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

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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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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.

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 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. 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 retraction, 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 instrument 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...
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 extubation 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
Several authors have reported that HN palsy can often result in dysphagia, dysphonia, and tongue deviation.

The eSLN often results in loss of a high-pitched tone rotation during regulation of vocal cord tension. Damage to the iSLN may cause laryngeal anesthesia, decrease the laryngeal cough reflex, and increase the risk of dysphagia and aspiration. 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. Since the iSLN provides sensory innervation to the larynx and motor innervation to the interarytenoid muscles, damage to the iSLN may cause laryngeal anesthesia, decrease the laryngeal cough reflex, and increase the risk of dysphagia and aspiration. 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. 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 tone. 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 level. Damage to the HN often results in dysphagia, dysphonia, and tongue deviation. Several authors have reported that HN palsy can be prolonged.

To reduce the risk of injury to these nerves, some publications indicated the importance of familiarity with the anatomical properties in the upper cervical anterior region and avoidance of excessive retraction by sufficient blunt dissection through soft tissues. 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 vessels; therefore, these vessels were a poor guide in identifying the branches of the SLN. In contrast, a cadaveric study proved that the iSLN always pierced the thyrohyoid membrane. 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 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 infrathyroid 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\(^\mathrm{15,16}\).

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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