Noninfectious prevertebral soft-tissue inflammation and hematoma eliciting swelling after anterior cervical discectomy and fusion

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OBJECTIVE Anterior cervical discectomy and fusion (ACDF) procedures are performed to treat patients with cervical myelopathy or radiculopathy. Dysphagia is a post-ACDF complication. When it coincides with prevertebral space enlargement and inflammation, surgical site infection and pharyngoesophageal perforation must be considered. The association between dysphagia and prevertebral inflammation has not been reported. The authors investigated factors eliciting severe dysphagia and its relationship with prevertebral inflammation in patients who had undergone ACDF.

MATERIALS The clinical data of 299 patients who underwent 307 ACDF procedures for cervical radiculopathy or myelopathy at Kushiro Kojinkai Memorial Hospital and Kushiro Neurosurgical Hospital between December 2007 and August 2014 were reviewed.

RESULTS After 7 ACDF procedures (2.3%), 7 patients suffered severe prolonged and/or delayed dysphagia and odynophagia that prevented ingestion. In all 7 patients the prevertebral space was enlarged. In 5 (1.6%) the symptom was thought to be associated with prevertebral soft-tissue edema; in all 5 an inflammatory response, hyperthermia, and an increase in the white blood cell count and in C-reactive protein level was observed. After 2 procedures (0.7%), we noted prevertebral hematoma without an inflammatory response. None of the patients who had undergone 307 ACDF procedures manifested pharyngoesophageal perforation or surgical site infection.

CONCLUSIONS Severe dysphagia and odynophagia are post-ACDF complications. In most instances they are attributable to prevertebral soft-tissue edema accompanied by inflammatory responses such as fever and an increase in the white blood cell count and in C-reactive protein. In other cases these anomalies are elicited by hematoma not associated with inflammation.

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KEY WORDS prevertebral soft-tissue edema; prevertebral hematoma; anterior cervical discectomy and fusion; pharyngoesophageal perforation; dysphagia

ANTERIOR cervical discectomy and fusion (ACDF) procedures are performed to treat patients with cervical myelopathy or radiculopathy.¹¹ Swallowing disturbance manifesting as dysphagia and/or odynophagia is a common postoperative complication; 1%–79% of patients manifest these symptoms.¹³ While minor postoperative dysphagia lasting for 48 hours is common, when it persists, it may be indicative of a postoperative compli-

cation.¹⁷ Severe dysphagia in the early postoperative period has been reported in 7% of patients.^{2,5}

Swallowing disturbance is related to impaired pharyngeal contraction near the surgical site, deficient laryngeal closure, laryngeal penetration, and post-swallowing aspiration. It is thought to be attributable to overt postoperative complications, e.g., anterior dislodging of the bone graft, esophageal perforation, prevertebral abscess, or he-

ABBREVIATIONS ACDF = anterior cervical discectomy and fusion; CRP = C-reactive protein; NSAID = nonsteroidal antiinflammatory drug; PEEK = polyetheretherketone; PVH = prevertebral hematoma; WBC = white blood cell.

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matoma, and to covert complications such as neurological and/or soft-tissue injuries.^{10,17} While some of these complications must be addressed immediately, others improve spontaneously. Surgical site infection and/or pharyngo-esophageal perforation should be considered in patients who experience severe swallowing disturbance and a local and/or general inflammatory response reflected by widening of the prevertebral space, hyperthermia, and increases in the white blood cell (WBC) count and C-reactive protein (CRP) level. However, the factors leading to swallowing disturbance are unclear, and the relationship between it and inflammation is not well understood.

We reviewed the medical records of 299 patients who had undergone 307 ACDF procedures for cervical radiculopathy or myelopathy to identify factors that elicit severe posttreatment swallowing disturbance and to elucidate its relationship with a local and/or general inflammatory response after ACDF.

Methods

To investigate the incidence of post-ACDF swallowing disturbance such as dysphagia and/or odynophagia, we reviewed the medial records of patients who had undergone the procedure to treat cervical radiculopathy or myelopathy. After excluding patients treated for cervical vertebral fractures or vertebral dislocation due to trauma, our study population comprised 299 patients who underwent 307 ACDF procedures at Kushihiro Kojinkai Memorial Hospital and Kushihiro Neurosurgical Hospital between December 2007 and August 2014. None of the patients suffered severe swallowing disturbance before ACDF; preoperatively, all had been able to ingest food.

The patient demographics and the characteristics of the ACDF procedures are shown in Table 1. The 299 patients who underwent 307 procedures ranged in age from 24 to 83 years. Fourteen patients (4.6% of procedures) had a history of previous ACDF surgery, and 2 other patients had undergone carotid endarterectomy or surgical removal of a thyroid tumor. All 307 ACDF procedures were performed at C3–7 via a right-sided approach; 190 (61.9%) involved a single level, and in 117 (38.1%), multiple levels were addressed. ACDF procedures involving a site above C-5, C3–4, and C4–5 were defined as a higher-level surgery and all others as lower-level procedures. For vertebral fixation we placed a cylindrical or box-shaped titanium cage (n = 221 procedures), a box-shaped polyetheretherketone (PEEK) cage (n = 82), or both (n = 4). In 2 procedures (0.7%) we additionally inserted an anterior plate.

The incidence of severe dysphagia, surgical site infection, and esophageal perforation within the 1st postoperative week was recorded. We focused on severe swallowing disturbance, a major clinical problem, defined as the inability to ingest food 2 days after the procedure due to dysphagia and/or odynophagia. This definition corresponds to severe dysphagia according to the Bazaz dysphagia score.² Our patients were given nonsteroidal antiinflammatory drugs (NSAIDs) routinely immediately after surgery to relieve pain at the surgical site. We defined patients receiving NSAIDs for longer than 3 days as NSAID users. Postoperative steroid treatment was not administered

TABLE 1. Patient demographics and ACDF procedures (n = 307)

Variable	Value
Patients	
Mean age in yrs $\pm$ SD	55.2 $\pm$ 12.5
Males/females	214 (69.7)/93 (30.3)
Previous op	16 (5.2)
ACDF	14 (4.6)
Carotid endarterectomy	1 (0.3)
Removal of thyroid tumor	1 (0.3)
Characteristics of ACDF procedures	
≥ 2 levels	117 (38.1)
Higher level	107 (34.9)
Prevertebral drainage	86 (28.0)
Cage type	
Titanium	221 (72.0)
PEEK	82 (26.7)
Both	4 (1.3)
Anterior plate fixation	2 (0.7)
Mean op duration in mins $\pm$ SD	135.1 $\pm$ 48.0
Postprocedure medication	
NSAID	132 (43.0)
Steroid	12 (3.9)

Values are presented as the number of patients (%) unless indicated otherwise.

routinely. In patients who had undergone ACDF for acute deterioration and those with an autoimmune disease, an allergic reaction, or postoperative radicular pain, we considered the use of steroids. Body temperatures higher than 37.5°C and 38°C were recorded as moderate and high hyperthermia, respectively. Increases in the WBC count ($> 1 \times 10^4/\mu\text{l}$) and in CRP level ($> 5 \text{ mg/dl}$) were also recorded.

All statistical analyses were performed using SPSS software (version 24, IBM Corp.). For univariate analysis we used the Fisher exact test, the chi-square test, or the Student t-test. Differences of $p < 0.01$ were considered significant. Numerical data are expressed as the mean $\pm$ standard deviation.

Results

In our study (299 patients, 307 procedures) we encountered no postprocedural infections at the surgical site and no esophageal perforation or airway obstruction. Although patients were able to ingest food 2 days after 300 ACDF procedures (97.7%), the remaining 7 procedures (2.3%) in 7 patients were followed by severe prolonged and/or delayed dysphagia and odynophagia (Table 2). Cervical radiographs of the 7 affected patients revealed marked enlargement of the prevertebral space. MRI and CT studies showed that it was attributable to remarkable prevertebral edema after 5 procedures (1.6%) and to prevertebral hematoma (PVH) after 2 procedures (0.7%).

The 5 patients with prevertebral edema (Cases 1–5, Table 2) suffered severe swallowing disturbance that started on postoperative Days 2–4. They complained of both severe dysphagia and odynophagia at the surgical site.

TABLE 2. Characteristics of the patients who experienced severe postprocedural dysphagia and odynophagia

Case No.	PVH	Age (yrs), Sex	Surgical Site	PV Drain	NSAIDs	Steroid	Temp*	WBC Count†	CRP‡	Dysphagia Start Day	Expl Surg Day	Discharge Day
1	No	48, M	C5–6	No	No	No	High	Increased	Increased	4	6	32
2	No	55, M	C4–5	Yes	No	Yes	Moderate	Increased	No change	2	3	10
3	No	64, M	C5–6	No	Yes	No	Normal	Increased	Increased	3	—	10
4	No	46, M	C4–5, C5–6	No	Yes	No	Moderate	Increased	Increased	2	—	12
5	No	70, M	C3–4	No	Yes	Yes	High	No change	Increased	3	—	9
6	Yes	55, F	C5–6	Yes	No	No	Normal	No change	No change	1	8	15
7	Yes	56, M	C3–4, C5–6	No	No	No	Normal	No change	No change	1	—	10

Expl surg = exploratory surgery; PV = prevertebral; Temp = temperature.

* Temperatures 38°C or greater and 37.5°C are expressed as high and moderate, respectively.

† A WBC count greater than $10^4/\mu\text{l}$ is expressed as increased.

‡ A CRP level greater than 5 mg/dl is expressed as increased.

Their symptoms subsequently worsened and persisted for about 1 week. Both patients with PVH (Cases 6 and 7) reported severe dysphagia without remarkable odynophagia on the 1st postoperative day. The patient in Case 6 with unmitigated dysphagia underwent a second, exploratory operation under local anesthesia and sedation 1 week after ACDF. A PVH was identified and removed; her swallowing disturbance disappeared immediately thereafter. In Case 7, dysphagia improved gradually and spontaneously within the 1st postoperative week.

In 5 patients with prevertebral edema (Cases 1–5), inflammatory responses were seen; 4 patients were febrile. The WBC count and CRP level were increased in 4 patients. These inflammatory responses peaked on postoperative Days 4–6. Three patients with prevertebral edema (Cases 3–5) received NSAIDs to control their postoperative pain or body temperature; 2 patients (Cases 2 and 5) were treated with steroids. One of these patients (Case 2) was given steroids prophylactically by the anesthesiologist to avoid airway problems immediately after a second exploratory operation but not before the manifestation of swallowing disturbance. The patient in Case 5 had an autoimmune disease and continued to be treated with steroids the day after ACDF.

Neither patient with PVH (Cases 6 and 7) exhibited an inflammatory response; these patients were not febrile and manifested no increase in the WBC count or CRP. Neither patient was treated with NSAIDs or steroids. Although NSAID or steroid therapy might mask inflammatory responses, they were more often seen in patients with prevertebral edema than in those with PVH.

Inflammatory responses, hyperthermia, and an increase in the WBC count and CRP level developed in parallel with prevertebral edema and odynophagia. No other factors, such as pneumonia, urinary tract infection, or digestive organ problems, were identified. Because we suspected surgical site infection in 2 patients (Cases 1 and 2) who presented with severe postoperative odynophagia, hyperthermia, and an increased WBC count, as well as elevated CRP (Case 1), they underwent exploratory surgery. Neither patient presented with hematoma, abscess, or esophageal perforation. In addition, in 1 of these patients (Case 1), minor iatrogenic injuries to the outer membrane of the esophagus were repaired. While there was no immediate

change in the swallowing disturbance of these patients, it improved gradually. The other 3 patients with prevertebral soft-tissue swelling (Cases 3–5) were followed up conservatively, and their severe swallowing disturbance resolved spontaneously. At the time of discharge, none of the 5 patients suffered significant dysphagia and/or odynophagia.

We reviewed the daily body temperature after 304 ACDF procedures in patients who were available for study for at least 6 postoperative days. The body temperature exceeded 37.5°C after 7 of the procedures; severe dysphagia and odynophagia due to prevertebral edema were observed after 4 ACDF operations. Among 297 patients without postoperative fever, only 1 patient (Case 3) suffered severe swallowing disturbance due to prevertebral edema ($p < 0.01$). The WBC count and the CRP level were recorded within the first 2 days after 307 ACDF procedures; after 92 procedures (30.0%) there was an increase in the WBC count ($> 1 \times 10^4/\mu\text{l}$), and it had no relationship with a morbidity of severe swallowing disturbance due to prevertebral edema. There was not an increase in the CRP level. Next, we looked at the WBC count and the CRP level recorded on the 3rd to 6th days after 305 ACDF operations, a period during which swallowing disturbance due to prevertebral edema was at its peak. We observed severe swallowing disturbance due to prevertebral edema after 4 of 10 procedures that were followed by an increase in the WBC count but after only 1 of 295 ACDF procedures (0.3%) that did not elicit a WBC count increase ($p < 0.01$). Swallowing disturbance due to prevertebral edema developed after 4 of 20 ACDF operations that were followed by an elevation in the CRP level but in only 1 of 285 procedures that were not. All 5 patients with severe postprocedure swallowing disturbance due to prevertebral edema manifested remarkable inflammation; in 4 patients the body temperature was increased, 4 presented with an increase in the WBC count and 4 had increased CRP levels. The inflammatory responses were associated with severe swallowing disturbance due to prevertebral edema; no such response was seen in patients with postprocedural PVH.

As increases in the body temperature, WBC count, and CRP level were associated with swallowing disturbance due to prevertebral edema, we looked further for risk factors. There was no significant difference in postprocedural morbidity with respect to the sex of the treated patients

FIG. 1. Case 1. Cervical lateral radiographs obtained before (A) and 1 (B), 3 (C), and 6 (D) days after ACDF and on the day following exploratory surgery (E). Progressive enlargement of the prevertebral space was most notable after exploratory surgery.

(procedures in males 5 of 214 vs procedures in females 0 of 93, $p = 0.33$), a history of previous surgery (1 of 16 vs 4 of 291 procedures, $p = 0.24$), multilevel surgery (0 of 117 vs 5 of 190 procedures, $p = 0.16$), higher-level surgery (3 of 110 vs 2 of 197 procedures, $p = 0.35$), the insertion of prevertebral drainage (1 of 86 vs 4 of 221 procedures, $p = 1.0$), the cage type (titanium 4 of 221 vs PEEK 1 of 82 vs mixed 0 of 4 procedures, $p = 0.91$), anterior plate fixation (0 of 2 vs 5 of 305 procedures, $p = 1.0$), and NSAID administration (3 of 132 vs 2 of 175 procedures, $p = 0.66$). In our analysis of the effect of steroid administration, 1 patient whose steroid therapy was started after the onset of severe swallowing disturbance was assigned to the group with no steroid administration. Steroids had no significant effect on the postprocedural development of prevertebral edema (1 of 11 vs 4 of 296, $p = 0.17$). Of the 307 ACDF procedures, 215 were performed by Surgeon A and 63 by Surgeon B. Different surgeons performed the remaining 29 operations. There was no operator-related difference in postoperative morbidity attributable to prevertebral edema (Surgeon A 3 of 215 vs Surgeon B 1 of 63 vs other surgeons 1 of 29, $p = 0.71$). The age and operative time were not significantly different in patients with and without prevertebral edema (age 56.6 ± 10.3 vs 55.2 ± 12.6 years, $p = 0.80$; operative time 121.2 ± 32.3 vs 135.3 ± 48.2 minutes, $p = 0.52$).

Representative Cases

Case 1

This 48-year-old man presented with a 6-month history of progressively worsening clumsiness and numbness in both upper extremities and cervical radicular pain to the left shoulder. Neurological and radiographic examinations indicated cervical radiculomyelopathy due to disc herniation into the spinal canal at the C5–6 level. The patient underwent ACDF at the C5–6 level under general anesthesia. The ventral aspect of the cervical vertebral bodies at C-5 and C-6 was exposed by dissecting the deeper fascia via a transverse skin incision on the right side. To visualize the operative field, 2 Cloward retractors were used to retract the soft tissue vertically and horizontally. After microdiscectomy, the posterior spur and fragments of the herniated disc were removed. This was followed by interverte-

bral fixation with twin-cylinder titanium cages introduced into the disc space. There was no intraprocedural cerebrospinal fluid leakage and no major iatrogenic cervical organ injury. The patient's symptoms disappeared postoperatively. The patient received cefazolin (intravenous 2 g/day for 5 days). Solid foods were restarted the day after surgery. He suffered mild dysphagia and odynophagia that disappeared by the 2nd postoperative day. However, on the 5th day he complained of severe dysphagia and odynophagia. His symptoms progressively worsened; he was unable to take food by mouth, he became febrile, and his WBC count and CRP level increased. Cervical radiography and MRI showed progressive tissue swelling and edema in the prevertebral space (Figs. 1A–D and 2). We suspected surgical site infection due to esophageal perforation because there was severe and progressive inflammation at his neck in the early postoperative period. On postoperative Day 6 he underwent esophagography to look for esophageal fistulas. No leakage of contrast medium out of the esophagus was observed.

Because we were unable to rule out infection or esophageal perforation, we punctured the prevertebral space with a needle under ultrasonographic guidance. Bloody effusion was collected, but there was no evidence of abscess. However, as the patient's dysphagia and odynophagia persisted and his temperature, WBC count, and CRP level continued to be elevated, he underwent exploratory surgery. Just before this surgery, we administered 10 ml of an indigo carmine solution (20 mg blue dye in 10 ml) orally to look for esophageal fistulas. The wound from the earlier operation was reopened under general anesthesia; inspection of the operative site showed no abscess or infection, while minor iatrogenic injuries to the esophageal outer membrane were found and repaired. A drain was placed in the prevertebral space and the operation was completed. Cefazolin (2 g/day for 5 days) and vancomycin (2 g/day for 5 days) were delivered intravenously. However, the patient's pain around his pharynx worsened, and his body temperature, WBC count, and CRP level continued to increase. Repeat cervical radiography showed extreme widening of the prevertebral space (Fig. 1E). After 2 days of fasting, his oral intake was restricted for 2 weeks to fluids only; thereafter, he received solid food. Results of a cell culture of fluid from the surgical field were negative. The

FIG. 2. Case 1. Cervical sagittal T2-weighted (left) and T1-weighted (right) MR images obtained after ACDF. Note marked prevertebral soft-tissue edema.

patient's serum procalcitonin level, recorded twice within a week after the second surgery was very low (0.06 and 0.04 ng/ml). One week later, the patient's dysphagia gradually improved, and his body temperature and laboratory data normalized. He was discharged without any prominent symptoms 32 days after the ACDF procedure. We attributed his dysphagia and hyperthermia to idiopathic, noninfectious inflammation at the prevertebral site.

Case 6

This 55-year-old woman had suffered for several months from numbness in the right hand and arms and severe pain radiating to the right shoulder and arm. Neurological examination showed impaired sensation in the bilateral C6–7 dermatomes. The deep tendon reflex was hyperactive; she manifested bilateral knee and ankle jerks. MRI demonstrated spinal canal stenosis at the C5–6 level due to C-5 and C-6 spurs. The diagnosis was cervical radiculomyelopathy. She underwent ACDF, and a PEEK box cage was placed.

Postoperatively, the patient's radicular pain in her right arm and shoulder disappeared. She was unable to eat due to dysphagia for the 1st postoperative week; she did not complain of strong odynophagia. Cervical CT and MRI studies showed a remarkably widened prevertebral space due to hematoma (Fig. 3). Neither the patient's body temperature nor her WBC count or CRP level was increased. Under local anesthesia and sedation, the patient underwent a second operation to remove the hematoma. Immediately thereafter, her dysphagia improved, and she was discharged on the 15th day after the original ACDF procedure without the anomaly.

Discussion

Of the 307 ACDF procedures performed in 299 patients, 7 (2.3%) elicited severe postoperative swallowing disturbance that resolved within a few weeks. We attributed swallowing disturbance in 5 patients to noninfectious prevertebral inflammation and in the other 2 to PVH. None manifested infection and/or pharyngoesophageal perforation.

Dysphagia after ACDF is related to pharyngeal contraction disturbance near the surgical site, and to deficient

FIG. 3. Case 6. The cervical MR images (left) and CT scan (right) acquired after ACDF shows a prevertebral hematoma (*).

laryngeal closure, laryngeal penetration, and/or post-swallowing aspiration. Anterior dislodging of the bone graft, retropharyngeal abscess, esophageal hematoma, and respiratory disturbance may require urgent treatment^{3,10,17} while nerve injury and/or soft-tissue damage may not need to be addressed surgically and may improve spontaneously.

Various degrees of postprocedural dysphagia have been reported.^{2,5,17} According to Frempong-Boadu et al.⁵ who used video laryngoendoscopy, dysphagia often occurs in the 1st week after ACDF, although most of their patients remained asymptomatic. Severe dysphagia, defined on the Bazaz dysphagia score as difficulty swallowing most food, was observed in 5.6%–7.0% of patients 1 month after ACDF; thereafter, this rate decreased to 0.5%–1.3%.^{2,5} These earlier findings are consistent with ours.

We think that postoperative dysphagia in our 7 patients was associated with enlargement of the prevertebral space. After 2 of 307 procedures (0.7%), MRI and/or CT studies showed that 2 patients (Cases 6 and 7) harbored remarkable PVHs. They elicited dysphagia on the 1st day post-ACDF but did not experience progression. In 1 patient (Case 7), dysphagia subsequently improved spontaneously; in the other (Case 6), it disappeared immediately after surgical hematoma removal. After 5 ACDF procedures (1.6%), we observed prevertebral soft-tissue edema rather than hematoma. It was difficult to differentiate between edema and surgical site infection and/or pharyngoesophageal perforation because the 5 affected patients reported significant pharyngeal pain and manifested an inflammatory response, i.e., hyperthermia (4 patients), an elevated WBC count (4 patients), and increased CRP levels (4 patients) that progressed for several days and occurred in parallel with prevertebral soft-tissue swelling. We think that the prevertebral space, the surgical site of the ACDF procedure, was the origin of inflammation and that inflammation after tissue damage inflicted by the ACDF procedure elicited the postoperative swallowing disturbance we observed.

Prevertebral soft-tissue edema is reported to be associated with postoperative dysphagia that progresses after ACDF and peaks on postoperative Days 3–4.^{16,18} Thereafter, it gradually improves and is normalized in 6 weeks.¹⁴ The site most prone to swelling lies between the lower endplates of C-3 and C-4; changes at the lower level are milder than at the higher level.^{1,16,18} According to Andrew

and Sidhu,¹ because the anatomy of the lower cervical spine is more constrained, the prevertebral space appears to be larger in the pharynx and the hypopharynx than in the more distal tracheal/esophageal portion of the neck. When ACDF is performed at the upper cervical level, the surgical level is proximal to C-5, which was thus reported as a risk factor for prevertebral soft-tissue swelling, whereas patient sex and operative time were not.^{16,18} There is disagreement as to whether multiple-level ACDF is associated with swelling of prevertebral soft tissues.^{16,18}

Prevertebral soft-tissue edema is thought to be a consequence of tissue damage.¹⁶ Local ischemia involving the pharyngeal and esophageal walls may be a crucial step in the development of postoperative dysphagia.^{6,7} In patients with dysphagia, the intraluminal esophageal pressure was significantly elevated, and their mucosal perfusion was significantly lower than that in asymptomatic patients.¹¹ Tissue injuries at sites remote from the ACDF site may be the result of tissue tethering from retraction. Because we identified an inflammatory response in patients with prevertebral edema but not in those with hematoma, we posit that edema was induced by inflammation due to tissue injury. Our hypothesis is supported by findings that the local or systemic administration of steroids effectively prevented prevertebral soft-tissue swelling, dysphagia, and airway problems.^{4,8,9} However, we were unable to identify a specific risk factor for prevertebral edema because this complication was present in only 5 patients after 307 ACDF procedures.

Surgical site infection due to pharyngoesophageal perforation is a life-threatening complication; its incidence has been reported to be less than 1.5%.¹⁵ However, the mortality rate in patients with this complication is high, and treatment must be started immediately. When it is started within 24 hours, the mortality rate is 20% but can be as high as 50% if treatment is delayed. After 5 of 307 ACDF procedures (1.6%), we observed prevertebral noninfectious inflammation that was difficult to distinguish from surgical site infection or pharyngoesophageal perforation based on the general and local inflammatory response. In fact, it was suggested that 2 of the 5 patients undergo additional exploratory surgery; however, both patients declined.

To our knowledge, ours is the first report to document that prevertebral soft-tissue edema can be accompanied by a noninfectious inflammatory response manifesting as hyperthermia and an increase in the WBC count and CRP level. Although post-ACDF dysphagia and odynophagia in the presence of prevertebral soft-tissue swelling and a general inflammatory response should suggest the possibility of pharyngoesophageal perforation and/or surgical site infection, these are rare complications, and noninfectious inflammation in prevertebral tissue can mimic surgical-site infection. After considering that prevertebral edema is often accompanied by inflammatory responses, the advisability of reopening the surgical site should be considered carefully as it may exacerbate prevertebral tissue swelling, inflammation, and dysphagia. A better alternative may be to rule out abscess by needle puncture under ultrasonographic guidance.

Prevertebral drainage did not markedly reduce the incidence of noninfectious inflammation or hematoma in the prevertebral space. However, none of the patients with

drainage experienced severe dysphagia due to the development of hematoma. This suggests that while the placement of a drain may help to inhibit the development of PVH, it may not suppress noninfectious prevertebral inflammation and edema because the level at which the prevertebral swelling occurs is different from the surgical level.^{1,16,18} Further studies are needed to address these issues.

We could not detect significant risk factors of prevertebral edema because of low morbidity in this study and the lack of sufficient power of the analysis. However, to avoid damage to prevertebral tissue is considered important. Therefore, we suggest the intraoperative intermittent release of retractors to minimize compression-associated tissue ischemia.^{11,12} Careful monopolar and bipolar coagulation adjacent to the pharynx and esophagus is also important. Although iatrogenic pharyngoesophageal injury is rare, the absence of wall injury should be confirmed at the completion of the surgical procedure.

Conclusions

Severe dysphagia and odynophagia occur as complications of ACDF. In most instances, they are attributable to prevertebral soft-tissue edema accompanied by inflammatory responses, such as fever and an increase in the WBC count and CRP level. In other surgically treated patients, they are elicited by hematoma not associated with inflammation.

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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: Yagi. Acquisition of data: Yagi, Okazaki. Analysis and interpretation of data: Yagi, Inagaki, O Saito. Drafting the article: Yagi. Critically revising the article: Irie, Inagaki, K Saito. Reviewed submitted version of manuscript: Irie. Statistical analysis: Yagi, Okazaki, Irie. Administrative/technical/material support: Okazaki. Study supervision: Nakagawa, Nagahiro, K Saito.

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