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Hypoglossal Nerve Palsy After Airway Management for General Anesthesia: An Analysis of 69 Patients

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Abstract

Isolated hypoglossal nerve palsy (HNP), or neurapraxia, a rare postoperative complication after airway management, causes ipsilateral tongue deviation, dysarthria, and dysphagia. We reviewed the pathophysiological causes of hypoglossal nerve injury and discuss the associated clinical and procedural characteristics of affected patients. Furthermore, we identified procedural factors potentially affecting HNP recovery duration and propose several measures that may reduce the risk of HNP. While HNP can occur after a variety of surgeries, most cases in the literature were reported after orthopedic and otolaryngology operations, typically in males. The diagnosis is frequently missed by the anesthesia care team in the recovery room due to the delayed symptomatic onset and often requires neurology and otolaryngology evaluations to exclude serious etiologies. Signs and symptoms are self-limited, with resolution occurring within 2 months in 50% of patients, and 80% resolving within 4 months. Currently, there are no specific preventive

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or therapeutic recommendations. We found 69 cases of HNP after procedural airway management reported in the literature from 1926–2013.

Introduction

Solitary hypoglossal nerve palsy (HNP) after airway management during general anesthesia is a rare complication that may occur after a variety of surgeries. By the end of the first postoperative day, patients typically present with ipsilateral tongue deviation and may exhibit speech and swallowing difficulties. HNP is often diagnosed postoperatively after a thorough workup to exclude stroke, hematoma, impending airway obstruction, and endotracheal trauma. Early consultation with otolaryngology and neurology can guide the diagnostic workup and help promptly identify these serious conditions. We believe that HNP is frequently missed by the anesthesia care team due to rapid hospital turnover of outpatients (i.e., same-day surgery) and delayed onset of symptoms characteristic of nerve palsy. Furthermore, residual anesthesia can hinder accurate neurological examinations and the characteristic delayed onset of symptoms. This review identifies the clinical signs and symptoms associated with HNP that help define its differential diagnosis. The current literature was reviewed for factors associated with the HNP diagnosis, including demographics, predisposing anatomical findings and procedural and airway-related characteristics. Management options, expected clinical course and factors affecting recovery duration as well as recommendations on preventive measures conclude the review.

Methods

We searched the National Library of Medicine (PubMed) and MEDLINE databases for publications reporting on patients manifesting symptoms of hypoglossal nerve injury after procedural airway management from 1926 through 2013. (Appendix Figure 1) Reports of airway management techniques containing endotracheal tube (ETT), supraglottic devices such as the laryngeal mask airway (LMA), and the Combitube were included[1–59] (Table 1). Cases in which hypoglossal nerve injury was likely due to the surgery itself, noted preoperatively or weeks after surgery, were excluded.[60–63] We obtained demographic (age, gender), surgical (type of surgery and specific procedure, positioning, anesthetic duration), airway and anesthetic management details (laryngoscope blade type and size, ETT or LMA size, cuff pressure or volume, side of tube securement, use of nitrous oxide (N_2O)), as well as neurapraxia course and time of onset. Recovery status was ascertained from each case report based on clinical observations of complete resolution (i.e., no further tongue deviation or symptoms), partial improvement (resolved tongue deviation with persistent symptoms), or no recovery (persistent tongue deviation and symptoms). The time until recovery or final clinic encounter (for patients without recovery) was recorded as the number of days after the procedure was completed. Information regarding neuromuscular blockade monitoring and recovery were inconsistently reported and thus excluded. Cases were included regardless of whether the above-stated characteristics were mentioned in each individual article. We retrieved HNP patient payment data from the American Society of Anesthesiologists Closed Claims database (1980-present), for which the data analysis methods have been previously reported.[64]

Statistical Analysis

Descriptive data are presented as mean with standard deviation (SD) and as percentage where appropriate. Patients were grouped based on the recovery status of their tongue deviation at time of follow-up (complete or partial recovery vs. no recovery), and analyzed using a Kaplan-Meier survival technique. Using the statistical software R version 3.0.0 (R Foundation for Statistical Computing, Vienna, Austria), we conducted a log-rank test to compare the time-to-recovery curves between airway type, gender, diagnosis (isolated vs multiple cranial nerves) and treatment subgroups. Kaplan-Meier summary statistics provide the mean and median times to recovery, and the times to recovery for the 25th, 50th and 75th patient quartiles. For patients with complete or partial recovery, a Pearson's correlation coefficient was calculated to examine the relationship between age or operative duration and the reported follow-up interval.

Results and Discussion

HYPOGLOSSAL NERVE PALSY: AIRWAY-RELATED MECHANISMS AND CLINICAL MANIFESTATIONS

Diagnosis—We identified 59 publications reporting 69 patients with HNP after procedural airway management in the literature through 2013 (Table 1). Diagnoses include isolated unilateral or bilateral HNP (n=46), as well as combined hypoglossal-lingual nerve neurapraxia (n=8) or hypoglossal-recurrent laryngeal neurapraxia (Tapia's syndrome) (n=15).

Clinical symptoms of HNP are nonspecific and include dysarthria (difficulty with articulation), dysphagia, and even dyspnea. On examination, unilateral deviation and elevation of the tongue ipsilateral to the injured side are pathognomonic for hypoglossal nerve injury and can be attributed to paralysis of the superior and inferior longitudinal muscles.[65] Later physical examination findings revealed unilateral atrophy and genioglossus muscle fasciculation, signifying denervation-reinnervation injury.[66,67]

Radiographic imaging, including computed tomography and magnetic resonance imaging, can help exclude ischemic stroke and hemorrhage, and provides confirmation of both supraglottic airway trauma and tongue atrophy[68,69](Figure 1). Extracranial Doppler and ultrasound studies can aid in the diagnosis of vascular dissection as a cause of HNP.[11,16] In persistent cases of HNP, electromyographic and nerve conduction studies demonstrated damage to the neural elements, a pathology that is not typical of transient neurapraxia.[6]

Proposed HNP Mechanisms—Most reported cases of HNP after airway management suggest involvement of the extracranial section of the hypoglossal nerve, which exits the skull through the hypoglossal canal and descends caudally, along with the internal carotid artery and jugular vein. At the mandibular angle, it passes anteriorly, deep to the posterior belly of the digastric muscle and reaches the submandibular region to enter the tongue.[67] At the undersurface of the tongue, numerous branches pass upward to supply its intrinsic muscles.[11,29,67] The 4 mechanisms of injury leading to HNP proposed in the literature are described in Figure 2. Tapia's syndrome (unilateral recurrent laryngeal nerve and hypoglossal nerve paralysis), a subset of hypoglossal nerve injury, is attributed to

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compression injury to intersecting extracranial fibers of both the hypoglossal and vagus nerves at the base of the tongue.[13,18,33,37,53]

PATIENT CHARACTERISTICS

Demographics—Table 1 and Figure 3a present the demographics of patients with HNP after procedural airway management. The majority of patients with isolated hypoglossal neurapraxia and Tapia's syndrome are male. No differences in demographics are seen between cases of solitary hypoglossal injury and combined cranial nerve neurapraxia. Although reporting bias must be considered, morphometric and forensic studies of the hyoid bone demonstrate greater absolute dimensions in males.[70,71] Ito et al. show that males have a longer length of the greater cornu (33.8 mm vs 29.8 mm), larger hyoid volume (4.31 cm^3 vs 2.95 cm^3) and exhibit earlier ossification of the connection between the hyoid body and greater cornu. Given these anatomical differences, male patients are more likely to experience hypoglossal nerve compression at the hyoid cornu level.

There does not appear to be any specific age range associated with anecdotal reports of HNP. Harnett et al. found a higher incidence of minor airway complications in infants receiving a LMA,[72] and multiple authors report postoperative HNP after LMA placement in adolescents.[26,28,31] On the other hand, several authors report findings of a calcified stylohyoid ligament on radiographic imaging in elderly patients.[17,30,38,50,59] In addition, Nagai et al. report a patient with rheumatoid arthritis, which is known to cause cervical (C1-C2) joint instability and bony ligamentous abnormalities.[50] It is conceivable that these anatomical abnormalities could stretch the nerve at the angle of the mandible and cause HNP. Additionally, a short neck may predispose to nerve stretching during laryngoscopy.[1,34]

Laterality of HNP—An earlier report of HNP suggests that right-sided neurapraxias aremore common, a finding that was originally attributed to the fact that most anesthesiologists are right-handed.[8] Nevertheless, most operators would use their right hand to introduce the ETT into the trachea regardless of their handedness. Theoretically, pressure exerted from the laryngoscope blade could predispose to unilateral hypoglossal injury when sweeping the tongue from the right to left before intubation. However, multiple subsequent case reports have demonstrated the bilateral incidence of this neurapraxia. Moreover, in those reports that mention the tube being taped to the right side, there is an equal prevalence of neurapraxic symptoms on either side.[7,15,16,30,52]

AIRWAY MANAGEMENT CHARACTERISTICS

Intubation—Various case reports address airway management strategies including tube size, method of laryngoscopy, and blade type/size. All studies that provide laryngoscope information for orotracheal intubation report the use of a Macintosh blade, either size 3 or 4.[2,7,8,15,27,30,45,47,48,52, 54,57] Figure 3b displays the reported airway management techniques that were used in patients who subsequently developed isolated or multiple cranial nerve neurapraxia. In their review, Dziewas and Ludemann show that HNP occurs after direct laryngoscopy and endotracheal intubation, LMA placement, and even after bronchoscopy.[11] Zamora and Saha discuss HNP after Combitube placement.[54] We found a greater number of

patients with HNP after ETT placement. During orotracheal intubation, neck hyperextension stretches the hypoglossal nerve on the anterior aspect of the C1 transverse process by as much as 1.3 cm. In addition, direct pressure exerted by the Macintosh blade at the base of the tongue causes soft tissue compression against the hyoid bone, possibly exacerbating the neurapraxia.[1,3,12,15,26,30,46,49,73,74]

Cuff Insufflation—Some authors suggest that ETT cuff pressure and LMA cuff insufflation may be associated with HNP, suggesting injury at the hyoid bone.[21,29,31,32,37,45,53,54] Seven patients were reported to have received at least 30 minutes of N_2O as part of their anesthetic management, which would predispose to diffusion of N_2O into the cuff resulting in increased cuff pressures.[12,19,29,32,36,45,50]

ETT cuff pressure: In 9 patients, the ETT cuff pressure was maintained < 20 cmH_2O, [2,7,10,12,16,22,27,52] while in 1 patient, the intracuff pressure was maintained at 30 cmH_2O before surgical draping.[10] Al-Benna described hypoglossal nerve injury in a patient with a maximum measured ETT cuff pressure of 34 cmH_20.[45] While there is an anatomical disparity between the location of the inflated ETT cuff and the hypoglossal nerve, it is possible that ETT cuff-related damage may be explained by anatomical variants, such as a low-looping hypoglossal nerve or tongue innervation from the superior root of the ansa cervicalis.

LMA cuff volume: Eight cases with LMA use mention cuff insufflation volume in the range of 15–40 ml. of air,[19,21,28,29,31,32,37,50] but did not mention goals for cuff pressure titration or intraoperative monitoring. Lumb and Wrigley demonstrated that LMA cuff pressures can increase by as much as 50% during brief periods of N_2O anesthesia.[75] Similarly, Trumpelmann and Cook reported on an overdistended LMA cuff after removal in a patient who had received N_2O during anesthesia.[32] Although the cuff insufflation volume varies considerably by LMA size and type, these unanticipated increases in cuff volume during longer cases can compress the hypoglossal nerve against the hyoid bone and cause HNP symptoms.

SURGICAL CHARACTERISTICS

Operative Duration and Reintubation—Anesthetic and procedural duration in the reported cases vary (Table 1). Aside from the complications associated with prolonged intubation, no studies have evaluated its relative contribution specifically to HNP. On the other hand, repeated airway management attempts,[5,29] intra- and postoperative reintubations,[6,27,28,40,57] and prolonged ventilatory support[27,35,40] increase the risk of iatrogenic trauma to the airway mucosa and underlying nerve structures. Three patients required reintubation due to respiratory failure.[6,27,40] Two additional patients required LMA replacement[28] or conversion to ETT[34] for preoperative supraglottic airway device dislocation. All 5patients with bilateral isolated HNP included1 of these factors of complex airway management.[6,27–29,35]

Surgical Considerations—Surgical subspecialties associated with subsequent isolated HNP or combined neurapraxias are displayed in Figure 3c and listed in Appendix Table 1.

However, HNP is frequently reported after otolaryngologic surgery. Dysarthria and ipsilateral tongue deviation are mentioned after rhinoplasty[3,7,22,38,52] and sinus surgery,[30,34] as well as after tonsillectomy[1,4,49,51,58,59] and periglottic excisions.[1,8,14] Throat pack placement during these surgeries can create pressure at the greater cornu of the hyoid,[2] and their frequent use is linked to combined hypoglossal-recurrent (Tapia's syndrome) and lingual nerve palsies.[12,22,52] Similarly, hematoma and other postsurgical upper airway swelling can result in delayed symptoms and dysarthria due to nerve compression.[9,10,19,76] The otolaryngology team can detect tongue deviation in patients with subclinical HNP (i.e., without symptomatic dysarthria) through frequent routine neurologic examinations that arenot consistently used in other specialties, contributing to an increased diagnostic rate and reporting bias.

Several authors report HNP after shoulder surgeries.[10,11,16,19,21,23,25,50] Neck rotation and undetected head movement underneath the surgical drapes can lead to prolonged traction of the hypoglossal nerve throughout the case.[5,16,37,46] During cardiac surgery, neck hyperextension and lateral flexion during sternotomy can compress the ETT cuff against the hypoglossal-recurrent laryngeal nerve, resulting in Tapia's syndrome.[13,42,43,57] Similarly, unanticipated position changes resulting in accidental extubation,[36] LMA malposition,[28] or change in airway management[34](e.g., switching from LMA to ETT) are associated with HNP.

Routine position changes after intubation, such as from semisupine (30 degrees) to the Fowler's position (70 degrees), can cause pressure injury to the nerve throughout its superficial course anterior to the mandible.[7,16,23,25,38,48,52] It is possible that even small position changes after airway securement, including during surgical preparation and draping, could predispose to hypoglossal nerve trauma. Conrardy et al. demonstrated that the ETT cuff can migrate from 3.8 – 6.4 cm with neck flexion or extension during intubation,[77] potentially injuring the subglottis. This pattern of trauma would more likely result in recurrent laryngeal nerve injury and dysphonia as in Tapia's syndrome.

CLINICAL COURSE AND MANAGEMENT

Symptom Onset—HNP is typically diagnosed in a delayed fashion, with more than half of the reported cases diagnosed the day after surgery. Nevertheless, all but 3 patients exhibited tongue deviation by the end of the first postoperative day.[10,12,33] Residual anesthesia may interfere with an early diagnosis of neurapraxia. Some patients after ear-nose and throat or general surgery do not exhibit signs or symptoms until their first postoperative day or later.[11,15,22,24,32,52] Due to the delayed onset of symptoms, neurapraxia can potentially develop after discharge and remain undiagnosed.

Recovery—HNP appears to be largely self-limited; of 60 patients with a reported recovery status and follow-up interval, 26 patients (43.3%) achieved resolution within 6 weeks after surgery, and an additional 24 patients (40.0%) were symptom-free within 6 months of their operative date. The 25th percentile, median, and 75th percentile are 28, 60 and 120 days, respectively. Several authors reported complete resolution 1 year after diagnosis,[6,9,12,14,20,22] while others found only partial recovery at variable follow-up

periods.[1,15,33,49] Five patients (8.3%) had persistent tongue deviation and dysarthria at follow-up intervals. The follow-up interval was not reported for four additional patients with persistent symptoms.[1,3,4,13,55,56] Patients with partial recovery demonstrated similar demographics and operative durations when compared to fully recovered patients. More than half of the patients with partial recovery are associated with Tapia's syndrome, and remaining neurologic deficits include persistent tongue deviation[15] or vocal fold immobility. Patients with isolated or combined cranial nerve neurapraxias (recurrent laryngeal, lingual, or glossopharyngeal nerves) are reported to recover at similar follow-up intervals (p=0.34). However, patients receiving an ETT exhibitedlater recovery postoperatively than patients in whom an LMA was used (p=0.003) (Figure 4). Indeed, the invasive technique (direct laryngoscopy), neck positioning and cuff pressures associated with ETT placement can be more traumatic to the airway mucosa and require longer healing times. In addition, the reported follow-up period for patients exhibiting complete recovery is similar between genders (p=0.09), and age is poorly correlated with the recovery follow-up interval (r= −0.090). There is a moderate positive correlation between operative duration and follow-up interval for patients with reported recovery status (r=0.49).

A few shortcomings must be considered when interpreting these recovery estimates and analyses. The reported data are extracted retrospectively from individual publications and several authors instead of 1 study. In addition, patients may have recovered earlier than the reported follow-up period in each publication, and patients with longer recovery times may be disproportionately represented in this sample of case reports. On the other hand, the correlations between age or operative duration and time to recovery exclude patients with persistent HNP who may have needed longer recovery times past the last recorded encounter.

Possible Preventive Measures—Potentially preventive measures are deduced by the postulated mechanisms of injury, with an emphasis on the use of less invasive methods of airway management (LMA instead of ETT) (Appendix Table 2). Indeed, some authors postulate that routine cuff pressure monitoring could decrease the incidence of HNP after surgery.[31,32] Although no neurapraxias were noted in their study of 200 patients receiving an LMA for ambulatory surgery, Seet et al. demonstrated a decrease in dysphagia and dysphonia at 1 hour and 1 day after surgery in patients whose LMA cuff pressures were limited to <60 cmH_2O.[78] Similarly, Ratnaraj et al. showed that maintaining ETT cuff pressure < 20 cmH_2O in patients undergoing cervical spine surgery significantly decreased the incidence of sore throat 24 hours after extubation.[79] Intermittent pressure cuff lowering during long operations or pressure-relief valves can decrease the risk of nerve compression,[29,75,80] and it follows that LMA or ETT cuff deflation during surgical positioning could also prevent iatrogenic injury to the hypoglossal and recurrent laryngeal nerves, respectively. Bohner et al. described the first use of a nerve stimulator for the successful identification and continuous monitoring of the hypoglossal nerve during an anatomically challenging carotid endarterectomy under general anesthesia.[81]

Treatment—Supportive measures for HNP during initial evaluation in the immediate postoperative period may include supplemental oxygen and respiratory monitoring. Ear-nose

and throat-guided rehabilitation measures include dietary modifications, logopedic treatment and electrical stimulation therapy.[82] Corticosteroid therapy has been shown to accelerate spontaneous recovery after Bell's palsy,[83] and multiple authors advocate a short course of high-dose steroids such as prednisone if airway edema is suspected.[5,7,15,24,26,28,33,46,50,53] However, there are no controlled studies of the benefits of these treatments on neurapraxic patients after surgery. In our review, patients receiving corticosteroid treatment demonstrated complete or partial recovery at similar follow-up periods compared to nontreated patients.

Closed Claims Data—There are only 4 nonsurgical hypoglossal nerve injury claims in the Anesthesia Closed Claims database (1980-present:10,093 claims). A difficult intubation with pharyngeal injury occurred in 1 claim, and an LMA was used in 2 claims. Three of the nonsurgical injuries were permanent, and 1 temporary. Only 1 of these 4 claims resulted in payment ($30,500 in 2012 inflation-adjusted dollars), a significantly smaller proportion when compared to other surgical anesthesia claims (58%, p=0.012). (Domino KB: Personal communication, 17th March 2014)

Conclusion

Hypoglossal neurapraxia after airway extubation is repeatedly reported after various surgeries. Nerve compression and overstretching can occur during both unexpected and routine position changes, including neck hyperextension for laryngoscopy and surgical positioning. Male patients may be more vulnerable given their larger hyoid bone dimensions. Excessive pressure in the ETT or LMA cuff, perhaps exacerbated by the use of N_2O, may produce injurious malposition of the airway devices. Early postoperative detection of tongue deviation and dysarthria, as well as consultation with neurology and otolaryngology consultants, can help exclude other serious etiologies including stroke and carotid dissection. Minimizing airway instrumentation during endotracheal intubation, along with consideration for intermittent pressure monitoring of the ETT cuff and position during long surgical procedures, may decrease the incidence of cranial nerve neurapraxias. While a short course of steroids may decrease swelling after airway removal, further studies need to be performed to ascertain their effect on the incidence of postoperative HNP and the recovery period for neurapraxic patients.

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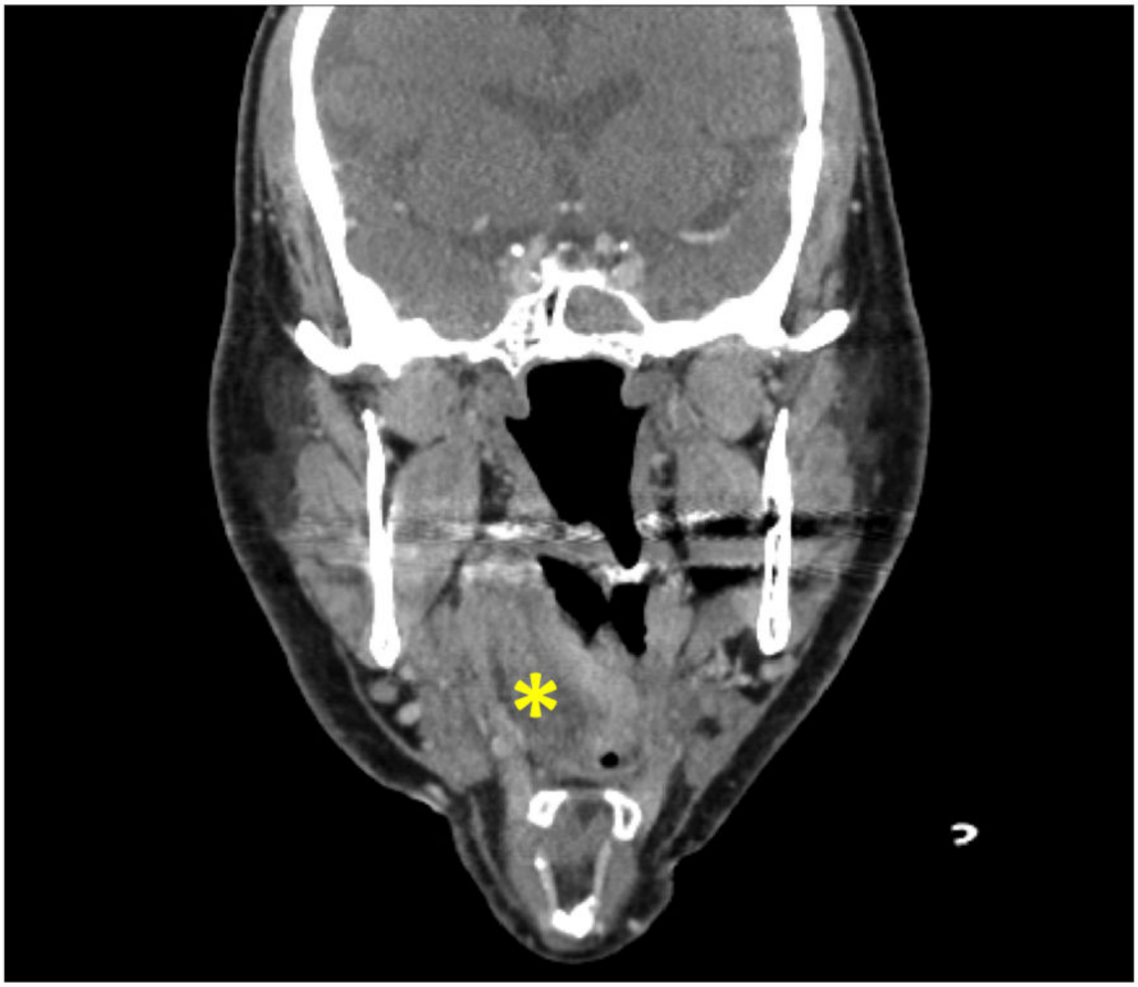

Figure 1.

Non-contrast computed tomography (CT) scan of the neck in a patient with hypoglossal nerve palsy (HNP). Asymmetric heterogeneous soft tissue swelling in the right anterolateral oropharynx, marked with an asterix (*), extending from base of the tongue to vallecula, is seen on the coronal section.

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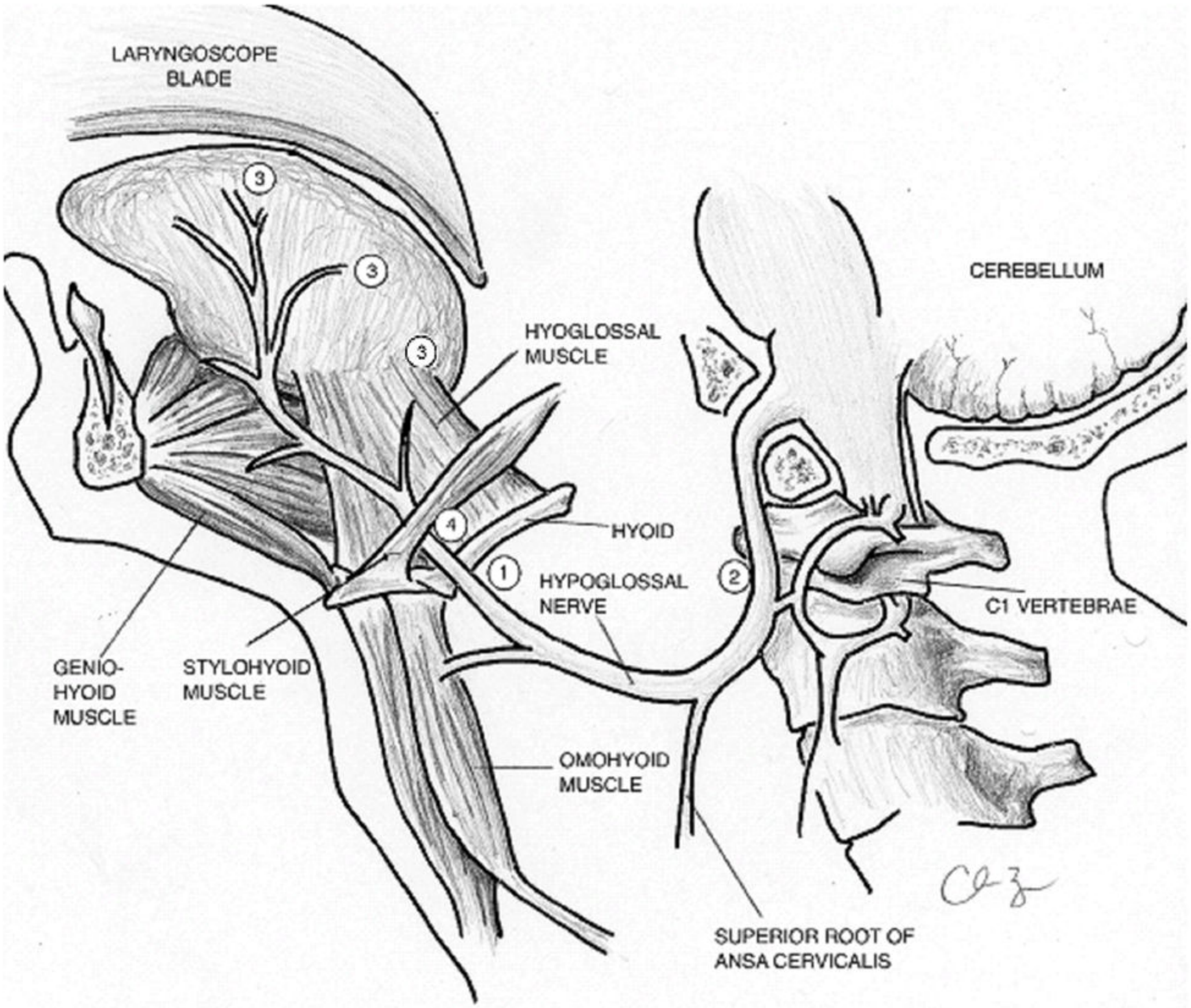
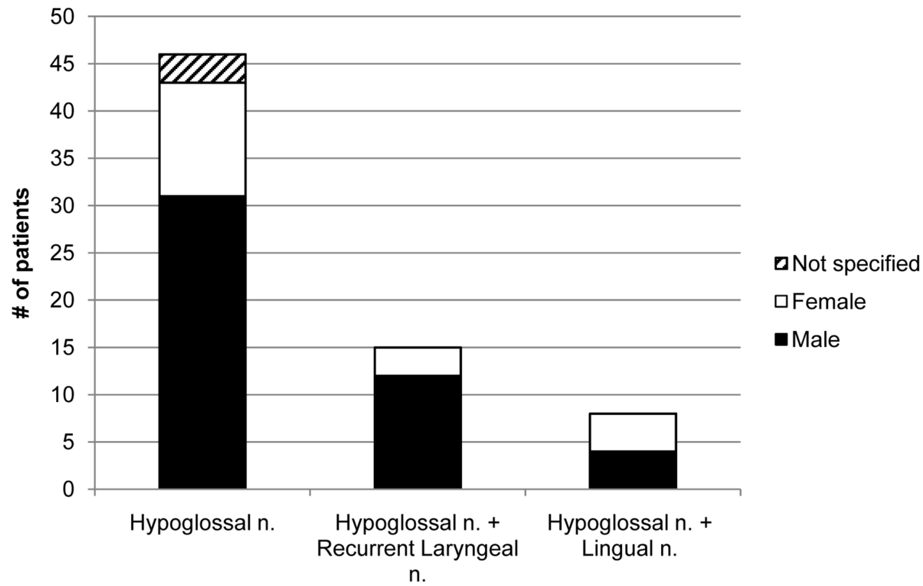


Figure 2.

Anatomic locations for hypoglossal nerve injury during airway management. (1) Nerve compression or impingement can occur at the hyoid bone where the nerve is relatively superficial in its course. [11, 23, 47, 48, 50, 79] (2) Nerve stretching can occur at the lateral aspect of the transverse process of the first cervical vertebrae (C1). (3) Pressure exerted by the laryngoscope blade can lead to lateral retraction and shearing of the distal nerve fibers that supply motor input to the tongue. (4) A calcified stylohyoid ligament has also been reported in association with hypoglossal nerve impingement. *Drawing courtesy of Dr. C. Barnes.*

a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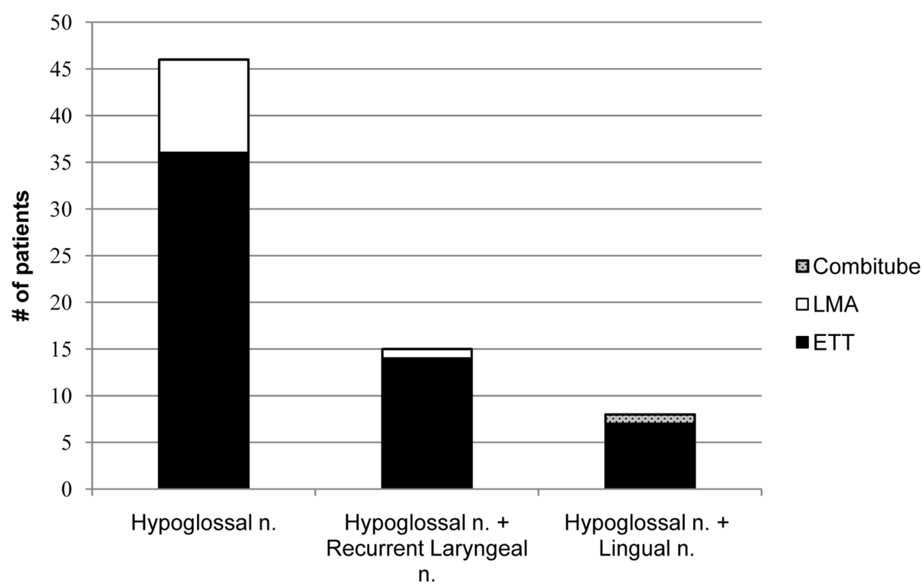
Hypoglossal n. + Recurrent Laryngeal n.
Hypoglossal n. + Lingual n.

b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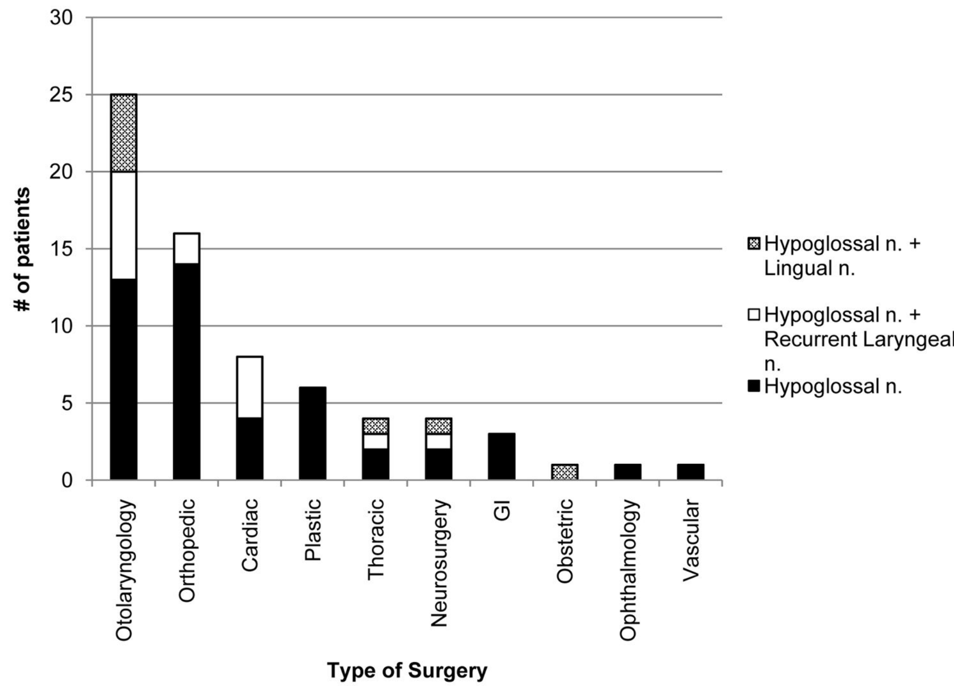

Figure 3.

Figures 3a–c. Distribution of hypoglossal nerve palsy (HNP) diagnoses. Gender (a), airway type (b), and surgery type (c) subgroups are separately delineated within each stacked column. Patients of male gender or those receiving an endotracheal tube composed the majority of reported hypoglossal neurapraxia cases. Twelve of 25 (48%) otolaryngology operations and 4 of 8 (50%) cardiac surgeries were associated with multiple cranial nerve palsies. *LMA = laryngeal mask airway; ETT = endotracheal tube.*

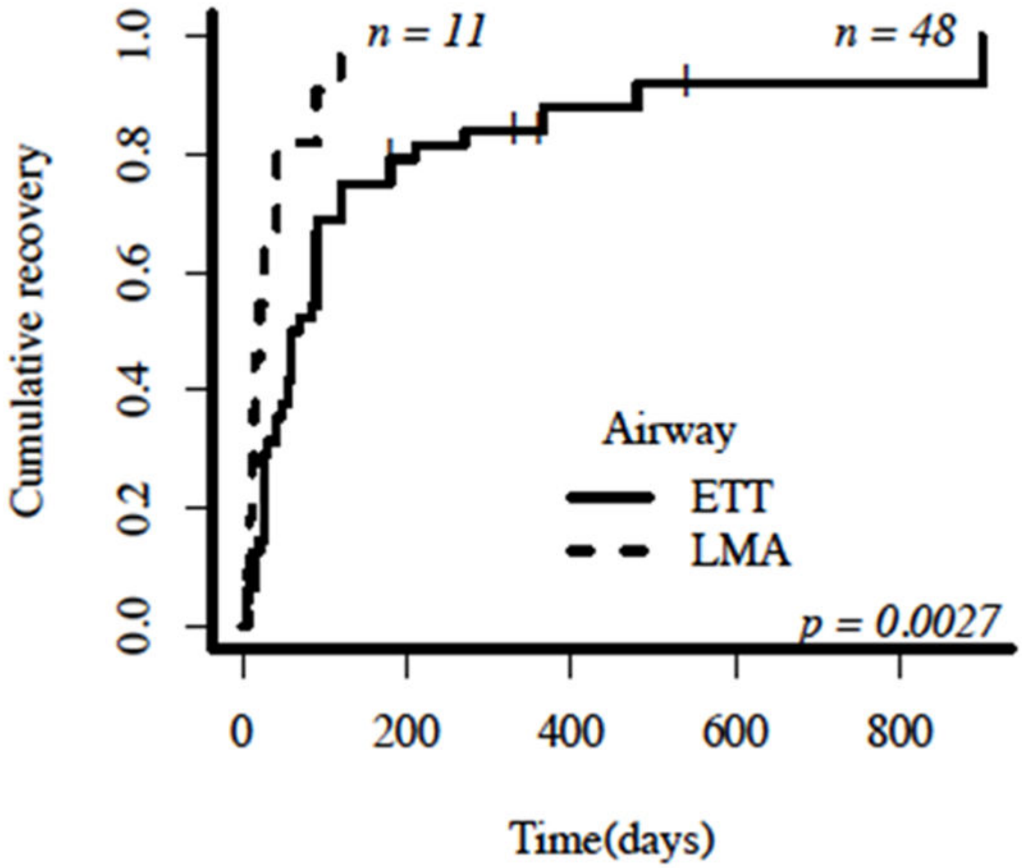

Figure 4.

Time-to-event curve demonstrating hypoglossal nerve palsy (HNP) recovery status based on airway management device. A vertical dash (|) represents patients with persistent tongue deviation (no recovery) at the time of follow-up reported in each individual case report; these patients are right-censored as their recovery status after the reported follow-up period is unknown. The x-axis describes the number of days after airway removal until the reported follow-up in each individual case study. The y-axis describes the cumulative recovery represented as the number of patients with a positive recovery status at any follow-up interval divided by the total number of patients in the subgroup. One patient who received Combitube was excluded from the airway subgroup analysis. *LMA = laryngeal mask airway; ETT = endotracheal tube.*

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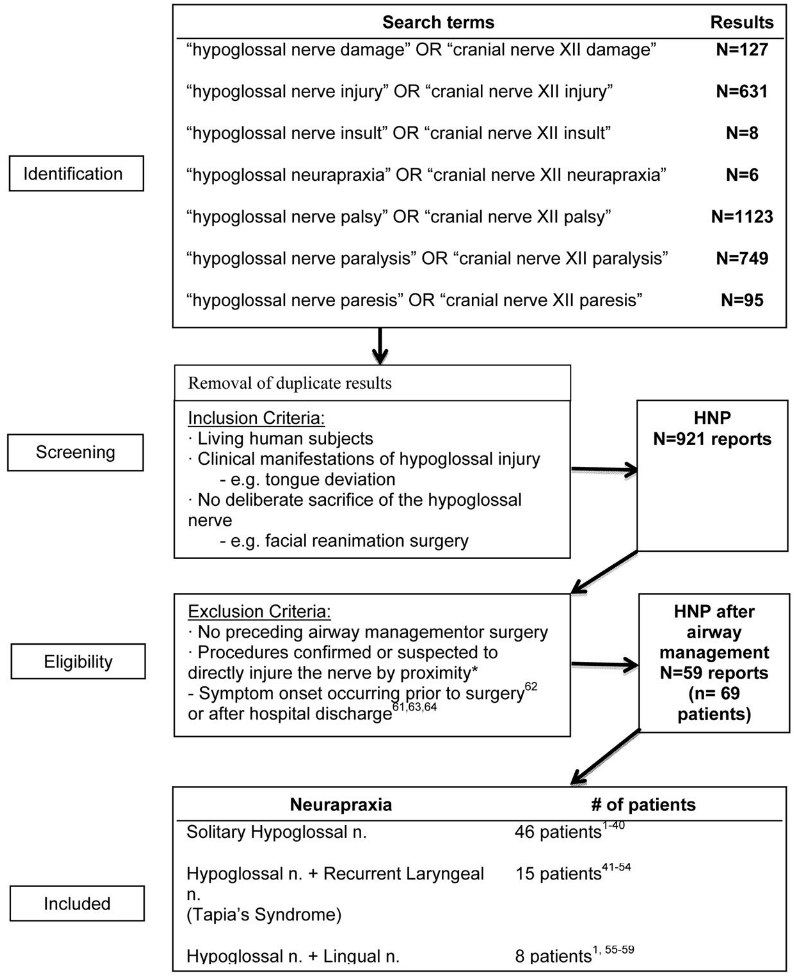

Appendix Figure 1.

Literature search results for hypoglossal nerve palsy (HNP) after procedural airway management. The subgroups of combined neurapraxias, in addition to solitary HNP, and their respective patient counts are listed. * *schwannoma resections, parapharyngeal/carotid body tumor resections, neck dissections, carotid endarterectomies and reconstructive procedures, neck dissections and parathyroid excisions.*[s33–s77]

Table 1

Characteristics of hypoglossal nerve palsy (HNP) patients after procedural airway management

Demographics	
Age (N=66)	Mean: 40.9 +/− 17.3 years (Range: 9 months – 74 years) *Unspecified: 3 patients*
Gender (N=66)	Male: 47 patients[1–44] Female: 19 patients[1,45–57] *Unspecified: 3 patients*
Laterality (N=64)	Left: 28 patients[2,5,9,12,13,16,18,19,21,23,25,26,30,32,34,36,40,43,46,48,49,53,55,56] Right: 29 patients[1, 3, 4, 8, 10, 11, 14, 15, 17, 20, 22,24,31,37–39,41,42,44,45,47, 50, 52, 54] Bilateral: 7 patients[6,7,27–29,33,35] *Unspecified: 5 patients*
Airway Type (N=69)	ETT: 57 patients[1–18,20,22,23,25,27,30,33,35,36,38–49,51–53,55–59] LMA: 11 patients[19, 21,24,26,28,29,31,32,34,37,50] Combitube: 1 patient[54]
Laryngoscope Blade Type (N=12)	Macintosh: 12 patients[2,7,8,15,27,30,45,47,48,52,54,57] *Unspecified: 57 patients*
Airway Size (N=33)	
ETT size (N=21)	Median: 8mm (Range 7–9mm)[2,5,7,10–12,15,16,27,30,36,39,44–48,52,57]
LMA size (N=11)	Median: 4 (Range 1.5–5) [19,21,24,26,28,29,32,50]
Combitube (N=1)	37 French[54] *Unspecified: 36 patients*
Operative Duration (N=37)	Mean: 131.0 +/− 77.2 minutes (range: 25–330 minutes) *Unspecified: 32 patients*
Symptom Onset (N=33)	
POD0	15 patients[7,11,16,19,23,25,26,28,31,34,36,44,46–48]
POD1 or thereafter	18 patients[1,2,10–12,15,22,24,32,33,39,40,42,45,50,52,54,57] *Unspecified: 36 patients*
Treatment (N=14)	
Corticosteroids	8 patients[7,24,26,28,33,42,43,46]
Vitamin B Complex	1 patient[8]
Combined treatment	5 patients[2,5,15,50,53] *Unspecified: 55 patients*
Recovery Status (N=65)	
Complete	45 patients (69.2%) [1,2,5–8,10–12,14,16,17,19–32,34–36,38–40,42,44–48,50,52,54,57] Median follow-up*: 7 weeks; Range: 6 days – 6 months
Partial	11 patients (16.9%) [1,9,15,18,33,37,41,43,49,53] Median follow-up: 7 weeks; Range: 2 weeks – 30 months
None	9 patients (15%) [1,3,4,13,55,56] Median follow-up**: 11 months; Range: 4 weeks – 12 months *Unspecified: 4 patients*

"N" represents the number of patient reports with the available information relevant to each field. No reported follow-up interval on 1 patient with complete recovery (*) and 4 patients with no recovery (**) *POD = postoperative day; ETT = endotreacheal tube; LMA = laryngeal mask airway.*

Appendix Table 1

HNP after Procedural Airway Management, 1926–2014

Author	Age	Sex	Primary diagnosis	Surgery	Position	Surgery length (min.)	Blade	Airway	Size (ETT or LMA)	Cuff pressure (cmH20) or volume (ml)	Side taped (ETT)	Side	N20?	Associated lingual/ recurrent injuries	Recovery	Symptom onset	Treatment
Al-Benna 2013[45]	24	F	breast ptosis	breast augmentation		90	Mac 3	ETT	7.5			R	Yes	No	2 weeks, Complete	POD1	
Haslam 2013[47]	56	F	osteoarthritis	TSA	beach chair		Mac 3	ETT	7		R	R	No	No	6 days, Complete	POD0	
Pariente 2013[39]	62	M	OA	shoulder arthroplasty	beach chair	200		ETT	7.5			R	No	No	4 weeks, Complete	POD3	
Varedi 2013[2]	27	M	zygomatic complex fracture	ORIF			Mac 3	ETT	7	20 cmH2O		L	No	Recurrent laryngeal (Tapias)	9 months, Complete	POD1	Vitamin B, cortico-steroids
Weissman 2013[40]	34	M	Burn, 4-% TBSA (20% full thickness)	multiple debridements	supine			ETT				L		No	4 weeks, Complete	POD1	
Lykoudis 2012[22]	32	M		open rhinoplasty				ETT		<20 cmH20		R.	No	Recurrent laryngeal (Tapias)	4 months, Complete	POD1	
Nalladaru 2012[42]	49	M	CAD	CABG				ETT				R		Recurrent laryngeal (Tapias)	10 weeks, Complete	POD1	cortico-steroids
Turan 2012[33]	15	M	ALL	tracheostomy				ETT				R+L	No	Recurrent laryngeal (Tapias)	14 days, Partial	POD21	cortico-steroids
Wadelek 2012[37]	57	M	impingement syndrome	arthroscopic acromioplasty	semi-supine	70		LMA	4	30 ml. air		R		Recurrent laryngeal (Tapias)	3 months, Partial		
Trujillo 2011[31]	0.8	M	b/lretino-blastoma	EUA, laser tx OU cryotherapy OS	supine, neutral	45	N/A	LMA	1.5	minimum volume		R	No	No	3 weeks, Complete	POD0	
Park 2011[41]	42	M	cerval spine herniated disk	C3-4 discectomy				ETT				R		Yes	2 months, Partial		
Rotondo 2009[43]	72	M	aortic valvular disease	AVR, MVR	supine			ETT				L		Recurrent laryngeal (Tapias)	3 months, Partial		cortico-steroids
Hung 2009[16]	57	M	rotator cuff tear	RCR, arthroscopy	beach-chair	108		ETT	7.5	<20 cmH2O	R	L.	No	No	3 weeks, Complete	POD0	
Lopes 2009[48]	36	F	N/A	breast reduction, abdominoplasty	semi-sitting (60)(120m) --> dorsal decubitus (150m)	270		ETT	7			L	No	No	6 months, Complete	POD0	
Lopes 2009[48]	64	F	s/p mastectomy for breast CA	breast reconstruction	lateral decubitus (160m) --> sitting position (120m) supine, 20 degrees	330	Mac 3	ETT	7.5			L	No	No	6 months, Complete		
Hong 2009[15]	37	M	cholelithiasis	laparoscopic CCY	semi- upright	85	Mac 4	ETT	7.5		22cm, R	R.	No	No	8 weeks, Partial	POD1	cortico- steroids, vitamin B
Kashyap 2009[18]	41	M	Fractures of R. parasymphis and L. condyle of mandible	ORIF facial fractures				ETT				L		Recurrent laryngeal (Tapias)	16 months, No		
Rhee 2008[25]	41	M	R. traumatic shoulder dislocation	Bankart repair	beach chair, 70 --> 30 for Bankart repair	130		ETT				L		No	6 weeks, Complete	POD0	
Rhee 2008[25]	71	M	wear and tear	mini-open rotator cuff repair, arthroscopy	beach chair, 70 --> 30 for Bankart repair	120		ETT				L		No	12 weeks, complete		
Rodriguez Ogando 2008[26]	15	M	SVT	electro-physiologic study, RFA	supine		N/A	LMA	4		N/A	L	No	No	15 days, Complete	POD0	cortico-steroids

Author	Age	Sex	Primary diagnosis	Surgery	Position	Surgery length (min.)	Blade	Airway	Size (ETT or LMA)	Cuff pressure (cmH20) or volume (ml)	Side taped (ETT)	Side	N20?	Associated lingual/ recurrent injuries	Recovery	Symptom onset	Treatment
Zamora 2008[54]	24	F	pregnancy- induced hypertension	caesarean delivery	supine/LUD	180	Mac 3, 4	Combi-tube	37 Fr	85 ml. air (pharyngeal), 12 ml. air (distal)	N/A	R	No	Lingual	3 months, Complete	POD1	
Nam 2007[24]	51	M	ulnar nerve palsy	ORIF supracondylar fx	supine	175	N/A	LMA	4	60–70 cmH2O	N/A	R	No	No	12 days, Complete	POD1	cortico-steroids
Yelken 2007[38]	22	M	difficulty breathing	septoplasty	supine, routine neck flexion	120		ETT				R		No	2 months, Complete		
Sotiriou 2007[57]	52	F	CAD	CABG	supine		Mac 3	ETT	8					Recurrent laryngeal (Tapias)	4 weeks, Complete	POD1	
Lo 2006[21]	48	M	humerusfx	humerusfx repair		120	N/A	LMA	3	10–15 cmH2O	N/A	L		No	2 weeks, Complete		
Batjom 2006[46]	33	F	N/A	b/l breast enhancement	semi-sitting	90		ETT	7			L		No	2 months, Complete	POD0	cortico-steroids
Soyal 2006[44]	32	M	rheumatic heart disease	AVR, MVR	supine	300		ETT	8			R		No	3 months, Complete	POD0	
Tesei 2006[52]	30	F	N/A	rhinoplasty	semirecum bent	100	Mac 3	ETT	7	<20 cmH2O	R	R	No	Recurrent laryngeal (Tapias)	4 weeks, Complete	POD1	
Una 2006[35]	28	M	yolk sac tumor	diagnostic mediatin- oscopy	supine		N/A	ETT				R+L		No	4 months, Complete		
Bramer 2006[6]	63	M	sigmoid colon CA	hemicolectomy	supine			ETT				R+L	No	No	7 months, Complete		
Cinar 2005[7]	20	M	N/A	rhinoplasty	semirecum bent	180	Mac 4	ETT	8.5	<20 cmH2O	middle	R+L	No	Recurrent laryngeal (Tapias)	4 weeks, Complete	POD0	cortico-steroids
Trumpelman 2005[32]	28	M	comminuted tibia/fibul a fracture	ORIF	supine	210	N/A	LMA	5	40 ml. air		L	Yes	No	4 months, Complete	POD1	
Sommer 2004[28]	15	M	scar tissue behind ears	excision	extreme side- rotation of head	180	N/A	LMA	4	air		R+L	No	No	4 weeks, Complete	POD0	cortico-steroids
Yavuzer 2004[53]	42	F	septal deviation, dorsal nasal hump	septo-rhinoplasty		65		ETT			midline	L		Recurrent laryngeal (Tapias)			cortico-steroids, vitamin B6-B12
Dogan 2003[9]	56	M	CAD, MI	CABG	supine			ETT				L		No	3 months, Partial		
Boisseau 2002[5]	42	M	recurrent dislocation of Glenohumeral joint	arthroscopy	upright sitting	130		ETT	8			L		Recurrent laryngeal (Tapias)	3 months, Complete		cortico- steroids, vitamin B1-B6
Dziewas 2002[11]	32	M	b/l shoulder dislocation	open repair of L. greater tubercle of humerus		75		ETT	8			R.	No	No	1 week, Complete	POD0	
Dziewas 2002[11]	74	M	esophageal perforation	esophageal resection, esophago-gastrostomy		285		ETT	8			R.	No	No	2 week, Complete	POD1	
Rubio- Nazabal 2002[27]	63	M	AAA rupture	aneurysm excision, graft	supine	240	Mac	ETT	8	<20 cmH2O	R	R+L	No	No	3 months, Complete		
Stewart 2002[29]	54	M	OA	knee arthroscopy		45	N/A	LMA	5	40 ml. air	N/A	R+L	Yes	No	6 weeks, Complete		
Umapathy 2001[34]	46	M	sinus issues	sinus surgery				LMA	4			L		No	6 weeks, Complete	POD0	
Drouet 1999[10]	20	M	Recurrent L. shoulder dislocation	shoulder surgery (thrust)	hyper- extension- inflexion, rotate 30 degrees to right	78		ETT	8	30 cmH2O		R.		No	2 months, Complete	POD2	
Evers 1999[12]	56	M	acromegaly	hypo-physectomy	supine	180		ETT	9	<20 cmH2O		L.	Yes	lingualis	4 months, Complete	POD3	
Sengupta 1999[56]	35	F	tuberculosis/Pott's disease	C3-4 corpectomy w/graft, C2-5 plating				ETT				L		No	18 months, No		
Streppel 1997[30]	35	M	sinus issues	paranasal sinus surgery	supine	85	Mac 4	ETT	9		R	L.		No	4 weeks, Complete		

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Author	Age	Sex	Primary diagnosis	Surgery	Position	Surgery length (min.)	Blade	Airway	Size (ETT or LMA)	Cuff pressure (cmH20) or volume (ml)	Side taped (ETT)	Side	N20?	Associated lingual/ recurrent injuries	Recovery	Symptom onset	Treatment
Venkatesh 1997[36]	65	M	CDH	b/l CDH drainage	supine			ETT	8		side	L.	Yes	No	6 days, Complete	POD0	
Baum-garten 1997[3]	45	M	septum deviation	nasal septoplasty			bronchoscope	ETT				R.		No	Unknown, No		
Condado 1994[8]	44	M	vocal cord hyperplasia	DL, excision		70	Mac	ETT				R.		lingualis	1 month, Complete		B1-B6-B12
King 1994[19]	55	M	humerusfx	orthopedic removal of Rush pins		25	N/A	LMA	4	25 ml. air		L	Yes	No	8 days, Complete	POD0	
Nagai 1994[50]	62	F	rheumatoid arthritis	L. TSA	Supine -- > R. lateral (donut-pillow and soft cushions)	180	N/A	LMA	3	20 ml. air		R.	Yes	No	1 week, Complete	POD1	cortico- steroids, vitamin B12
Smoker 1993[51]	17	F	unknown	tonsillectomy				ETT						No			
Mullins 1992[23]	40	M	L. rotator cuff tear	RCR, arthroscopy	beach chair (70 degrees), down to 30 degrees for Bankart repair	70		ETT				L.		No	8 weeks, Complete	POD0	
Donati 1991[55]	3	F	recurrent tonsillitis	tonsillectomy				ETT				L		No	6 months, No		
Donati 1991[55]	12	F	recurrent tonsillitis	tonsillectomy				ETT				L		No	11 months, No		
Michel 1990[49]	42	F	tonsillitis	tonsillectomy				ETT				L.		No	30 months, Partial		
Gelmers 1983[13]	41	M	CAD	CABG		180		ETT				L		Recurrent laryngeal (Tapias)	12 months, No		
Gelmers 1983[13]	36	M	bronchiectasis	thoracotomy		120		ETT				L		Recurrent laryngeal (Tapias)	12 months, No		
Boenninghaus 1982[4]	36	M	tonsillitis	tonsillectomy				ETT				R.		No	Unknown, No		
Hinze 1976[14]	27	M	vocal cord polyp	DL, excision				ETT				R.		lingualis	3 months, Complete		
Bumm 1974[58]				tonsillectomy				ETT						No			
Bumm 1974[58]				bronchoscopy				ETT						No			
Agnoli 1970[1]	48	F	vocal cord hyperplasia	DL, excision		40		ETT				R.		lingualis	4 weeks, Complete	POD1	
Agnoli 1970[1]	24	F		tonsillectomy				ETT				R.		lingualis	Unknown, No		
Agnoli 1970[1]	57	F		DL, excision				ETT				R.		lingualis	Unknown, No		
Agnoli 1970[1]	71	F	vocal cord hyperplasia	DL, excision		65		ETT				R.		No	13 weeks, Partial		
Agnoli 1970[1]	53	M	vocal cord polyposis	DL, excision		50		ETT				R.		No	7 weeks, Partial		
Konrad 1960[20]	32	M	aortic arch abnormality, unspecified	cardiac aortic arch surgery				ETT				R.		No	12 months, Complete		
Kaess 1955[17]	58	M	lung disease, unspecified	diagnostic bronchoscopy				ETT				R.		lingualis	6 weeks, Complete		
Guthrie 1926[59]			unknown	tonsillectomy			bronch-oscope	ETT						No			

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ALL = acute lymphoblastic leukemia, AAA = abdominal aneurysm repair, b/l = bilateral, CA = cancer, CAD = coronary artery disease, CABG = coronary artery bypass graft, CCY = cholecystectomy, CDH = congenital diaphragmatic hernia, DL = direct laryngoscopy, ETT = endotracheal tube, fx = fracture, LMA = laryngeal mask airway, Mac= Macintosh (blade), MI = myocardial infarction, MVR = mitral valve repair, N2O = nitrous oxide, OA = osteoarthritis, OD = post-operative day, ORIF = open reduction and internal fixation, OSA = obstructive sleep apnea, RCR = rotator cuff repair, RFA = radiofrequency ablation, SVT = supraventricular tachycardia, TBSA = total body surface area

Appendix Table 2

Proposed Measures to Reduce the Risk of HNP Associated with General Anesthesia

- Use a supraglottic airway device (e.g., LMA) rather than ETT for short procedures (≤2 hours), if deemed safe after individual patient evaluation
- Avoid neck hyperextension, traumatic or multiple laryngoscopies by using a fiberoptic intubation technique when these situations are anticipated
- Check patient positioning intermittently, with special attention to the patient's head and airway securement
- Implement intermittent cuff pressure monitoring +/− cuff desufflation, especially during longer operations and when nitrous oxide (N2O) is administered.
- Initiate early specialty consultation and diagnostic workup of patients with multiple neurologic abnormalities to evaluate for neurovascular abnormalities (e.g., stroke, carotid dissection)
- Identify promptly patients with impending airway compromise and triage appropriately (e.g., does the patient need a longer duration of close monitoring, medical treatment, or retinubation?)
- Follow-up with outpatients with questionable symptoms or complaints, especially within the first few days after orthopedic and otolaryngology procedures