Injury to the recurrent laryngeal nerve (RLN), hoarseness, and throat pain are known to occur after the anterior approach in cervical spine procedures. Recurrent laryngeal nerve palsy after anterior cervical spine procedures has been reported to be the most frequent nerve complication; its incidence has been reported to be as low as 2% and as high as 21.6%. The suggested causes for this injury include intraoperative traumatic division of the vagus nerve or RLN, postoperative edema of perineural tissue with subsequent healing and scar formation, entrapment of the nerve between retractors and the endotracheal tube (ET) cuff, and overstretching of the nerve during lateral retraction of the trachea for exposure of the cervical spine.

Stretching of the RLN may be the most probable mechanism of injury, especially if the approach is right sided. The right RLN has a shorter vertical rise, a more oblique course, and a shorter length compared with the left RLN. Placement of the retractor during a right-sided approach to the cervical spine will result in displacement of the RLN from its course as well as significant tension on the nerve at the inferior border of the retractor as the vagus is pulled laterally and the larynx is pulled medially. This stretch, which could reach a maximum level of 24% of the total nerve length, would be great enough to disrupt the perineural blood flow and compromise the nerve.

Endotracheal tube cuff pressure may also contribute to pharyngeal and RLN injury. The size of the tube and the area of contact with the tracheal mucosa have been shown to be important determinants in the development of postoperative throat pain and hoarseness. Placement of the Caspar retractor greatly increases ET cuff pressure, which could lead to pharyngeal injury secondary to reduced mucosal blood flow. Increased cuff pressure could also re-
nitrous oxide was administered during anesthesia. Body 2
dal in a 50% air/oxygen mixture. Additional fentanyl (1–
tenance anesthesia consisted of isoflurane 1 to 2% end ti-
was determined by the anesthesiologist supervising the
was applied to the upper airway. Endotracheal tube size
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heads were fixed in a frame or who exhibited severe neu-
or fiberoptic laryngoscopy while the patient's head was
venously to facilitate intubation performed either by direct
(2–3
spectrometer, pulse oximeter, and rectally placed tempera-
thumbs-up position. All patients were monitored with an
and protected with foam pads, and hands were placed in the
neck or carotid artery surgery.

Clinical Material and Methods

Patient Population

After obtaining approval by our institutional review
board and informed written consent from patients, 60
patients (American Society of Anesthesiologists physical
status 1–3) undergoing anterior cervical discectomy, cor-
pectomy, or fusion procedures were admitted to the study.
On the day prior to surgery a detailed neurological exam-
ination was performed, including assessment for evidence
of RLN and pharyngeal integrity. This same examination
was performed immediately after and at 24 hours post-
surgery. Patients were excluded if they were obese
(greater than 150% of ideal body weight), exhibited any
preexisting compromise of the RLN that caused hoarse-
ness, dysphagia, or dysphonia, or had undergone previous
neck or carotid artery surgery.

Preparation for Surgery

All patients were positioned supine with their arms
adducted and placed at their sides. Elbows were padded
and protected with foam pads, and hands were placed in the
thumbs-up position. All patients were monitored with an
electrocardiograph, automated blood pressure cuff, mass
spectrometer, pulse oximeter, and rectally placed tempera-
ture probe. After preoxygenation, anesthesia was induced
intravenously with thiopental (3–5 mg/kg) and fentanyl
(2–3 μg/kg). Succinylcholine (1 mg/kg) was used intra-
venously to facilitate intubation performed either by direct
or fiberoptic laryngoscopy while the patient's head was
maintained in the neutral position. For patients whose
heads were fixed in a frame or who exhibited severe neu-
rological symptoms (such as weakness, severe pain with
movement, or loss of neurological function) awake fiberop-
tic intubation was performed with topical lidocaine that
was applied to the upper airway. Endotracheal tube size
was determined by the anesthesiologist supervising the
case. No further muscle relaxants were used, and the
patient was allowed to recover spontaneously from paral-
sis prior to the initiation of the surgical procedure. Main-
tenance anesthesia consisted of isoflurane 1 to 2% end ti-
dal in a 50% air/oxygen mixture. Additional fentanyl (1–
2 μg/kg) was administered intravenously, if needed. No
nitrous oxide was administered during anesthesia. Body
temperature was maintained throughout the surgery within
1°C of preinduction values with use of a lower-body heat-
ing blanket.

Intraoperative Monitoring

After intubation, the ET cuff was filled with air, and the
volume was adjusted until an audible leak was apparent at
approximately 20 cm H2O positive ventilatory pressure.
This was considered to be the "just-seal" volume. The pilot
balloon on the ET was then connected to a three-way stop
cock attached to an air-filled transducer that had been
zeroed at atmospheric pressure. The stop cock was opened
in line, and the transmitted pressure obtained (just-seal
pressure) was considered to be consistent with the cuff
pressure transmitted from the ET. At this time, a post-
cricoid laryngeal surface electrode (LSE) was placed. This
electrode has a curved paddelike signal-collecting end that
contains two electrodes on its concave face, which abuts
the two cricoarytenoideus muscles, and a convex face with
a single electrode to make contact with the inferior con-
strictor muscle. The electrodes are encased in a pliable
handle with wires extending from the top. The EMG wires
terminate with a safety connector that fits into the head box
of the recording device. The electrode was placed with the
use of a No. 3 Miller laryngoscopic blade that was used to
 elevate the ET and larynx as a unit. After the postcricoid
space was visualized, the electrode was inserted into the
pharynx with the plate parallel to the posterior pharyngeal
wall. The electrode handle was deviated cranially along
the posterior pharyngeal wall and a 4 × 4 inch sponge
was gently inserted into the mouth to hold the electrode
in place. The LSE wires were then connected to a moni-
tor (Viking 2E; Nicolet Biomedical Instruments, Madison,
WI) that displays both continuous free-run and evoked
EMG activity from direct stimulation of the cranial nerves.
Filter settings for waveform analysis were between 10 Hz
and 10 kHz, with sensitivity set at 10 to 50 μV and a time
base for free-run analysis determined to be 200 msec.
Baseline EMG activity was recorded after intubation and
post–cricoid LSE electrode placement, before skin inci-
sion, and after recovery from muscle relaxants under stable
anesthetic conditions. Electromyographic activity was re-
corded in microvolts, and this baseline measurement was
used for comparisons with all intraoperative observations.

Demographic data were collected as well as the size of
the ET, duration of intubation, type of intubation tech-
nique, and number of attempts required to intubate the
patient. The EMG values and ET cuff pressures were
determined at baseline (immediately after intubation and
placement of LSE prior to incision), after placement of
retractor, and immediately after its removal. In addition,
significant EMG potential changes (> 20% of baseline
value) that occurred during the use of a hand-held retrac-
tor or surgical manipulation were also recorded. After the
surgical procedure, patients were examined for evidence
of RLN injury (hoarseness) or pharyngeal trauma (sore
throat). These symptoms were followed to determine if
they resolved over the next 24 hours. Patients who still
complained of symptoms but in whom no stridor or air-
way compromise was demonstrated during oral intake
were discharged from the hospital and, 1 week postdis-
charge, they were reexamined for resolution of symptoms.
Those in whom no or minimal improvement was demonstrated were referred to an otolaryngologist for evaluation and further treatment.

**Statistical Analysis**

At the completion of the study, patients were divided into groups based on clinical evidence of dysphonia, sore throat, or neither symptom in the 24-hour period after surgery. Demographic data as well as duration of intubation, number of intubation attempts, and size of the ET were compared among groups by using one-way analysis of variance. Endotracheal tube cuff pressure and EMG potentials were compared at baseline, when the Caspar retractor was inserted, and when it was removed by using analysis of variance whereas intragroup comparisons with baseline values over time were performed by conducting paired t-tests The Chi-square test was to compare non-parametric variables among groups. All values are represented as mean ± standard error of the mean with significance reported at the p < 0.05 level.

**Results**

Forty patients (67%) complained of sore throat in the postanesthesia care unit (PACU), and 23 patients (38%) complained of hoarseness and dysphonia. All 23 patients with dysphonia also experienced a sore throat; these patients were considered to be the symptomatic group. No differences were noted in airway class or number of intubation attempts between patients who experienced hoarseness and/or sore throat and those with no symptoms. The duration of intubation was longer in the symptomatic than asymptomatic patients (195.7 ± 15.3 minutes compared with 174.5 ± 8.2 minutes, respectively; p < 0.05) and there were nearly twice as many female patients in the symptomatic compared with the asymptomatic group (52% and 27%, respectively). All patients were noted to have increases in ET cuff pressure when the Caspar retractor was inserted and a return toward baseline pressures after the retractor was removed. The EMG values increased after insertion of the retractor in all patients; no significant differences in these values were noted in either patient group.

In nine of the patients who had reported hoarseness, dysphonia, and sore throat in the PACU, similar symptoms persisted 24 hours post surgery. These patients were considered to be the group with the most severe injury. No differences were noted between these nine symptomatic patients and those without symptoms in number of intubation attempts, airway class, ET size, or intubation technique (Table 1). The duration of intubation was again longer in these nine patients than in those with no symptoms after 24 hours (Table 1). Baseline ET cuff pressures were higher in these nine patients compared with those without symptoms (Fig. 1). In all patients, cuff pressures increased after the Caspar retractor was inserted and returned toward baseline values after the retractor was removed. However, in the group that remained symptomatic 24 hours after surgery, cuff pressures remained higher than in those who experienced no symptoms (Fig. 1). In three patients who experienced hoarseness but no sore throat 24 hours postoperatively, cuff pressure values at each measurement period were similar to those obtained in patients without symp-

<table>
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<th>TABLE 1</th>
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<td>Postoperative comparisons between symptomatic and asymptomatic patients</td>
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<tr>
<td>Characteristic (9 patients)</td>
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<tr>
<td>age (yrs)</td>
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<tr>
<td>height (cm)</td>
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<td>weight (kg)</td>
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<td>duration of intubation (mins)</td>
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<td>ET size (mm inside diameter)</td>
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<td>no. of intubation attempts</td>
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* p < 0.05 compared with asymptomatic group.

The mean peak intraoperative cuff pressure in the nine symptomatic patients was 52.6 ± 8.9 mm Hg. This value was higher than that observed in those without symptoms (35.7 ± 2.2 mm Hg; p < 0.005).

Baseline EMG potentials were observed to be between 15 and 18 μV in all patients. These EMG potentials increased in all patients when the Caspar retractor was placed (Fig. 2). Although EMG values fluctuated during the procedure, the mean values tended to be higher than those obtained before retractor placement. After the retractor was removed, EMG potential activity decreased toward baseline values in most patients (Fig. 2). In a few patients who experienced prolonged hoarseness and sore throat, very high EMG activity was demonstrated at some point during the procedure, but neither timing of the peaks nor directional group changes were systematically associated with symptoms.

Two patients suffered hoarseness and dysphonia for more than 1 week. In the first patient mild throat pain and dysphonia experienced immediately after surgery resolved within 24 hours. In this patient minimal cuff pressure and EMG changes were shown during retractor placement and surgical manipulation. At follow up 1 week later, the patient was again observed to have mild dysphonia and was referred to a speech therapist; the symptoms gradually resolved after 1 month. The second patient, one of the nine with prolonged symptoms, experienced a severe sore throat and dysphonia immediately after surgery and at 24 hours post surgery. This patient was noted to have spontaneous EMG electrical activity of 270 μV (15–18 times greater than baseline values) when a hand-held retractor was used to obtain surgical exposure to facilitate disc removal and with electrocautery near the spinal cord. All cuff pressures were in the expected range for asymptomatic patients. One week postoperatively the patient was still noted to have a weak voice and dysphonia. Endoscopy revealed a paralyzed vocal cord ipsilateral to the surgical field, and the patient underwent teflon injection that resolved the symptoms.
Pharyngeal and RLN injury after cervical spine surgery

**Discussion**

Damage to the RLN after anterior cervical spine procedures is common, occurring in 2% to 21.6% of patients. In previous reports, the incidence of dysphonia and transient hoarseness immediately after surgery was 38%. This higher incidence may be explained by the prospective nature of our study. In previous reports, the authors used a retrospective database to make their comparisons. In many instances, the incidence of dysphonia/transient hoarseness was either underreported or simply attributed to intubation. In the present study, we specifically evaluated hoarseness and sore throat postoperatively and used real-time neurophysiological monitoring to see if we could determine the time at which the RLN was most at risk. The hoarseness and dysphonia noted immediately postsurgery in our 23 patients may have been caused by nonspecific tracheal irritation by the ET. However, there were no distinguishing characteristics of intubation such as tube size, gender, or difficulty with the intubation procedure that appeared to contribute in this outcome. Patients with these symptoms were noted to have been intubated for longer periods of time. The more prolonged the period of intubation, the longer the time that the ET is in contact with the tracheal mucosa, which, with low-pressure, high-volume cuffs, could cause mucosal membrane or ciliary damage. In the present study, the incidence of hoarseness and sore throat 24 or more hours after surgery; no significant differences were noted.

In the nine patients who experienced hoarseness and dysphonia in the PACU, symptoms continued 24 hours after surgery. This number represents 15% of the study population and is more in agreement with previous observations. The prolonged length of symptoms suggests that the insult was more severe than in those patients whose symptoms resolved within 24 hours. This again implies that in the previous retrospective reports the authors only reported the most severe cases that may have been caused by either direct trauma to the vocal cord by the ET or to injury of the RLN. In this subgroup, higher baseline cuff pressures compared with asymptomatic patients and a more pronounced increase in cuff pressure during retraction were demonstrated. These results are comparable with those obtained by Sperry and coworkers, who have also noted increases in cuff pressure when retractors are used. It is interesting that with lower just-seal pressures to prevent damage to the trachea and RLN. Although an increase in cuff pressure during retraction was demonstrated in all patients, those whose symptoms were prolonged also had significantly elevated pressure after retraction. Interestingly, the elevated pressure postretraction observed in the patients with the most severe symptoms was close to the 25–mm Hg level that is accepted as the pressure needed to maintain capillary blood flow to the tracheal mucosa.

Compound EMG monitoring of the posterior cricoid muscles demonstrated resting baseline potentials between 15 to 18 µV in all patients, which is slightly lower than the values reported by some investigators but within the ranges reported by others. In previous studies RLN monitoring during thyroid surgery and evoked compound EMG monitoring have been used to identify the nerve within the tumor bed or to assess the integrity of the nerve once the surgical resection has been completed. In this study, we assessed the spontaneous compound EMG activity of the muscles of the posterior pharynx and used this as a surrogate to measure recurrent LNS. Irritation of the nerve, as a result of direct contact during surgical manipulation or traction on the nerve during placement of surgical retractors, should cause changes in spontaneous activity of the nerve, which would be reflected in the spontaneous firing of the muscle bed that is being monitored. In all of our patients there were wide swings in activity during the procedure; in the one patient who underwent the teflon injection, dramatically increased EMG activity during surgical manipulation at two specific time points indicated when damage to the nerve likely occurred. However, in the group with prolonged...
hoarseness (≥ 24 hours), EMG activity did not systematically differ from that in asymptomatic patients.

Excessive stretch to the RLN, especially on the right side during retraction of neck structures for cervical spine exposure, has been demonstrated in cadaveric preparations. 3 The left RLN is fairly redundant along its course and shows no evidence of stretch during muscle retraction in the neck. However, the right nerve is extremely prone to stretch-related injury and, at a 4-cm retraction width, has been shown to incur a maximum stretch of 24% more than its normal length. The results of other studies have demonstrated that an 8% nerve stretch causes a 50% reduction in blood flow, which was reversed after a return to the resting length. 2 The large degree of stretch observed during anterior cervical retraction could disrupt portions of the nerve fibers and lead to spontaneous, uncoordinated firing of the RLN that would be manifest as an increase in EMG activity with subsequent failure of the nerve and hoarseness in the PACU. In any event, in this study EMG activity may have identified the most severe case during the time of injury, but the changes seen in that patient did not differ from those seen in many patients who were not symptomatic.

Conclusions

In summary, we have confirmed that the symptoms of sore throat and hoarseness of brief duration found immediately after anterior cervical spine procedures are very common (38%), but no distinguishing patient or perioperative characteristics were discovered that explain this frequent outcome. Persistent dysphonia and pain, however, were much less common (15%) but were clearly associated with higher ET cuff pressures that were present after achieving just-seal pressures and persisted during and after retraction. Whereas EMG monitoring of the posterior or pharyngeal muscles may detect an injury in progress, we were not able to determine any systematic indicators by using this technique. We conclude that meticulous attention to achieving just-seal pressures in the ET cuff of 20 mm Hg or less prior to surgical manipulation may be the single most important contributor to reducing the incidence of prolonged sore throat and dysphonia after anterior cervical spine surgery and other cervical procedures that may cause distraction of the trachea.

References


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