

Upper cervical anterior fusion with a particular focus on superior laryngeal nerve and hypoglossal nerve

Naoki Okamoto and Seiichi Azuma

Department of Orthopedics, Saitama Red Cross Hospital, Saitama, Japan

Abstract:

Introduction: During upper cervical anterior fusion involving C2, the branches of the superior laryngeal and hypoglossal nerves traversing the operative field are at risk for injury, mainly from excessive retraction and/or incidental ligation. These injuries would cause postoperative dysphagia and/or dysphonia that are often transient but might sometimes persist for several months. The aim of this study was to describe our modified approach for upper cervical anterior fusion and to examine the surgical outcomes and postoperative complications in a small case series.

Methods: Four patients underwent upper cervical anterior fusion at our institution. Detaching the omohyoid and sternohyoid muscles from the hyoid bone increased the mobility of the hyoid bone and enabled visualization of the thyrohyoid membrane. This maneuver facilitated access to C2 without excessive retraction to the larynx and the hypoglossal nerve traversing above the hyoid bone. Moreover, this maneuver enabled easy identification and dissection of the internal branch of the superior laryngeal nerve piercing the thyrohyoid membrane.

Results: Three patients underwent C2-3 fusion and one patient underwent C2-5 fusion followed by instrumentation. In all patients, wide, adequate exposure of C2 and proper instrumentation was achieved, and both the internal branch of the superior laryngeal nerve and the hypoglossal nerve were identified and preserved. No patient experienced remarkable postoperative dysphagia, dyspnea, and dysphonia. Solid union was achieved in all patients.

Conclusions: The technique of detaching the infrahyoid muscles from the hyoid bone during upper cervical anterior fusion involving C2 reduced the traction force to the larynx and the hypoglossal nerve, enabled easy identification of the internal branch of the superior laryngeal nerve, and prevented postoperative complications, such as dysphagia.

Keywords:

anterior cervical fusion, upper cervical spine, superior laryngeal nerve, hypoglossal nerve, infrahyoid muscle

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Introduction

In upper cervical anterior fusion, the anatomic presence of vital neurovascular structures makes the surgical approach difficult. In particular, the branches of the superior laryngeal nerve (SLN) and hypoglossal nerve (HN) traversing the operative field are at risk for injury by excessive retraction and/or by incidental ligation^{1,2)}. Injury to these nerves would cause postoperative dysphagia and/or dysphonia that are often transient but sometimes persist and lead to life-threatening complications³⁾.

The aim of this study was to describe the details and estimate the surgical outcomes of our modified technique during upper cervical anterior fusion, with attention to the

branches of the SLN and HN. Furthermore, we aimed to discuss the efficacy of detaching the infrahyoid muscles from the hyoid bone, particularly in reducing the risk of severe complications, such as persistent dysphagia.

Materials and Methods

Four consecutive patients who underwent instrumented anterior cervical fusion involving C2 at our institution between 2015 and 2016 were included in this study. Informed consent was obtained prior to surgery from all patients who participated in this study. For the first case, an otolaryngologist supported us during the surgery. From the second case onward, we, the spinal surgeons, operated without instruc-



Figure 1. This photograph shows the correct patient position and the markings to indicate the superficial structures of the upper neck, including the hyoid bone (*white arrow*), submandibular gland (*asterisk*), inferior edge of the mandible (*black arrow*), and anterior margin of the sternocleidomastoid muscle (*double arrowhead*). Nasal intubation is performed. The neck is extended and rotated approximately 30° contralateral to the side of the surgical approach. In traumatic cases, the Halo vest is removed, and only the Halo crown is applied for intraoperative skull traction, as necessary.

tions from the said otolaryngologist. For the three trauma patients, Halo vest was applied preoperatively and removed postoperatively. In all patients, rigid neck collars were applied for 3 months postoperatively. All patients were followed up for at least 1 year.

Surgical Technique

Each patient was placed in the supine position with the neck extended and rotated approximately 30° contralateral to the side of the surgical approach (Fig. 1). Nasal intubation was preferred over oral intubation because it allowed full jaw closure to maximize access to the upper cervical spine.

The standard approach was from the left side to avoid recurrent laryngeal nerve injury. A wide transverse incision was made from the midline to the anterior margin of the sternocleidomastoid muscle at the level of the hyoid bone. The incision was made more than one fingerbreadth below the inferior edge of the mandible to prevent damage to the marginal mandibular branch of the facial nerve^{4,5}. The platysma was transected along the line of the skin incision, followed by subplatysmal dissection and identification of the submandibular gland located just below the platysma (Fig. 2 A). The facial vein, which coursed vertically in the lateral side of the submandibular gland, should be ligated. The submandibular gland was provided mobility by opening the lower part of its capsule and bluntly dissecting below it before retracting rostrally. The submandibular triangle, which comprised the inferior edge of the mandible and both bellies of the digastric muscle, would then be exposed just below

the submandibular gland.

The HN traversing toward the tongue muscles at C2 level was identified and tagged in the submandibular triangle (Fig. 2B). This nerve must be protected to avoid excessive traction injury in the subsequent procedures. The palpable hyoid bone, to which the infrahyoid muscles were attached, was identified immediately below the digastric muscle. Of these infrahyoid muscles, the omohyoid and sternohyoid muscles were detached from the inferior edge of the hyoid bone and reflected caudally. The thyrohyoid membrane between the hyoid bone and the thyroid cartilage was then exposed just deep to these infrahyoid muscles.

The internal branch of the SLN (iSLN) traversed at C3/4 level and pierced the thyrohyoid membrane caudal to the genu of the hyoid bone and just deep into the sternohyoid muscle^{1,2,5}. Blunt dissection between the thyrohyoid membrane and the carotid sheath was performed to expose the iSLN that usually ran along with the superior laryngeal artery (Fig. 2C), which was ligated as necessary. The iSLN should be dissected as long as possible lateral to the thyrohyoid membrane and medial to the carotid sheath. Because the SLN is vulnerable to stretch injury due to retraction³, longer dissection would help reduce this risk by decreasing the force required for retraction.

The mobility of the hyoid bone was restricted in the rostral and medial directions by the omohyoid and sternohyoid muscles. Detaching these infrahyoid muscles increased the mobility of the hyoid bone and the larynx. As a result, adequate exposure of C2 was achieved without excessive retraction to the HN traversing above the hyoid bone and the larynx.

Blunt dissection was performed to separate the plane medial to the carotid sheath and lateral to the larynx down to the paravertebral fascia. The fascia was cut longitudinally to expose the longus colli muscle and the anterior aspect of vertebrae. Thereafter, the longus colli muscle was mobilized, and self-retaining blade retractors were placed in the medial and lateral sides (Fig. 2D). The retractors were placed gently in the rostral and caudal sides, with careful attention to the HN and iSLN. Through this quadrilateral space, adequate visualization of the anterior aspect of C2 and C3 was achieved while protecting the HN and iSLN. As a result, following decompression and instrumentation procedures were precisely performed (Fig. 2E). It was not necessary to re-attach the omohyoid and sternohyoid muscles to the hyoid bone. In cases that required multilevel fusion, the iSLN was retracted not caudally but rostrally and protected together with the HN because additional exposure in the caudal side was needed.

Results

This study included one man and three women with mean age of 64 years. The demographic and surgical data for this patient series are described in Table 1. Single-level C2-3 fusion with titanium cage and plate instrument was performed

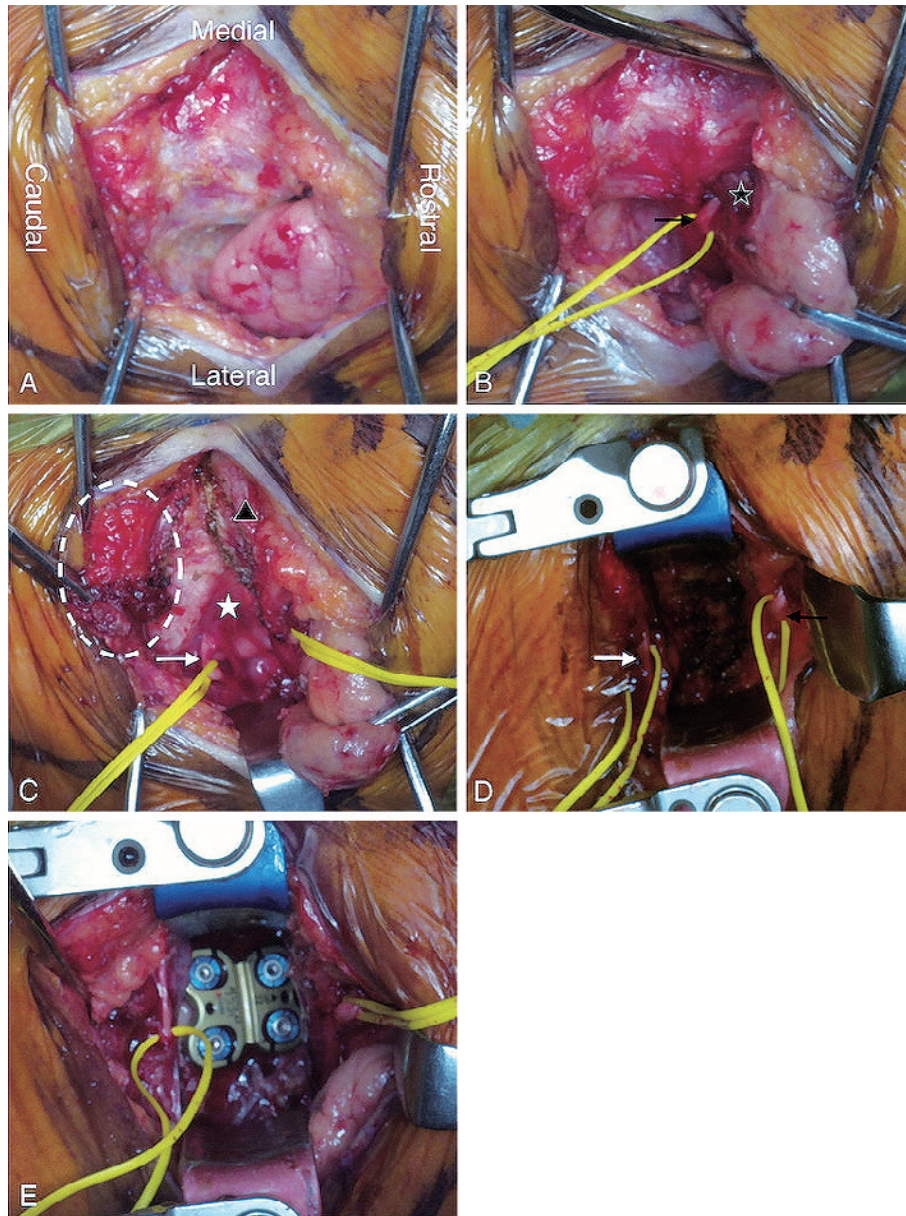


Figure 2. Intraoperative photographs during C2-3 fusion.

(A) After subplatysmal dissection, the submandibular gland becomes visible. (B) The hypoglossal nerve (*black arrow*) is dissected in the submandibular triangle (*black star*) after retracting the submandibular gland rostrally. (C) The internal branch of the superior laryngeal nerve (*white arrow*) piercing the thyrohyoid membrane (*white star*) is dissected after detaching the omohyoid and sternohyoid muscles (*encircled area*) from the inferior edge of the hyoid bone (*black arrowhead*). (D) The anterior aspect of C2 and C3 becomes visible while protecting the hypoglossal nerve (*black arrow*) in the rostral side and the internal branch of the superior laryngeal nerve (*white arrow*) in the caudal side. (E) Proper instrumentation is achieved under direct visualization of C2.

on three trauma patients. Multilevel C2-5 fusion with iliac bone graft and plate instrument was performed on one ossification of the posterior longitudinal ligament (OPLL) patient (Fig. 3).

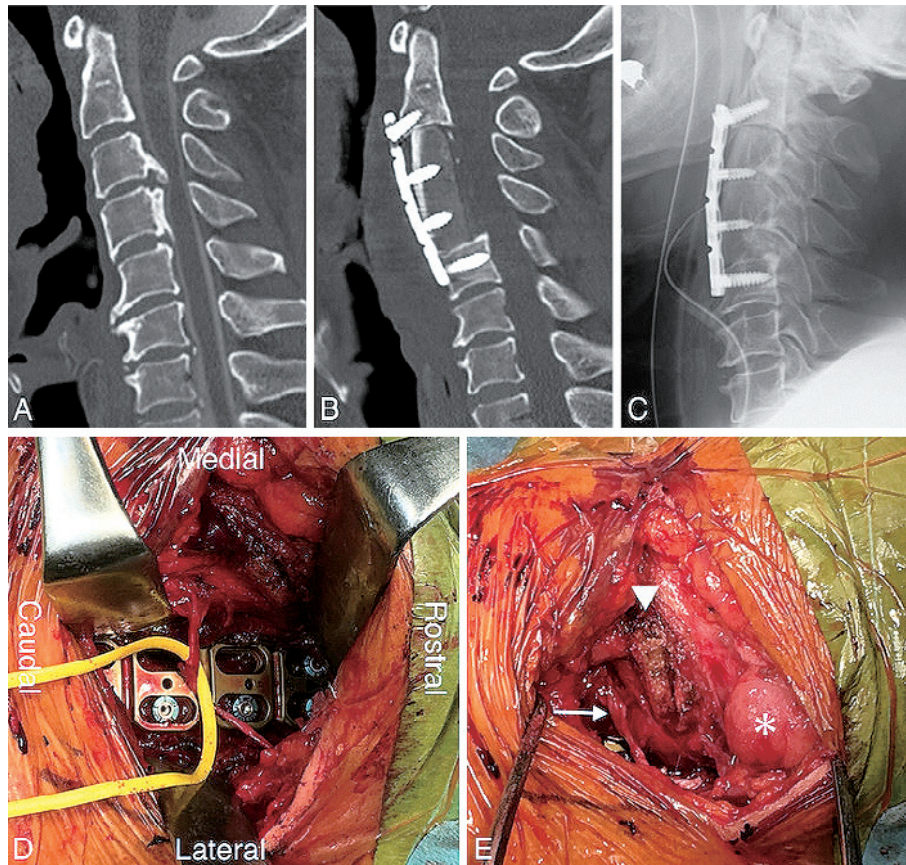
In all patients, the iSLN and HN were identified and successfully preserved intraoperatively. The external branch of the SLN (eSLN) was not identified in any patient. Wide adequate exposure of C2 enabled precise and secure decompression and instrumentation in all patients. Successful extu-

bation was performed immediately after surgery and reintubation was not required in all patients. No patient experienced postoperative complications such as dysphagia, dyspnea, dysphonia, and neurological deficit. In all patients, instrumentation failure was not observed. Furthermore, reconstructive computed tomography revealed successful solid fusion 6 months after operation.

Table 1. Characteristics of the Patients who Underwent Upper Cervical Anterior Fusion.

Case No.	Age (yr), Sex	Diagnosis	Symptom	Procedure	Operative time (min)	Amount of hemorrhage (g)	Complication
1	54, F	Hangman's fracture	Neck pain	C2-3 fusion	183	10	None
2	65, F	Hangman's fracture	Neck pain	C2-3 fusion	134	50	None
3	84, F	C2/3 traumatic subluxation	Quadriplegia	C2-3 fusion	104	5	None
4	52, M	C3-4 OPLL	Myelopathy	C2-5 fusion	293	100	None

OPLL, ossification of the posterior longitudinal ligament

**Figure 3.** A 52-year-old man with C3-4 OPLL (case 4).

(A) Preoperative sagittal reconstructed CT myelography shows the OPLL from C3 body to C4/5 interspace. (B and C) Postoperative sagittal reconstructed CT and lateral radiograph show C2-5 fusion with an iliac bone graft and plate instrument. (D) Intraoperative photograph shows the internal branch of the superior laryngeal nerve, which traverses the operative field at C3/4 level. This nerve is retracted rostrally and is protected during decompression and instrumentation. (E) The internal branch of the superior laryngeal nerve (*white arrow*), the exposed hyoid bone (*white arrowhead*), and the submandibular gland (*asterisk*) are preserved after instrumentation procedures.

Discussion

In this study, we demonstrated a modified surgical approach for upper cervical anterior fusion involving C2. We believed that detaching the omohyoid and sternohyoid muscles from the hyoid bone was useful to better identify and dissect the iSLN and to increase hyoid bone mobility. This maneuver provided adequate access and direct visualization of the anterior aspect of C2 and facilitated proper instrumentation without excessive traction force to the HN and the

larynx. There were no remarkable postoperative complications.

Several surgical approaches and their outcomes after upper cervical anterior fusion have been reported in literature. The most frequent approach-related complication was dysphagia, which was often transient, but sometimes persisted for several months and could have been life threatening. Many previous studies showed a relatively high incidence (9%-56%) of postoperative dysphagia that persisted for more than a few months; although rare, permanent

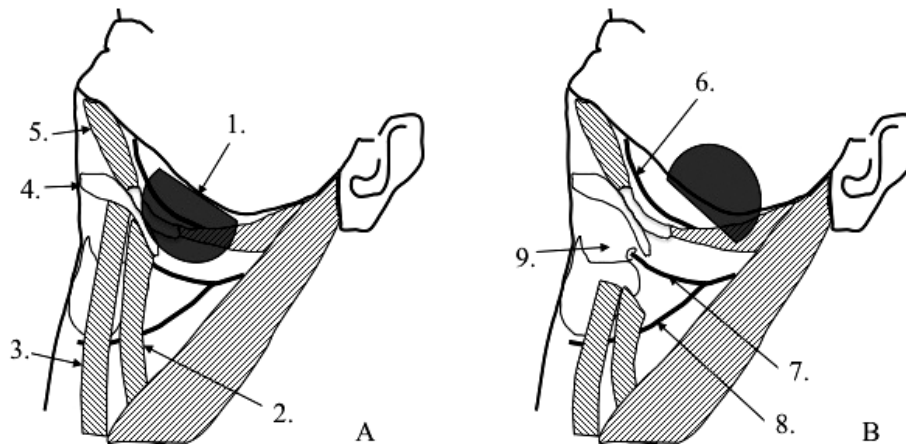


Figure 4. Schematic diagrams of surgical approach.

1. submandibular gland, 2. omohyoid muscle, 3. sternohyoid muscle, 4. hyoid bone, 5. digastric muscle, 6. hypoglossal nerve, 7. internal branch of the superior laryngeal nerve, 8. external branch of the superior laryngeal nerve, and 9. thyrohyoid membrane.

(A) Among the infrahyoid muscles, the omohyoid and sternohyoid restrict the mobility of the hyoid bone and the larynx. In addition, these muscles cover the thyrohyoid membrane which is the piercing point of the internal branch of the superior laryngeal nerve.

(B) The omohyoid and sternohyoid muscles are detached from the hyoid bone, and the submandibular gland is reflected rostrally. Detachment of these muscles from the hyoid bone increases the mobility of the hyoid bone and the larynx in contralateral side and rostral direction and reveals the piercing point of the internal branch of the superior laryngeal nerve.

dysphagia was also reported in one case^{3,4,6-10}. Severe persistent dysphagia is caused mainly by dysfunction of the iSLN or HN that traverses the upper cervical anterior region.

The SLN originates from the vagus nerve within the carotid sheath and bifurcates into the internal and external branches. The iSLN, which is mainly a sensory branch, courses transversely at the C3/4 level, pierces the thyrohyoid membrane, and usually accompanies the superior laryngeal artery^{1,2}. Since the iSLN provides sensory innervation to the larynx and motor innervation to the interarytenoid muscles¹, damage to the iSLN may cause laryngeal anesthesia, decrease the laryngeal cough reflex, and increase the risk of dysphagia and aspiration¹¹. In contrast, the eSLN is mainly a motor branch that courses distally toward the cricoid cartilage, approximately at the C4-6 level, and usually courses posterior to the superior thyroid artery^{1,2}. The eSLN innervates the cricothyroid muscle in response to cricoid cartilage rotation during regulation of vocal cord tension. Damage to the eSLN often results in loss of a high-pitched tone¹². Although the eSLN was retracted laterally with the carotid sheath and was not usually observed in the upper cervical anterior region, attention should be paid while dissecting near the superior thyroid artery. The HN provides ipsilateral motor innervation to the tongue and is at a relatively high risk for damage near the C2-3 level¹. Damage to the HN often results in dysphagia, dysphonia, and tongue deviation. Several authors have reported that HN palsy can be prolonged^{3,13,14}.

To reduce the risk of injury to these nerves, some publications indicated the importance of familiarity with the ana-

tomical properties in the upper cervical anterior region and avoidance of excessive retraction by sufficient blunt dissection through soft tissues³⁻⁵. However, efforts toward practical methods to identify, protect, and reduce traction force to these nerves, particularly the SLN, have been few. From our experience, the SLN was often difficult to identify because there were some variations in the course of the nerve, specifically in relation to the superior thyroid vessels¹²; therefore, these vessels were a poor guide in identifying the branches of the SLN³. In contrast, a cadaveric study proved that the iSLN always pierced the thyrohyoid membrane⁵. We considered that the thyrohyoid membrane was a good marker of the iSLN location.

In our approach, we detached the omohyoid and sternohyoid muscles covering the thyrohyoid membrane from the hyoid bone and reflected these caudally. This maneuver enabled visualization of the thyrohyoid membrane, and therefore, easy identification of the iSLN. Furthermore, we were able to achieve longer dissection of this nerve lateral to the thyrohyoid membrane and medial to the carotid sheath to avoid excessive traction injury. The tension of the omohyoid and sternohyoid muscles on the hyoid bone restricts access to the upper cervical spine¹⁴. Therefore, detaching these infrahyoid muscles would increase the mobility of the hyoid bone and the larynx. This maneuver would provide better accessibility of the anterior aspect of C2 and reduce the traction force to the larynx and the HN located in the rostral side of the operative field (Fig. 4). This maneuver would not affect swallowing and speech function. There are four infrahyoid muscles: the sternohyoid, sternothyroid, thyrohyoid,

and omohyoid. They are responsible for the positioning of the hyoid bone along with the suprahyoid muscles. All infrahyoid muscles except the thyrohyoid depress the hyoid bone. Infrahyoid myotomy is a conventional operative method and is sometimes performed for ease in elevation of the hyoid bone and the larynx during deglutition and articulation^{15,16}.

There were several limitations to our study that should be noted, including the small sample size and lack of sufficient evaluation of the eSLN in the multilevel fusion case. Further study on a large sample size, including multilevel fusion cases, is required to verify the efficacy of our modified approach. Nevertheless, we believe that our modified approach could prevent severe postoperative complications.

In conclusion, detachment of the omohyoid and sternohyoid muscles from the hyoid bone during upper cervical anterior fusion provided wide and adequate exposure of C2-3 level without excessive retraction to the larynx, the iSLN, and the HN, resulting in the absence of remarkable complications, such as persistent dysphagia.

Conflicts of Interest: The authors declare that there are no conflicts of interest.

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