

# Prevalence and Outcomes in Patients Undergoing Reintubation After Anterior Cervical Spine Surgery: Results From the AOSpine North America Multicenter Study on 8887 Patients

Global Spine Journal  
2017, Vol. 7(1S) 96S-102S  
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sagepub.com/journalsPermissions.nav  
DOI: 10.1177/2192568216687753  
journals.sagepub.com/home/gsj  


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## Abstract

**Study Design:** A multicenter, retrospective cohort study.

**Objective:** To evaluate clinical outcomes in patients with reintubation after anterior cervical spine surgery.

**Methods:** A total of 8887 patients undergoing anterior cervical spine surgery were enrolled in the AOSpine North America Rare Complications of Cervical Spine Surgery study. Patients with or without complications after surgery were included. Demographic and surgical information were collected for patients with reintubation. Patients were evaluated using a variety of assessment tools, including the modified Japanese Orthopedic Association scale, Nurick score, Neck Disability Index, and Short Form-36 Health Survey.

**Results:** Nine cases of postoperative reintubation were identified. The total prevalence of this complication was 0.10% and ranged from 0% to 0.59% across participating institutions. The time to development of airway symptoms after surgery was within 24 hours in 6 patients and between 5 and 7 days in 3 patients. Although 8 patients recovered, 1 patient died. At final follow-up, patients with reintubation did not exhibit significant and meaningful improvements in pain, functional status, or quality of life.

**Conclusions:** Although the prevalence of reintubation was very low, this complication was associated with adverse clinical outcomes. Clinicians should identify their high-risk patients and carefully observe them for up to 2 weeks after surgery.

## Keywords

multicenter study, anterior cervical surgery, reintubation, hematoma/edema evacuation, rare complications, clinical outcomes

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## Introduction

Anterior cervical spine surgery is commonly used for the treatment of degenerative disease, trauma, tumor, and infection.<sup>1-6</sup> The number of patients undergoing anterior surgery has increased during the past few decades and this approach has generally been accepted as a safe and reliable procedure.<sup>7,8</sup> Increasing rates of anterior surgery are likely due to technical advances and improved safety and because of expanding indications to older and sicker populations.<sup>8</sup> Anterior cervical surgery often results in significant improvements in functional status and quality of life in patients with a wide range of neurological deficits.<sup>1,2,9</sup>

However, the anterior approach may also be associated with an increased risk of certain perioperative complications.<sup>10</sup> For example, one of the most serious complications following anterior surgery is airway compromise resulting from a postoperative hematoma or from soft tissue swelling due to edema.<sup>10-12</sup> Hematoma formation likely results from venous bleeding or inadequately controlled arterial sources,<sup>13,14</sup> whereas edema in prevertebral soft tissue is typically caused by surgical manipulation.<sup>15,16</sup> Obstruction of the upper airway can lead to anoxic brain injury or death.<sup>12,17-19</sup> To manage these potentially catastrophic complications, reintubation should promptly be conducted for airway management. The reported frequency of reintubation after anterior cervical surgery ranges from 0.56% to 5.2%.<sup>13,16-19</sup> In addition to reintubation, wound re-exploration with hematoma evacuation may also be needed.<sup>13</sup>

Despite its severity, there are only a small number of studies that examine patients undergoing postoperative reintubation after anterior cervical surgery.<sup>13,17-19</sup> These studies only evaluated the prevalence and risk factors of reintubation; little is known about clinical outcomes following this complication. Furthermore, there is a lack of multicenter studies with large sample sizes of consecutive patients. As a result, there is a need to comprehensively analyze patient functional status following reintubation and to determine whether this complication is associated with inferior surgical outcomes.

In view of this knowledge gap, we conducted a large-scale multicenter study to determine the precise prevalence of emergency reintubation after anterior cervical surgery and to evaluate the impact of this complication on clinical outcomes.

## Methods

### Subjects

We conducted a retrospective multicenter study involving high-volume surgical centers from the AOSpine North America Clinical Research Network. Centers were selected based on their excellence in spine care and their clinical research infrastructure and experience. Patients were included in this study if they met the following inclusion criteria: (1) anterior cervical spine surgery at any level(s) from C2 to C7; (2) index surgery performed from January 1, 2005, to December 31, 2011; (3) experienced postoperative reintubation within 30 days of index surgery; and (4) aged 18 or older. Patients with or without

complications after surgery were included. Patients were excluded if they underwent cervical spine surgery to treat the following complications: esophageal perforation, epidural hematoma, C5 palsy, recurrent laryngeal nerve palsy, superior laryngeal nerve palsy, hypoglossal or glossopharyngeal nerve palsy, dural tear, brachial plexopathy, blindness, graft extrusion, misplaced screws requiring reoperation, anterior cervical infection, carotid artery injury or cerebrovascular accident due to carotid stenosis, vertebral artery injuries, Horner's syndrome, thoracic duct injury, quadriplegia, intraoperative death, revision of arthroplasty, and pseudomeningocele.

Medical records for 8887 consecutive patients who received anterior cervical spine surgery were reviewed at 19 sites to identify those who required reintubation. Trained research staff at each site abstracted data of patients with complications from the following sources: medical records (age, gender, height, weight, smoking status, duration of hospitalization, diagnosis, treatment history including previous cervical surgery, and scores of manual muscle test) and surgical charts (name of surgeon, date of surgery, surgical time, perioperative blood loss, cervical levels of surgery, surgical approach technique, presence or absence of endotracheal tube, laryngeal mask, cervical traction, neuromonitoring, spinal hardware, grafting, and adverse event). Data on complications were also extracted, including date of diagnosis, time from surgery to initial symptoms, type of complication, treatment (surgery or nonsurgery), test for diagnosis, and use of gastric tubes. Data was recorded on study-specific paper case report forms. Copies of case report forms were transferred to the AOSpine North America Clinical Research Network Methodological Core for processing, cleaning, and data entry.

### Data Collection

Extensive data was collected for patients who required reintubation, including demographic information, diagnosis, medical history, surgical summary, and treatment of complication. Clinical outcomes were evaluated at baseline and at final follow-up, using the modified Japanese Orthopaedic Association (mJOA), the Nurick score, the Neck Disability Index (NDI), and the Short Form-36 version 2 (SF-36) Physical Component Score (PCS) and Mental Component Score (MCS). Visual Analogue Scale (VAS) was used to evaluate patients' arm/shoulder and neck pain using distance measurement.

### Statistical Analysis

Means  $\pm$  standard deviations (SD) were used to describe continuous variables, and frequencies and percentages were used to summarize categorical variables. Baseline and final follow-up scores in functional status were compared using a nonparametric Wilcoxon signed-rank test. A *P* value less than .05 was considered statistically significant. Scores were only compared when the sample size was greater than 4 patients.

**Table 1.** Demographic and Perioperative Data in Patients With Reintubation.

Patient	Age (Years)	Gender	BMI	Diagnosis	Surgical Level	Surgical Time (Minutes)	Blood Loss (mL)	Time to Initial Symptom (Hours)	ICU/Hospital Stay (Days)	Outcome
1	48	Female	31.2	Infect	C2-C4	NA	1000	120	5/18	Death
2	69	Male	41.8	Myel	C3-C5	185	NA	168	18/NA	Resolved
3	45	Female	27.1	Radicul	C4-C7	242	NA	12	1/NA	Resolved
4	32	Female	48.9	Myel	C5-C7	152	50	4	4/7	Resolved
5	67	Male	31.8	Disc, Myel, Radicul	C3-C6	NA	200	24	3/8	Resolved
6	52	Male	28.0	Disc	C5-T1	186	100	24	0/2	Resolved
7	42	Male	34.9	Myel, Radicul	C5-C6	120	100	7	0/1	Resolved
8	50	Female	22.0	Disc, Radicul	C5-C6	140	20	168	0/1	Resolved
9	44	Male	23.7	Disc, Radicul	C5-C7	180	150	24	1/2	Resolved
Average	49.9	—	32.2	—	—	172.1	231.4	61.2	3.6/5.6	—

Abbreviations: BMI, body mass index; ICU, intensive care unit; Infect, infection; Myel, myelopathy; Radicul, radiculopathy; Disc, degenerative disc disease; NA, not available.

## Results

### Demographic Data

Nine cases of postoperative reintubation were identified in this multicenter study (Table 1). The prevalence of this complication was 0.10% (9/8887) and ranged from 0% to 0.59% across participating institutions. Of the 9 patients, there were 5 men and 4 women, with a mean age of  $49.9 \pm 11.8$  years (range 32-69 years). The mean body mass index was  $32.2 \pm 8.7$  (range 22.0-48.9). Patients' diagnoses were radiculopathy (n = 5; patients 3, 5, 7-9), degenerative disc disease (n = 4; patients 5, 6, 8, 9), myelopathy (n = 4; patients 2, 4, 5, 7), and infection (n = 1; patient 1). See Table 1. Comorbidities included hypertension (n = 5; patients 1-5), peripheral vascular disease (n = 1; patient 2), chronic pulmonary disease (n = 1; patient 3), and diabetes without end-organ damage (n = 1; patient 5). Two patients were smokers: one a current smoker (patient 1) and the other a previous smoker (patient 3). Information was not available on timing of smoking cessation, duration of habit, or pack years. Two patients underwent previous cervical surgeries: one received a laminectomy and anterior cervical decompression and fusion (ACDF; patient 5) and the other an ACDF (patient 8).

### Surgical Factors

Endotracheal tubes were used in all patients. Intraoperative cervical traction was used in 2 patients (patients 1, 3). The neck was rotated in one patient during surgery (patient 1). All patients underwent an ACDF with a mean operative duration of  $172.1 \pm 39.7$  minutes (range 120-242 minutes). The average number of fused levels was  $3.2 \pm 1.0$  (range 2-5 levels). Plates were used in all patients, and cages were used in 2 patients (patients 1, 2). Autograft and allograft were performed in 6 (patients 1, 5-9) and 7 patients (patients 3-9), respectively. Mean blood loss during the procedure was  $231.4 \pm 344.1$  mL (range 20-1000 mL). One patient underwent a blood transfusion due to excessive blood loss (1000 mL; patient 1).

### Course of Pre- and Post-Reintubation

The mean time from anterior cervical surgery to initial symptoms for reintubation was  $61.2 \pm 69.9$  hours (range 4-168 hours). Six patients received reintubation within 24 hours (patients 3-7, 9), whereas 3 patients experienced this complication between 5 and 7 days of surgery (patients 1, 2, 8). To assist with diagnosis, 2 patients underwent imaging examination: one magnetic resonance imaging (patient 1) and the other X-ray (patient 5).

Eight patients underwent surgical evacuation of the hematoma/edema (patients 2-9), and postoperative drainage was used for an average of  $21.0 \pm 5.0$  hours (range 12-24 hours; patients 2, 3, 5-9). In one patient, a percutaneous gastric tube was used for 8 days (patient 2).

Six out of 9 patients were treated in an intensive care unit (ICU), with a mean duration of stay of  $3.6 \pm 5.7$  days (range 0-18 days; patients 1-5, 9). The mean length of hospital stay for all patients was  $5.6 \pm 6.2$  days (range 1-18 days).

### Clinical Outcomes

Following reintubation, 1 patient died and 8 patients recovered. The mean time between baseline and final follow-up examination was  $14.3 \pm 7.2$  months (range 9-27 months). Pre- and postoperative mJOA and Nurick scores were available in 5 patients (patients 5-9). Although there was a trend toward a slight improvement at final follow-up, the change in mJOA ( $16.8 \pm 1.8$  at baseline,  $17.4 \pm 1.3$  at final follow-up;  $P = .18$ ) and Nurick scores ( $0.8 \pm 1.3$  at baseline,  $0.6 \pm 1.3$  at final follow-up;  $P = .32$ ) were not statistically significant (Table 2). For the other clinical outcomes, the number of patients was too small to perform statistical comparisons; however, change scores did not achieve the minimum clinically important difference on the NDI (n = 4:  $27.0 \pm 11.8$  at baseline,  $26.0 \pm 19.3$  at final follow-up), VAS at arm/shoulder (n = 3:  $4.3 \pm 3.5$  at baseline,  $0.3 \pm 0.6$  at final follow-up), VAS at neck (n = 3:  $4.3 \pm 1.2$  at baseline,  $2.7 \pm 3.8$  at final follow-up), SF-36 PCS (n = 3:  $42.8 \pm 8.0$  at baseline,  $39.7 \pm 15.0$  at final follow-up),

**Table 2.** Baseline and Final Follow-up mJOA and Nurick Scores in Patients With Reintubation.

	Baseline Score (Mean $\pm$ SD)	Final Follow-up Score (Mean $\pm$ SD)	P
mJOA (n = 5)	16.8 $\pm$ 1.8	17.4 $\pm$ 1.3	.18
Nurick (n = 5)	0.8 $\pm$ 1.3	0.6 $\pm$ 1.3	.32

Abbreviations: mJOA, modified Japanese Orthopaedic Association scale.

**Table 3.** Baseline and Final Follow-up NDI, VAS, and SF-36 Scores in Patients With Reintubation.

	Baseline Score (Mean $\pm$ SD)	Final Follow-up Score (Mean $\pm$ SD)
NDI (n = 4)	27.0 $\pm$ 11.8	26.0 $\pm$ 19.3
VAS (arm/shoulder) (n = 3)	4.3 $\pm$ 3.5	0.3 $\pm$ 0.6
VAS (neck) (n = 3)	4.3 $\pm$ 1.2	2.7 $\pm$ 3.8
SF-36 PCS (n = 3)	42.8 $\pm$ 8.0	39.7 $\pm$ 15.0
SF-36 MCS (n = 3)	42.3 $\pm$ 11.1	44.4 $\pm$ 18.5

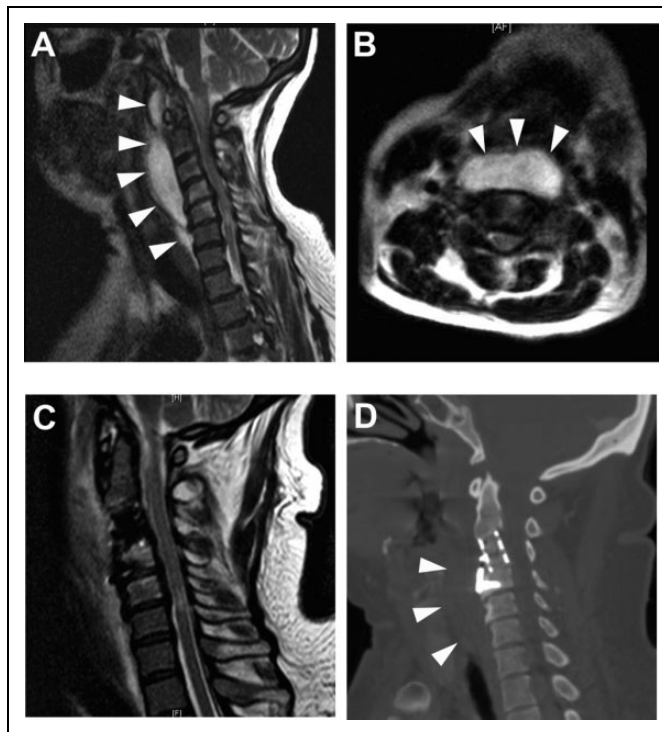
Abbreviations: NDI, Neck Disability Index; VAS, visual analogue scale; SF-36, Short Form-36; PCS, Physical Component Score; MCS, Mental Component Score.

and SF-36 MCS (n = 3: 42.3  $\pm$  11.1 at baseline, 44.4  $\pm$  18.5 at final follow-up). See Table 3.

### Case Presentation (Patient 1)

A 48-year-old female, who had comorbidities including hepatitis C virus with liver cirrhosis and human immunodeficiency virus (HIV), was transferred from another hospital with a 1-week history of worsening neck pain. Magnetic resonance imaging showed large prevertebral collection with low- and high-intensity signal change on T1- and T2-weighted images, respectively, which extended from C1 through the cervicothoracic junction (Figure 1A and B). There was a ventral epidural collection with similar signal intensity extending from C1 to the C2-C3 level that appeared to cause significant canal narrowing, with cerebrospinal fluid effacement and severe cord flattening.

She underwent surgery, which consisted of a C3 corpectomy, evacuation of epidural abscess, and placement of titanium mesh cage with an anterior plate between C2 and C4. Three days after surgery, the patient was successfully weaned off the ventilator and extubated. Postoperative computed tomography scans and magnetic resonance imaging showed a significant decrease in the size of the prevertebral abscess (Figure 1C). Residual fluid collection with rim enhancement was noted at the skull base down to the C4 level within and outside the spinal canal. Soft tissue edema within the oropharynx and hypopharynx was prominent and narrowed the airway (Figure 1D). Five days postoperatively, delirium occurred due to hepatic encephalopathy, and the patient received reintubation for airway management. Her condition worsened with multisystem organ failure secondary to underlying sepsis. Her



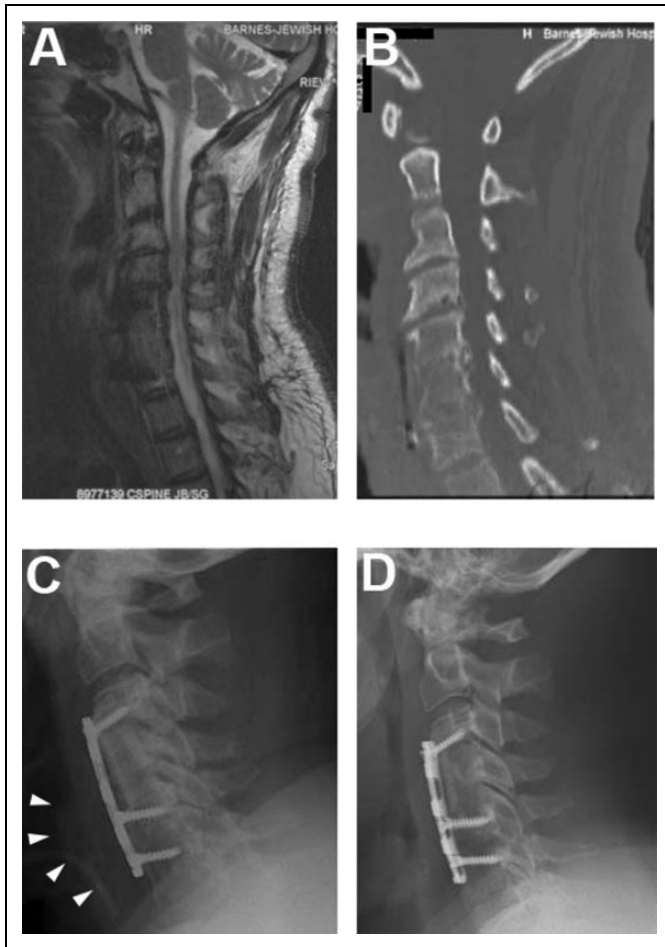
**Figure 1.** Case presentation (Patient 1). (A and B) Preoperative T2-weighted sagittal (A) and axial at C3/4 level (B) magnetic resonance (MR) imaging. Note that prevertebral abscess was prominent (arrowheads). (C) Three days postoperative T2-weighted sagittal MR imaging. (D) Three days postoperative sagittal computed tomography scans. Note that soft tissue edema in front of cervical vertebrae compressed and narrowed the airway (arrowheads).

family elected for terminal extubation with comfort measures, and she expired 10 days postsurgery.

### Case Presentation (Patient 5)

A 67-year-old male developed recurrent signs and symptoms of myelopathy following a laminectomy and C5-C7 ACDF at an outside institution. This patient had a mJOA score of 14 and a Nurick grade of 3. Radiographic examinations showed cord compression at C3/4 and C4/5 with spinal stenosis (Figure 2A and B). He received a second surgery: C3-C6 ACDF with a total corpectomy of C4. Ossification of the posterior longitudinal ligament was detected on the left side, mostly from an osteophyte that had ossified the anterior dura. A dural tear occurred while removing the osteophyte. Collagen matrix was put on top without suture. Bone allograft with off-label bone morphogenetic protein (8.4 mg) was used and a plate was placed.

On the next day in the afternoon, the patient began to experience respiratory distress. Radiographic examination showed retropharyngeal space swelling (Figure 2C), consistent with a hematoma. The patient returned to the operating room for evacuation of hematoma. Spinal fluid leakage was noted. The anterior cervical plate and graft material were removed, the dural tear was sutured, and collagen matrix was used on top



**Figure 2.** Case presentation (Patient 5). (A) Preoperative T2-weighted sagittal magnetic resonance imaging. (B) Preoperative sagittal computed tomography imaging. (C and D) Cervical lateral X-ray imaging at 1 day (C) and 4 months (D) after surgery. Note that compared to the image at 4 months postoperatively, soft tissue swelling was observed at retropharyngeal space (C; arrowheads).

of the suture. Grafted bone and anterior plate were placed. Wound was closed over a drain. Miami J collar was used, and the patient was transferred to the ICU. He stayed for 3 days at the ICU, and was then transferred to the general ward. His stay in the hospital was 8 days.

Four months after surgery, the patient demonstrated significant functional recovery (mJOA = 18, Nurick grade 0; Figure 1D); however, his status regressed by 1 year postoperatively (mJOA = 15, Nurick grade 3).

## Discussion

This large multicenter study demonstrated that reintubation is an extremely rare complication, occurring in 1 out of 1000 patients undergoing anterior cervical spine surgery. Patients who experienced this complication did not exhibit significant gains in functional status. This is in contrast to typical results observed following anterior cervical spine surgery.<sup>1,2</sup> In addition, one patient (11.11%) died following reintubation.

In this study, 67% of patients complained of initial symptoms of airway compromise by 24 hours postoperatively. Given the pathology of postoperative uncontrollable bleeding and inflammatory edema, it is reasonable to conclude that airway problems should typically occur within 24 to 72 hours following surgery.<sup>15,16,18</sup> However, 33% of the patients in our study presented with symptoms at a later time point, between 5 and 7 days. Similar to these results, other studies have demonstrated the occurrence of delayed airway compromise 1 to 2 weeks after anterior surgery.<sup>13,20</sup> Yu et al reported that a patient experienced respiratory difficulty with neck swelling 16 days following surgery and was diagnosed with active bleeding from the right superior thyroid artery following emergent angiography.<sup>20</sup> Attending surgeons should therefore be aware that this complication can occur up to 2 weeks postoperatively and should monitor their high-risk patients cautiously during this time period.

Marquez-Lara et al reported that reintubation was significantly associated with a longer hospital stay and greater hospital costs.<sup>17</sup> In attempt to reduce the rate of reintubation and associated physical and economic burdens, some institutions have implemented unique prophylactic treatments. For example, Epstein et al established a protocol after combined anterior-posterior surgery to maintain intubation overnight postoperatively and to only remove the tube after residual tracheal swelling has subsided (evaluated by bronchoscope).<sup>21</sup> Hart et al also developed a protocol that requires limited crystalloid fluid resuscitation intraoperatively with maintenance of blood pressure using vasopressors.<sup>22</sup> Prophylactic procedures for airway management should be carefully considered and adopted depending on patient condition and surgical stress.

The association between clinical outcomes and reintubation has been previously investigated by O'Neill et al in a single-center study. Due to a limited sample size, however, this study could not compare pre- and postoperative NDI scores in patients who required reintubation following anterior cervical surgery.<sup>13</sup> In contrast, our multicenter study comprehensively evaluated outcomes in patients with this complication using a variety of assessment tools. Based on our findings, there were no significant differences between baseline and postoperative mJOA or Nurick scores. In addition, the improvements observed on all scales, including the mJOA, Nurick, VAS, NDI, and SF-36 MCS, were not meaningful based on the defined minimum clinically important difference for these metrics.<sup>23-25</sup> Furthermore, patients exhibited a decline in status on the SF-36 PCS. Patients with airway complications requiring reintubation with evacuation therefore do not achieve as much functional and quality of life improvement after anterior surgery as expected and have lower change scores than previously reported series.<sup>23-25</sup>

The prevalence of reintubation in this study was 0.10% and ranged from 0% to 0.59% across participating institutions. The frequency of this complication was lower compared to rates reported in previous studies.<sup>16,18,19</sup> A possible explanation for this difference is that, in previous studies, the number of patients who underwent anterior surgery was much smaller

than in our series; these smaller sample sizes might result in a higher reported prevalence of this complication.<sup>16,18,19</sup> On the other hand, a recent study with a large population-based database reported that the rate of reintubation was 0.56%, a figure similar to our result.<sup>17</sup> Since our multicenter, large-scale study included consecutive cases, our results likely represent a more accurate prevalence of reintubation compared to studies with smaller and nonconsecutive samples.

It is also important to identify predictors of reintubation after ACDF in order to identify high-risk patients and implement appropriate intraoperative and postoperative management strategies. Sagi et al demonstrated that intraoperative blood loss greater than 300 mL, prolonged surgery longer than 5 hours, and exposure at or above C4 were all major risk factors for postoperative reintubation.<sup>18</sup> In a large-scale database study, Marquez-Lara et al conducted a logistic regression analysis and reported that significant predictors include age older than 65 years, obesity, 3+-level fusions, comorbidities such as anemia and congestive heart failure, and postoperative complications such as aspiration pneumonia, dysphagia, and thromboembolic events.<sup>17</sup> With reference to these predictors, a higher body mass index in our cases might have increased the risk of reintubation with airway compromise after ACDF (Table 1). Reintubation may also result in longer length of ICU and hospital stay, similar to the results of a previous study.<sup>17</sup> For patients at a higher risk of this complication, prophylactic treatment and/or cautious postoperative observation should be considered.

### Strengths and Limitations

The major strength of this study is that we were able to evaluate the rate of reintubation in a large sample of patients treated at multiple institutions. We believe that our estimate of prevalence likely reflects the true rate of this complication in patients undergoing anterior cervical spine surgery. We were also able to evaluate surgical outcomes in these patients using functional assessment tools such as mJOA and Nurick scores. On the other hand, this study also has several limitations. First, the number of patients with reintubation was small ( $n = 9$ ), which reduces the statistical power and leads to higher risk of a type II error. In fact, the number of patients with NDI, VAS, and SF-36 was too small to statistically evaluate the clinical outcomes. Second, we only focused on reintubation after extubation and not on delayed extubation, which prevents a complete and comprehensive examination of airway compromise following anterior cervical surgery. Third, all institutions did not have a database that tracked complications. Since this is a retrospective study, it is possible that the total prevalence of reintubation may be lower than estimated. Therefore, we have included the range of rates of reintubation across institutions rather than just the total prevalence in order to provide the most accurate picture of our findings. Finally, there was no control group to evaluate important risk factors associated with reintubation.

### Conclusion

This large-scale multicenter study indicated that the prevalence of reintubation after anterior cervical surgery was 0.10% and

ranged from 0% to 0.59% across participating institutions. Initial symptoms of airway compromise occurred within 24 hours of surgery or by 1 week after surgery, indicating that attending surgeons should carefully observe their high-risk patients for at least 2 weeks. With respect to surgical outcomes after reintubation, patients did not exhibit significant improvements in functional outcomes at final follow-up, suggesting that this complication may result in suboptimal outcomes. To avoid reintubation, prophylactic treatment strategies should be considered depending on patient condition, relevant risk factors, and surgical stress. A prompt decision should be made to perform surgical evacuation of the hematoma, if present, to assist with airway management.

### Authors' Note

This study was ethically approved by the institutional ethics committees at all participating sites.

### Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Narihito Nagoshi reports grants from AOSpine North America during the conduct of the study; Michael G. Fehlings reports grants from AOSpine North America during the conduct of the study; Hiroaki Nakashima reports grants from AOSpine North America during the conduct of the study; Lindsay Tetreault reports grants from AOSpine North America during the conduct of the study; Jeffrey L. Gum reports grants from AOSpine North America during the conduct of the study, personal fees from Medtronic, Alphatec, Stryker, LifeSpine, Acuity, Pacira, PAKmed, Gerson Lehrman Group, personal fees from OREF, AOSpine, personal fees from Acuity, other from Medtronic, personal fees from MiMedx, Pacira Pharmaceuticals, Alphatec, grants from Fischer Owen Fund, nonfinancial support from American Journal of Orthopaedics, nonfinancial support from American Journal of Orthopaedics, The Spine Journal, outside the submitted work; Zachary A. Smith reports grants from AOSpine North America during the conduct of the study; Wellington K. Hsu reports grants from AOSpine North America during the conduct of the study, personal fees from Medtronic, personal fees from Stryker, personal fees from Bacterin, personal fees from Graftys, personal fees from Ceramtec, personal fees from Relevant, personal fees from Bioventus, personal fees from Globus, personal fees from SpineSmith, outside the submitted work; Chadi A. Tannoury reports grants from AOSpine North America during the conduct of the study; Tony Tannoury reports grants from AOSpine North America during the conduct of the study; Vincent C. Traynelis reports grants from AOSpine North America during the conduct of the study, grants from National Institutes of Health, outside the submitted work, and Consultant for Medtronic Royalties from Medtronic Institutional Fellowship Support from Globus; Thomas E. Mroz reports other from AOSpine, during the conduct of the study, personal fees from Stryker, personal fees from Ceramtec, other from Pearl Diver, outside the submitted work; Ziya L. Gokaslan reports grants from AOSpine North America during the conduct of the study, grants from AOSpine North America, personal fees from AO Foundation, grants from AOSpine, outside the submitted work; Mohamad Bydon reports grants from AOSpine North America during the conduct of the study; Bruce C. Jobse reports grants from AOSpine North America during the conduct of the study; Eric M. Massicotte reports grants from AOSpine North America

during the conduct of the study, grants from Medtronic, Depuy-Synthes Spine Canada, personal fees from Watermark consulting, grants from AOSpine North America, nonfinancial support from AOSpine North America, outside the submitted work; and K. Daniel Riew reports personal fees from AOSpine International, other from Global Spine Journal, other from Spine Journal, other from Neurosurgery, personal fees from Multiple Entities for defense, plaintiff, grants from AOSpine, grants from Cerapedics, grants from Medtronic, personal fees from AOSpine, personal fees from NASS, personal fees from Biomet, personal fees from Medtronic, nonfinancial support from Broadwater, outside the submitted work; Paul M. Arnold reports grants from AOSpine North America during the conduct of the study; other from Z-Plasty, other from Medtronic Sofamore Danek, other from Stryker Spine, other from FzioMed, other from AOSpine North America, other from Life Spine, other from Integra Life, other from Spine Wave, other from MIEMS, other from Cerapedics, other from AOSpine North America, outside the submitted work; Anthony F. De Giacomo reports grants from AOSpine North America during the conduct of the study.

### Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This study was sponsored by AOSpine North America Inc, a 501(c)3 nonprofit corporation.

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