	0.085
Symptom duration $\geq$ 1 yr	1.482 (0.602–3.648)	0.392		
Preop Nurick grade of 4 or 5	0.858 (0.336–2.192)	0.749		
3-level corpectomy	0.973 (0.125–7.586)	0.979		
Skip corpectomy	11.154 (3.522–35.321)	<0.001*	7.647 (2.284–25.599)	0.001
OPLL	3.833 (1.531–9.600)	0.004*	3.258 (1.263–8.402)	0.015
Diabetes mellitus	4.474 (1.169–17.118)	0.029		
Previous cervical surgery	3.444 (0.728–16.306)	0.119		

* Factor inserted into the logistic regression model.

TABLE 5. Univariate and multivariate analyses of risk factors associated with surgical-site infections (n = 16) following CC

Risk Factor	Univariate Analysis		Multivariate Analysis	
	OR (95% CI)	p Value	OR (95% CI)	p Value
Age ≥ 50 yrs	1.027 (0.379–2.784)	0.958		
Symptom duration ≥ 1 yr	0.707 (0.253–1.979)	0.509		
Preop Nurick grade of 4 or 5	2.118 (0.774–5.791)	0.144		
Multilevel corpectomy	3.582 (0.804–15.963)*	0.094	3.244 (0.717–14.681)	0.127
OPLL	1.090 (0.372–3.199)	0.875		
Skip corpectomy	3.893 (0.815–18.587)*	0.088	2.948 (0.608–14.303)	0.180
Diabetes mellitus	1.342 (0.167–10.780)	0.782		

* Factor inserted into the logistic regression model.

ated with pseudomeningocele and fistula formation, airway compromise, and meningitis.^{12,31,39} Unintended dural tears following CC reported in literature range from 0% to 8%.^{11,14,15,36,38} However, the incidence of CSF leak following ventral decompression of cervical OPLL is significantly higher as compared with CSM, since the disease process in OPLL intimately involves the dura.^{1,8,23,63,64}

Our results indicate that OPLL and skip CC are important risk factors for dural tear following CC. Our experience in managing CSF leak following CC for OPLL was the subject of a previous publication,²⁷ which also demonstrated that intraoperative repair followed by postoperative lumbar subarachnoid drainage could obviate the need for revision surgery in most patients. Dural tears following CC for CSM were also managed successfully with the same strategy. It is unclear why dural tears were common in patients undergoing skip CC, although we note that the indication for skip CC was OPLL in 50% of cases. However, it is likely that the high incidence of dural tear with skip CC is also the reason it contributed to increased overall morbidity in our study. A caveat to this remains the fact that the low incidence of dural tear may have contributed to overfitting of the model. Older age was associated with dural tears on univariate analysis in our study. O'Neill et al.⁴⁶ note a similar association and attributed it to age-related loss of tensile strength of the dura, which has also been observed in lumbar spine surgery.^{20,61,66}

C-5 Radiculopathy

Postoperative C-5 radiculopathy complicates between 1.6% and 12% of ventral decompressive procedures for CSM or OPLL.^{4,19,25,26,44,47,60,70,71} The pathogenesis of C-5 radiculopathy is poorly understood and is believed to be multifactorial. Postulated hypotheses include 1) direct intraoperative neural injury, 2) “tethering” of the short C-5 nerve root, and 3) ischemic and reperfusion injury of the spinal cord.^{53,56,58,68,71} In our data, the performance of a C-4 or a C-5 corpectomy was not associated with a greater risk for C-5 palsy ($p = 0.139$ and $p = 0.588$, respectively), making intraoperative injury to the root unlikely. One of the risk factors suggested by Saunders⁵⁷ is a wide decompression in excess of 15 mm. Odate et al.⁴⁷ also recommended limiting the corpectomy width to less than 15 mm to avoid C-5 palsy. Traction generated by anterior dural expansion

following CC in the presence of restricted spinal cord movement may possibly cause C-5 root dysfunction, particularly in cases in which the ventral rootlets are adherent to the dura.^{47,57} This may have contributed to the development of this complication in a patient who underwent a C-6 CC in this series. Since all our decompressions were conservative and none exceeded 16 mm, it is likely that this played a role in reducing the number of C-5 palsies noted in our series.

In a subgroup analysis of 255 patients undergoing anterior corpectomy for degenerative disease, Nassr et al.⁴⁴ noted C-5 palsy to be more common in male patients and in those undergoing multilevel procedures. Age and number of corpectomy levels were also the strongest risk factors for postoperative C-5 palsy in the series described by Bydon et al.⁶ A diagnosis of OPLL,^{25,29} particularly in those patients with a high occupying ratio,³⁰ also appears to confer an increased risk for C-5 palsy. In our study, no clinical, imaging, or surgical factor was found to be predictive of C-5 palsy. This is likely because of the low incidence of this complication in our series, which makes statistical comparisons less reliable. The role of a prophylactic C4–5 foraminotomy is controversial; while there may be some merit to it in cases of posterior fusion procedures,^{42,54} it remains technically difficult in conjunction with a CC and may be in itself associated with a slight increase in C-5 radiculopathy with anterior approaches.⁶

Graft Migration and Donor Site Morbidity

Although reconstruction of the vertebral defect following CC was originally performed with an iliac or fibular strut graft, anterior cervical plating is commonly performed today, with most authors also recommending additional instrumentation to stabilize the osseous construct. We have previously published our experience with acute graft extrusion using a “modified keystone” method and shown that the acute graft extrusion rates was less than 2% and was not only comparable but better than that reported for most instrumented series.³² While a statistically significant learning curve was also apparent, interestingly, we noted that the extrusion rates were not related the number of corpectomy levels.³² In fact, none of the patients undergoing a 3-level CC experienced graft extrusion. The most common cause of this complication appears to be im-

proper fashioning of the graft, and this problem is usually completely eliminated as the surgeon's experience grows. Although, even in experienced hands, a fracture of an osteoporotic autograft can still occur, the incidence of this complication in our series was comparable to the incidence in studies reporting outcomes in instrumented CC. Fessler et al.¹⁸ reported on graft-related and technical complications complications for patients stratified by immobilization technique (halo vest, hard collar, or anterior plate). We analyzed their data using GraphPad and found no statistically significant between-groups differences. Other authors have also demonstrated no statistically significant decrease in graft extrusion rates with additional anterior cervical plating, which may be particularly pertinent for buttress plates and multilevel CC.^{16,51,55,69} Additionally, the high cost and complications related to spinal hardware, therefore, continue to dissuade us from performing instrumentation in our patients. Donor site pain and morbidity is often implicated in a reluctance to use tricortical iliac crest or fibular strut autografts. Serious complications such as local hematomas or infections were very rare in our series, occurring in 0.2% and 1.9% of cases, respectively, and no patient required reoperation for harvest-related problems. This compares favorably to what has been described in literature.^{2,9,13,45,58,59} It must be noted, however, that female sex, obesity, and the presence of medical risk factors predispose to morbidity at the harvest site.⁵⁹ Additionally, although our overall infection rate of 3.4% is relatively low, especially when compared with rates in contemporary reports by authors employing instrumentation, more than half of all surgical infections occurred at the graft site in our series. We acknowledge that cage-assisted reconstruction may provide an attractive alternative to both allo- and autografts, although the biomechanical advantage of a cage in the absence of anterior cervical plating remains uncertain.²⁸ Nevertheless, our favorable experience and low rate of morbidity achieved with the uninstrumented CC over the last 2 decades encourage us to maintain this practice.

Strengths and Limitations of This Study

This study suffers from limitations inherent to its retrospective nature. We did not have an objective system for documenting nonsevere dysphagia in our patients, nor did we have data on estimated blood loss at surgery. Furthermore, given that this is a single-surgeon series that spans a period of over 15 years, it is uncertain whether surgeon experience may have impacted complication rates in this series. We also do not have data on early settling of fibular grafts, but our experience with long-term subsidence following 3-level CC has been described in a previous study,²² which demonstrated a mean subsidence of 5.7 mm. Although some degree of settling of the graft is associated with fusion, this is usually not significant enough to affect patient outcome or warrant intervention. These limitations notwithstanding, this study describes complication rates in the largest single-surgeon cohort of patients undergoing CC for CSM or OPLL described in literature.

Conclusions

Complications following CC for CSM and OPLL are infrequent. On multivariate analysis, the execution of a skip

corpectomy appears to be significantly associated with the development of complications. OPLL and skip procedures remain the most important risk factors for dural tear. We did not find any risk factors for postoperative C5 palsy, dysphagia or acute graft extrusion after CC.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Rajshekhar. Acquisition of data: all authors. Analysis and interpretation of data: Rajshekhar, Sarkar. Drafting the article: all authors. Critically revising the article: Rajshekhar, Sarkar. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Rajshekhar. Statistical analysis: Sarkar. Administrative/technical/material support: Rajshekhar, Nair. Study supervision: Rajshekhar.

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