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LITERATURE REVIEW

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The effectiveness of reducing endotracheal cuff pressure after retractor placement to decrease postoperative laryngeal dysfunction in anterior cervical surgery: a meta-analysis

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OBJECTIVE The authors sought to determine if a consensus could be reached regarding the effectiveness of endotracheal tube cuff pressure (ETTCP) reduction after retractor placement in reducing postoperative laryngeal dysfunction after anterior cervical fusion surgery.

METHODS A literature search of MEDLINE (PubMed), EMBASE, Cochrane Central, Google Scholar, and Scopus databases was performed. Quantitative analysis was performed on data from articles comparing groups of patients with either reduced or unadjusted ETTCP after retractor placement in the context of anterior cervical surgery. The incidence and severity of postoperative recurrent laryngeal nerve palsy (RLNP), dysphagia, and dysphonia were compared at several postsurgical time points, ranging from 24 hours to 3 months. Heterogeneity was assessed using the chi-square test, I^2 statistics, and inverted funnel plots. A random-effects model was used to provide a conservative estimate of the level of effect.

RESULTS Nine studies (7 randomized, 1 prospective, and 1 retrospective) were included in the analysis. A total of 1671 patients were included (1073 [64.2%] in the reduced ETTCP group and 598 [35.8%] in the unadjusted ETTCP group). In the reduced ETTCP group, the severity of dysphagia, measured by the Bazaz-Yoo system in 3 randomized studies at 24 hours and at 4–8 weeks, was significantly lower (24 hours [standardized mean difference: −1.83, p = 0.04] and 4–8 weeks [standardized mean difference: −0.40, p = 0.05]). At 24 hours, the odds of developing dysphonia were significantly lower (OR 0.51, p = 0.002). The odds of dysphagia (24 hours: OR 0.77, p = 0.24; 1 week: OR 0.70, p = 0.47; 12 weeks: OR 0.58, p = 0.20) were lower, although not significantly, in the reduced ETTCP group. The odds of a patient having RLNP were significantly lower at all time points (24 hours: OR 0.38, p = 0.01; 12 weeks: OR 0.26, p = 0.03) when 3 randomized and 2 observational studies were analyzed. A subgroup analysis using only randomized studies demonstrated a similar trend in odds of having RLNP, yet without statistical significance (24 hours: OR 0.79, p = 0.60). All other statistically significant findings persisted with removal of any observational data.

CONCLUSIONS Based on the current best available evidence, reduction of ETTCP after retractor placement in anterior cervical surgery may be a protective measure to decrease the severity of dysphagia and the odds of developing RLNP or dysphonia.

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KEYWORDS endotracheal tube cuff pressure; anterior cervical surgery; laryngeal nerve palsy; postoperative dysphagia; tracheal retraction

Anterior cervical spine surgery has been reported to result in laryngeal dysfunction in a significant proportion of patients, with up to 60% of patients experiencing dysphagia in the immediate postsurgical period.[1–3] The clinical symptomatology of laryngeal dysfunction is broad because it depends on both anatomical region and the degree of nerve injury. In mild cases that do not significantly hinder function of the laryngeal nerve, patients may only experience dysphagia or sore throat. However, in severe cases of laryngeal nerve paralysis, pa-

ABBREVIATIONS ACDF = anterior cervical discectomy and fusion; ETT = endotracheal tube; ETTCP = endotracheal tube cuff pressure; GRBAS = grade, roughness, breathiness, asthenia, strain; PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analyses; RLNP = recurrent laryngeal nerve palsy; SMD = standardized mean difference.

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tients may experience dysphonia, changes in vocal pitch, difficulty breathing, or aspiration.[4–7] Although endotracheal tube (ETT) cuff pressure (ETTCP) may alone be responsible for causing tracheal injury or postoperative sore throat, retractor placement during anterior cervical surgery may cause excessive pressure and mechanical deformation of the trachea and esophagus.[8,9] Proposed pathophysiology for subsequent injury includes the compression of the laryngeal nerve between the ETT balloon and retractor blade or by distraction of the laryngeal nerve on the contralateral side.[8,10] Symptoms may also result from ischemia, given that retractor pressure can exceed mean arterial pressure and mucosal perfusion pressure in up to half of patients.[1,11]

Deflation and reinflation of the ETT cuff after retraction to maintain a "just-seal" pressure is thought to have a protective effect during anterior cervical spine surgery, and reduces the likelihood of postoperative laryngeal dysfunction.[3,5,7,8] However, there is still a lack of consensus in the literature regarding this practice. Therefore, to better elucidate the relationship between reduced ETTCP and postoperative laryngeal dysfunction, we performed a systematic review and meta-analysis of currently available literature.

Methods

A systematic review of the literature was performed in accordance with the study guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[12]

Study Selection

A literature search was designed to identify articles on patient cohorts who had their ETT cuff deflated and reinflated after retraction compared with patients who had unadjusted ETTCP after retraction, specifically in anterior cervical spine surgery. Two authors (A.M. and D.W.G.) queried MEDLINE (PubMed), EMBASE, Cochrane Central, Google Scholar, and Scopus databases for articles published from the establishment of each database to September 2021. Our search was as follows: ("cuff pressure" OR "endotracheal cuff" OR "cervical retraction" OR "esophageal retraction" OR "endotracheal tube" OR retraction OR "Intubation, Intratracheal/adverse effects"[Mesh:NoExp] OR "Deglutition Disorders/prevention and control"[Mesh:NoExp]) AND (hoarseness OR dysphagia OR dysphonia OR "laryngeal nerve" OR "vocal cord palsy" OR "vocal cord palsies" OR "mucosa ischemia" OR "Hoarseness"[Mesh] OR "Hoarseness/surgery"[Mesh] OR "Vocal Cord Paralysis/etiology"[Mesh] OR "Deglutition Disorders/surgery"[Mesh:NoExp]) AND ("anterior cervical spine" OR "anterior cervical discectomy" OR "Cervical Vertebrae/surgery"[Mesh] OR "Diskectomy"[Mesh:NoExp] OR "Intervertebral Disc/surgery"[Mesh] OR "Spinal Diseases/surgery"[Mesh:NoExp] OR "Spinal Fusion"[Mesh]).

After removing duplicate articles from the initial search, the master list of studies underwent 3 stages of review by 2 authors (A.M. and D.W.G.) including 1) title screening, 2) abstract screening, and 3) full-text eligibility assessment. Each author performed these steps independently and compared selection of articles in each successive stage.

Inclusion criteria of studies were as follows: 1) English language, 2) data from human samples, and 3) reports in the context of anterior cervical spine surgery in which retractors were used. It was required that each study include both an intervention (reduced ETTCP) and control (unadjusted ETTCP) group. The study also had to assess postsurgical laryngeal dysfunction by reporting recurrent laryngeal nerve palsy (RLNP), dysphagia, dysphonia, or sore throat either as categorical data or by a standardized scoring system. Individual case reports and cadaveric studies were excluded from analysis. The study quality was assessed using the following criteria: 1) random sequence generation; 2) allocation concealment; 3) blinding of outcome assessment; 4) equal sex distribution; 5) standard side of approach; 6) similar timing of outcome assessment; 7) selective reporting; and 8) incomplete outcome data reported.

Data Extraction

One author (A.M.) extracted and imported the following data into an electronic spreadsheet: study design, study type, publication year, author, number of subjects in comparator groups, ETTCP in comparator groups, description of laryngeal dysfunction, and duration of operation, intubation, and retraction. For each comparator group, the number of patients with symptomatology (either laryngeal nerve palsy, dysphonia, dysphagia, or sore throat) was recorded at all available time points up to 12 weeks after surgery. If reported, standardized scoring systems were also recorded at all available time points. If the degree of dysphagia was measured by the Bazaz-Yoo system[2] (grades: none [no episodes of difficulty swallowing]; mild [only rare episodes of difficulty swallowing]; moderate [occasional swallowing difficulty with solid foods]; or severe [swallowing difficulty with solids and liquids]), the values 1, 2, 3, and 4 were attributed to none, mild, moderate, and severe, respectively, and were used to generate score means and SDs, as described by Kowalczyk et al.[3]

Statistical Analysis

When available, data were pooled among studies. Groups were assessed at corresponding postsurgical time points of 24 hours, 1 week, 4 weeks, 6 weeks, 8 weeks, or 12 weeks. If more than 1 study was not available for a given time point, studies were grouped in follow-up time ranges. The primary outcomes were analyzed and interpreted using a summary odds ratio if data were dichotomous and standardized mean difference (SMD) if continuous, with the corresponding 95% confidence interval. Statistical significance was set at 0.05. Heterogeneity was assessed using the chi-square test, I^2 statistics, and inverted funnel plots. A random-effects model was used, irrespective of I^2 value, to provide a conservative estimate of the level of effect. Subgroup analysis with only randomized data was performed in cases in which observational data were used for comparison. Data were initially entered in Microsoft Excel 2021 (version 16.53); analyses were conducted in RevMan5 (version 5.4.1, The Cochrane Collaboration).[13]

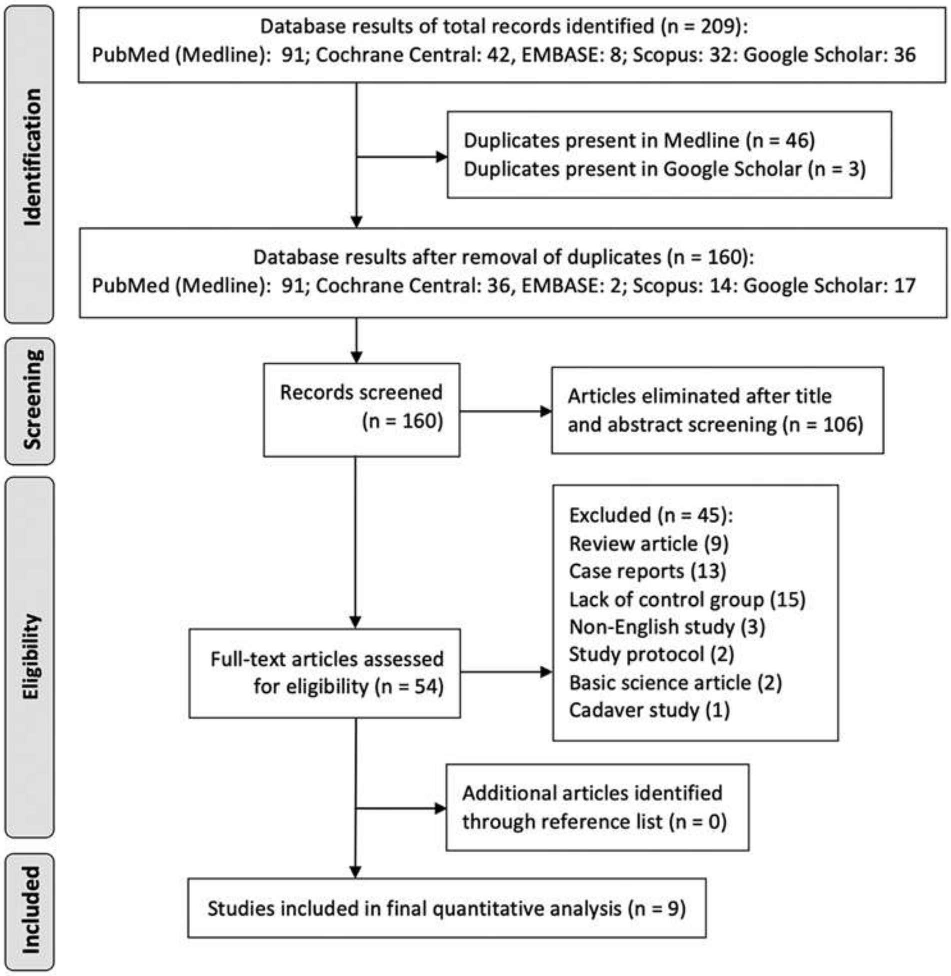

FIG. 1. PRISMA flow diagram. Data added to the PRISMA template (from Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Med.* 2009;6[7]:e1000097) under the terms of the Creative Commons Attribution License.

Results

Study Identification and Characteristics

Details of the article selection process are shown in the PRISMA attrition diagram in Fig. 1. Overall, 160 original articles were retrieved from the literature search. Title and abstract screening eliminated 106 of those articles. The remaining full-text articles were then carefully read by 2 authors (A.M. and D.W.G.), who eliminated all except for 9 studies. Although the references of each study that were deemed fit for inclusion were also searched, no additional study meeting eligibility was identified.

All studies were published between 2000 and 2021. There were 7 randomized studies including 529 patients, 1 prospective study including 242 patients, and 1 retrospective study including 900 patients. Among randomized studies, sample sizes ranged from 24 to 162. The total number of patients was 1671 (1073 [64.2%] in the reduced ETTCP group and 598 [35.8%] in the unadjusted ETTCP [control] group). An evaluation of study quality and risk of bias in each study is shown in Fig. 2.

A summary of patient and study characteristics is shown in Tables 1 and 2. Most studies reported categorical values of combinations of either RLNP, dysphagia, dysphonia, or sore throat. Three studies reported dysphagia measured by the Bazaz-Yoo scoring system, of which dichotomous data could also be derived. One study used the dysphagia disability index (i.e., DDI). Two studies assessed dysphonia using the grade, roughness, breathiness, asthenia, strain (GRBAS) scoring system. Additionally, 4 studies analyzed the effect of single versus multilevel fusion on laryngeal dysfunction. One study analyzed the relationship between corpectomy with cage implant and the presence of dysphagia at 2 months. Considering all patients in the included studies, the pooled mean age was 48.3 years (SD 7.6, mean range 46–57 years) and the sex distribution was 947 male (56.7%) and 724 female (43.3%).

Pressure Change After Retraction

Six randomized studies reported continuous data on cuff pressure measurements in units of mm Hg for both comparator groups during retraction.[7,14–18] The reduced ETTCP group involved deflating the ETT cuff after retraction and subsequently reinflating and maintaining a just-seal pres-

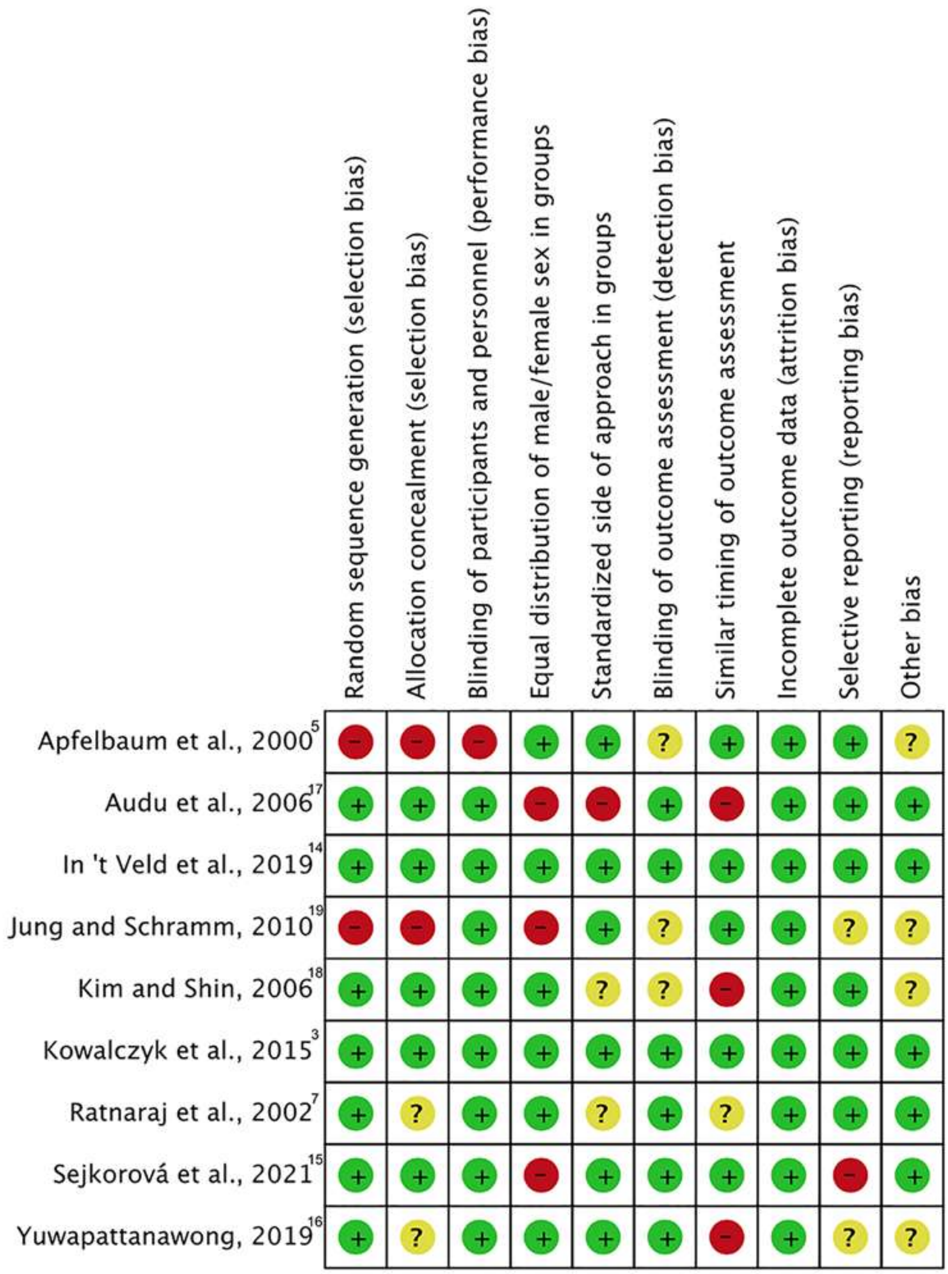

FIG. 2. Risk of bias summary table. + = low risk of bias; − = high risk of bias; ? = unclear risk of bias. Figure is available in color online only.

sure for the remainder of the procedure. The unadjusted ETTCP group involved monitoring the pressure without altering the cuff pressure at any point during the procedure after intubation. The pooled mean cuff pressure was 19.6 mm Hg (SD 4.1, mean range 18–20 mm Hg) in the reduced ETTCP group and 37.1 mm Hg (SD 2.0, mean range 24.6–50.0 mm Hg) in the unadjusted ETTCP group. The pressure was significantly lower throughout the duration of surgery in the reduced group compared to the unadjusted group (weighted mean difference −8.61, 95% CI −9.68 to −7.54, $p < 0.00001$). The individual pressure means with SD are listed alongside corresponding study data in Table 2.

Recurrent Laryngeal Nerve Palsy

Five studies (3 randomized, 2 observational) were available to determine rate of RLNP at 24 hours,[5,7,15,17,19] and 3 studies (1 randomized, 2 observational) were available at 12 weeks.[5,15,18] Four of 5 studies used laryngoscopy to determine recurrent laryngeal nerve function, which was deemed intact after direct visualization of vocal cord mobility. The remaining study reported no method of assessment and zero incidence of nerve palsy in either group.[18] At 24 hours postsurgery, the incidence of RLNP from 5 studies was 2.9% (27/930) in the reduced ETTCP group and 9.0% (41/454) in the unadjusted ETTCP group. At the next

TABLE 1. Demographic characteristics of patients who underwent anterior cervical surgery

Authors & Year	Study Population	No. of Pts	Age in Yrs (mean ± SD)	Sex M/F (%)	Approach Rt/Lt (%)
Sejkorová et al., 2021[15]	ACDF	98	53 ± 10.4	41/59	100/0
Yuwapattanawong, 2019[16]	ACDF	24	57 ± 15	63/37	100/0
In 't Veld et al., 2019[14]	Anterior cervical surgery	162	51 ± 1.1	44/56	100/0
Kowalczyk et al., 2015[3]	Anterior cervical surgery	50	47 ± 10	74/26	100/0
Jung & Schramm, 2010[19]	Anterior cervical surgery	242	52, SD not available	67/33	0/100
Audu et al., 2006[17]	Anterior cervical surgery	94	47 ± 10.9	57/43	88/12
Kim & Shin, 2006[18]	Anterior cervical surgery	50	52, SD not available	48/52	Not available
Ratnaraj et al., 2002[7]	Anterior cervical surgery	51	52 ± 11	43/57	Not available
Apfelbaum et al., 2000[5]	Anterior cervical surgery	900	46, SD not available	58/42	100/0

Pts = patients.

available time point, which was 12 weeks postsurgery, the incidence of RLNP from 3 studies was 0.5% (4/848) in the reduced ETTCP group and 2.6% (10/392) in the unadjusted ETTCP group. At 24 hours, the odds of a patient having RLNP from 5 studies were lower in the reduced ETTCP group (OR 0.38, 95% CI 0.18–0.80, p = 0.01). At 12 weeks postsurgery, the odds of a patient in this group having RLNP in 3 studies remained significantly lower (OR 0.26, 95% CI 0.08–0.90, p = 0.03). The estimate of effect for all studies at both time points is shown in Fig. 3. A subgroup analysis of the 3 randomized studies at the 24-hour time point demonstrated no significant difference in odds of RLNP (OR 0.79, 95% CI 0.33–1.90, p = 0.60). A subgroup analysis of only randomized data at 12 weeks could not be performed given that only 1 randomized study was available.

Dysphonia

The terms "hoarseness" and "dysphonia" were used interchangeably throughout studies, and thus were treated as interchangeable throughout this review. Six studies (5 randomized, 1 observational) reported dysphonia incidence at varying time frames, including 24 hours, 1 week, and 8 weeks.[7,14–16,18,19] The overall incidence of dysphonia at 24 hours postsurgery from 6 studies was 20.1% (69/343) in the reduced ETTCP group and 32.7% (96/284) in the unadjusted ETTCP group. As shown in Fig. 4, the odds of developing dysphonia at this same time point were significantly lower in the group with reduced ETTCP (OR 0.51, 95% CI 0.33–0.79, p = 0.002, $I^2 = 0$). In a subgroup analysis using only the 5 randomized studies, the odds of developing dysphonia at this same time point remained

TABLE 2. Summary of study designs and outcomes in patients who underwent anterior cervical surgery

Authors & Year	No. in Group (ETTCP, mean ± SD)	Follow-Up	Outcome Measures	LOE
Sejkorová et al., 2021[15]	49 control (41.7 ± 15.3 mm Hg); 49 intervention (20 mm Hg)	24 hrs, wks 6 & 12	Dysphagia, dysphonia, RLNP (laryngoscopy)	I
Yuwapattanawong, 2019[16]	12 control (24.5 ± 2.3 mm Hg); 12 intervention (20 mm Hg)	24 hrs, wk 4	Dysphagia, sore throat, dysphonia*†‡	I
In 't Veld et al., 2019[14]	81 control (33 ± 13.2 mm Hg); 81 intervention (20 mm Hg)	24 hrs, wk 8	Dysphagia, sore throat, dysphonia*†‡	I
Kowalczyk et al., 2015[3]	25 control (NA); 25 intervention (15 mm Hg)	24 hrs, wks 6, 12, & 24	Dysphagia, soft-tissue swelling, SF-36*§	I
Jung & Schramm, 2010[19]	93 historical control (NA); 149 intervention (<20 mm Hg)	24 hrs, wks 1 & 12	RLNP (laryngoscopy), dysphonia	II
Audu et al., 2006[17]	39 control (50 ± 49 mm Hg); 55 intervention (18 mm Hg)	24 hrs	RLNP (laryngoscopy)	I
Kim & Shin, 2006[18]	25 control (32.3 ± 7.3 mm Hg); 25 intervention (20 mm Hg)	24 hrs, wk 1	Dysphagia, sore throat, dysphonia†	I
Ratnaraj et al., 2002[7]	24 control (32 ± 9 mm Hg); 27 intervention (20 mm Hg)	24 hrs, wk 1	Dysphagia, sore throat, dysphonia, RLNP†	I
Apfelbaum et al., 2000[5]	250 historical control (NA); 650 intervention (15 mm Hg)	Wks 1–16 (range)	RLNP (laryngoscopy)	III

LOE = level of evidence; NA = not applicable.
* Degree of dysphagia measured by Bazaz-Yoo system.
† Sore throat assessed by visual or verbal numeric grading scales.
‡ Degree of dysphonia measured by GRBAS.
§ Degree of dysphagia measured by DDI (dysphagia disability index).

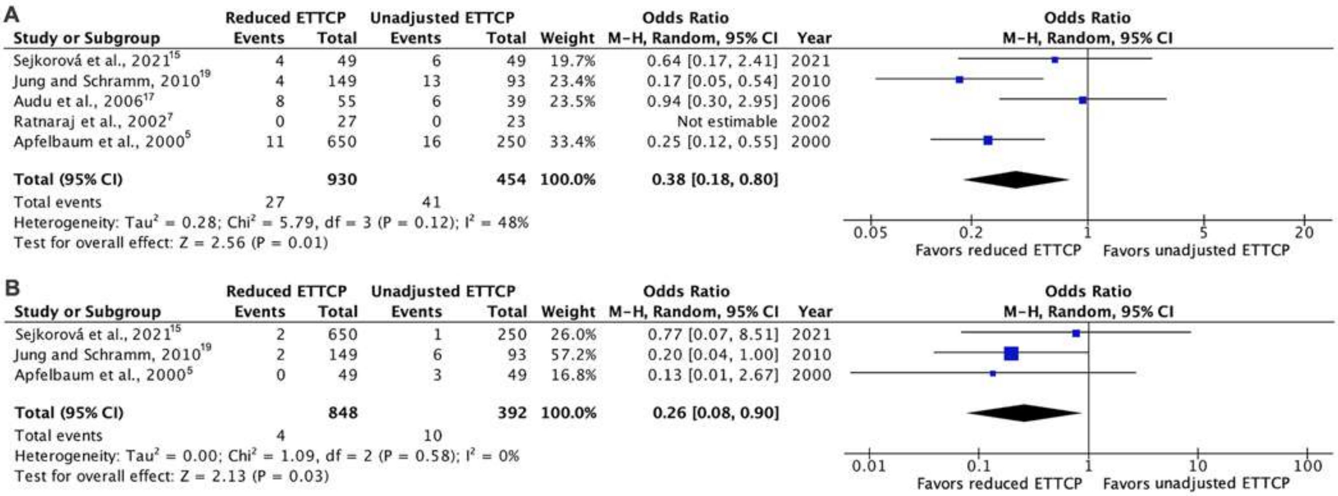

FIG. 3. Forest plot of comparison of RLNP at 24 hours (**A**) and 12 weeks (**B**) postsurgery. Note that a subgroup analysis of the 3 randomized studies at the 24-hour time point, however, demonstrated no significant difference in odds of RLNP. Subgroup analysis of only randomized studies at 12 weeks could not be performed. M-H = Mantel-Haenszel. Figure is available in color online only.

significantly lower in the reduced ETTCP group (OR 0.54, 95% CI 0.35–0.84, p = 0.006, I^2 = 0). At 1 week and at 8 weeks postsurgery, respectively, the incidence was 11.5% (2 studies, 6/52) and 0 (1 study, 0/49) in the reduced ETTCP group, and it was 10.2% (2 studies, 5/49) and 4.1% (1 study, 2/49) in the unadjusted ETTCP group. No significant effect was detected among 2 studies at 1 or 8 weeks postsurgery.

Dysphagia

Six randomized studies were available to assess dysphagia, which was reported in a manner that could be compared as either incidence or with Bazaz-Yoo scores. At 24 hours, 1 week, and 4–8 weeks postsurgery, the incidence of dysphagia was 42.3% (82/194), 19.2% (10/52), and 22.5% (32/142), respectively, in the reduced ETTCP group, and 47.6% (91/191), 24.5% (12/49), and 32.4% (46/142) in the unadjusted ETTCP group. The odds of having dysphagia after surgery in patients in the reduced ETTCP group was not significantly reduced at any time point (Fig. 5). However, Bazaz-Yoo scores, which characterize dysphagia presence and severity, were significantly lower in the reduced ETTCP group at all available time points (24 hours [SMD −1.83, 95% CI −3.57 to −0.09, p = 0.04] and 4–8 weeks [SMD −0.40, 95% CI −0.79 to −0.01, p = 0.05]). The measure of effect is shown in Fig. 6.

Discussion

It was recently estimated that more than 132,000 people undergo anterior cervical discectomy and fusion (ACDF) surgery in the United States per year.[20] Laryngeal dysfunction following anterior cervical surgery, including ACDF, is known to occur and may significantly affect a patient's quality of life in the postsurgical recovery period. Contributions to this clinical symptomatology are thought to be multifactorial and to change in likelihood depending on sex, operative time, method of intubation, and cervical level of surgery.[4,6,9,21,22] However, the reduction of ETTCP after retractor placement is thought to be a protective measure.[1,6,11,23] Thus, after a fixed retractor is placed against the trachea to expose the anterior cervical spine, the anesthesiologist may be instructed to deflate and reinflate the ETT cuff, maintaining the cuff at a just-seal pressure (15–20 mm Hg) throughout the duration of surgery.[8,24] This practice has been studied as a way to potentially reduce incidence or severity of either laryngeal nerve palsy, dysphonia, dysphagia, or sore throat.[4–7] It is also thought that reduction of tracheal pressures may minimize local

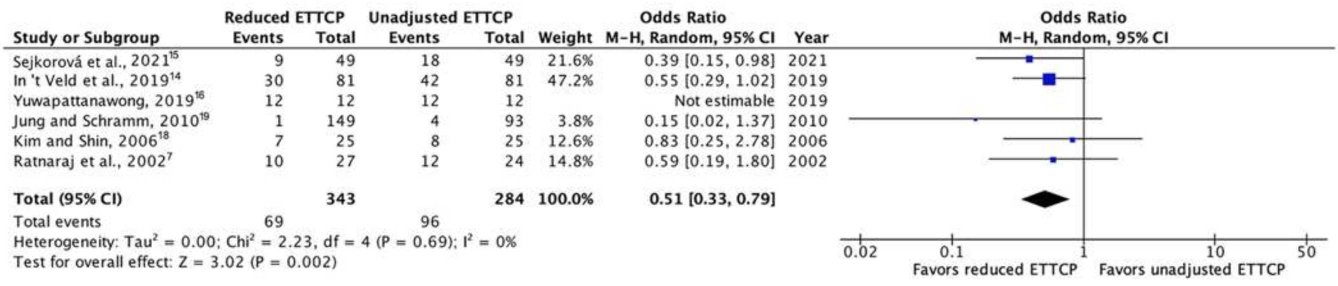

FIG. 4. Forest plot of comparison of dysphonia (hoarseness) at 24 hours. Subgroup analysis of the 5 randomized studies yielded no significant difference. Figure is available in color online only.

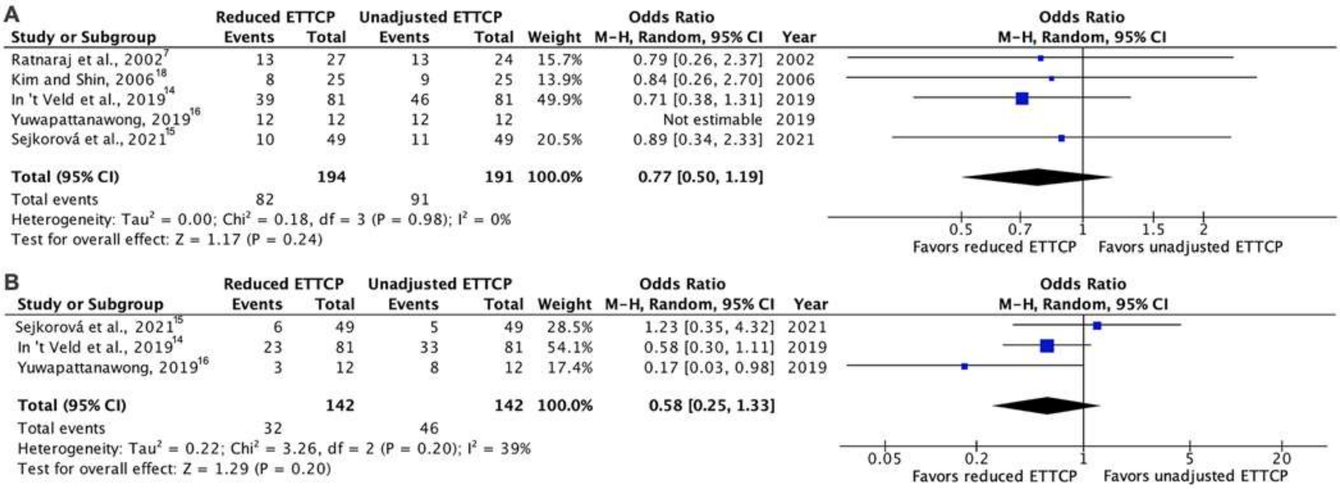

FIG. 5. Forest plot of comparison of dysphagia at 24 hours (**A**) and 4–8 weeks (**B**) postsurgery. Figure is available in color online only.

ischemia, given that retractor pressure can exceed mean arterial pressure and arrest mucosal perfusion during the retractor-dependent portion of surgery.[1,11]

In the present meta-analysis, we combined the results from 9 studies comparing the incidence and severity of clinical symptoms related to laryngeal function in both groups.[3,5,7,14–19] In the reduced ETTCP group, we found significantly lower odds of RLNP at both time points, lower odds of having dysphonia at 24 hours, and a lower severity of dysphagia measured by Bazaz-Yoo scores at all time points. When only randomized study data were used, all statistically significant findings persisted except for RLNP at 24 hours and 12 weeks. Notably, there was variation in the sample sizes of each study, in the types of controls used, and in the time points at follow-up assessment, which limited the reliability of some of our analyses.

After pooling data from 6 studies, we found that the mean pressure of the ETT cuff, which approximates pressure within the trachea, was significantly lower if the cuff was deflated and reinflated after retractor placement (weighted mean difference −8.61, $p < 0.00001$). Sperry et al. examined the effect of the Caspar retraction system on ETTCP during anterior cervical spine surgery, and found pre- and postretractor pressures to be 15.2 ± 1.6 versus 43.2 ± 5 mm Hg, respectively.[8] In a different analysis, Jellish et al. examined pre- and postretractor pressure by stratifying patients by the presence or absence of laryngeal dysfunction after surgery.[24] They found the mean intraoperative cuff pressure to be 52.6 ± 8.9 mm Hg in symptomatic patients compared to 35.7 ± 2.2 mm Hg in asymptomatic patients ($p < 0.005$).

The development of recurrent laryngeal nerve paralysis after anterior cervical surgery is an adverse event that is less commonly seen, which was classified by absence of vocal cord movement after surgery. In 1973, Heeneman first described the presence of RLNP in a cohort of 85 patients, specifically in the context of the anterior cervical approach.[10] Included in his report were proposed mechanisms of injury, including direct nerve trauma caused by either the Cloward retractor or inadvertent surgical dissection of the nerve, or pressure-induced causes such as prolonged operative time and overstretching of the recur-

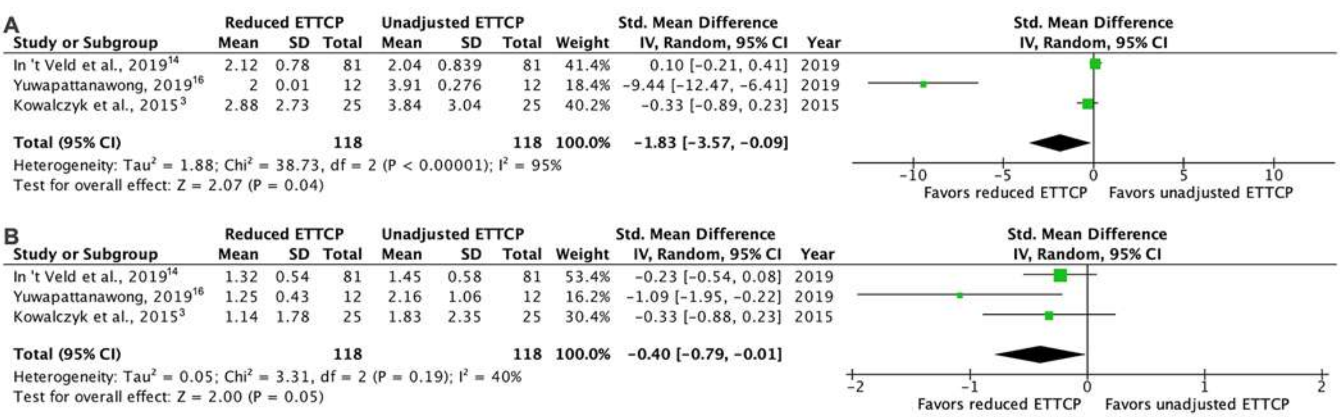

FIG. 6. Forest plot of comparison between Bazaz-Yoo scores at 24 hours (**A**) and 4–8 weeks (**B**) postsurgery. Figure is available in color online only.

rent branch by a right-sided approach. Since these reports, others have attempted to meaningfully characterize the anatomical relationship of pressure on the trachea and resulting injury such as induced ischemia by local arterial tamponade.[1,11,22] In the present review, only 1 study had significantly different retraction times, which may have confounded outcomes.[7] Moreover, side of approach was generally standardized, with the exception of 2 studies that failed to mention the approach,[7,18] and 1 study that had unequal distribution of approach.[17] Of studies included in this review, Jung and Schramm were the only to report detailed analysis of this finding by describing the incidence of both recurrent laryngeal nerve paresis and paralysis and the presence or absence of hoarseness.[19] In 5 additional studies, dysphonia was reported generally with dichotomous data, but also using the GRBAS scale in 2 other studies. In 't Veld et al. and Yuwapattanawong et al. both used the GRBAS scale, with the only significant finding being reduced severity of dysphonia at 24 hours in the reduced ETTCP group in Yuwapattanawong's study.[14,16] Due to differences in follow-up times, GRBAS scales could not be formally compared.

In the present formal analysis among 6 studies, there were significantly lower odds of having postoperative dysphonia in the reduced ETTCP group at 24 hours. Although the odds of dysphonia at further time points were formally compared, no significant differences were detected. Lack of significant effect may have been due to the smaller sample size of studies reporting dysphonia at later time points (2 studies at 1 week and 1 study at 8 weeks). Nevertheless, our analysis supports cuff pressure reduction as an effective measure to reduce the odds of developing dysphonia at 24 hours postsurgery.

Regarding dysphagia, the present analysis of 6 randomized studies found that the odds of dysphagia were not significantly reduced in the reduced ETTCP group, yet the severity of dysphagia was significantly reduced, as shown in Figs. 5 and 6. An explanation for this finding may be that because dysphagia is a subjective measure, it is possible that a similar incidence of dysphagia could be a result of patient misinterpretation of local pain limiting function, rather than actual pathological changes that resulted from surgical damage. This is supported by the significantly lower Bazaz-Yoo dysphagia scores, which indicate that complaints of dysphagia were less severe, and perhaps were less likely to be clinically significant if cuff pressure was adjusted after retraction. Thus, the present analysis supports cuff pressure reduction as an effective measure that reduces the severity of postoperative dysphagia.

Some limitations are worth noting. First, the largest study included in this review (n = 900) was retrospective and used historical controls.[5] Another prospective study also used a historical control group, which prevented randomization and blinding throughout the course of performing those 2 studies.[5,19] Additionally, it should be noted that 1 of the randomized studies had a relatively unequal distribution between control (n = 39) and treatment (n = 55) groups, which we found to be unusual.[17] However, no methodological concerns were otherwise noteworthy or concerning in their study. Another limitation was the distribution of sex in comparator groups. Three studies included in the present quantitative synthesis found, through subgroup analysis, that female patients had a significantly ($p < 0.05$) higher likelihood of being symptomatic from dysphagia or dysphonia.[7,14,18] This was detected in studies in which treatment and controls were randomly allocated and sex, among other factors, was matched in groups to minimized confounding the outcome. For this reason, it is possible that studies with unmatched sex distribution[15,17,19] may have confounded overall findings of effect when those were used in formal analysis. Finally, the variability of time points of outcomes assessment was the largest barrier to formal synthesis of studies. The most reported outcomes were available at 24 hours postsurgery. Other time points ranged anywhere from 1 to 12 weeks, which prompted us to compare studies within the range of 4–8 weeks as a single analysis in some cases, and undoubtedly introduced variability into the analysis. Nevertheless, the strongest associations were not detected when time ranges were used, but rather at 24 hours (RLNP, dysphagia [Bazaz-Yoo], and dysphonia) or 12 weeks (RLNP). The only significant finding when a time range was used was dysphagia (Bazaz-Yoo) at 4–8 weeks (Fig. 6B). The lack of similar time points also contributed to fewer studies per formal analysis (range 2–6 studies). It should be noted that when only randomized data were used, the significant findings of dysphagia severity (Bazaz-Yoo) and dysphonia persisted, whereas RLNP was no longer significant at 24 hours and could not be analyzed at 12 weeks.

Finally, we acknowledge that cuff pressure is not the only factor that may contribute to postsurgical laryngeal function, and that the cause is likely to be multifactorial. In fact, recent studies have begun to investigate the practice of reducing ETTCP, along with local irrigation with methylprednisolone and reduced or dynamic retraction as a singular intervention group.[6,21,25] Others have demonstrated that patients with longer operative times, higher cervical levels in surgery, and female sex are more likely to be symptomatic.[4,24,26] Although the literature reports mixed results, multilevel procedures and corpectomies may also increase the risk of laryngeal dysfunction. Sejkorová et al. showed that in the unadjusted group, single-level fusion resulted in a significantly lower rate of dysphagia ($p = 0.03$).[15] Likewise, Apfelbaum et al. found that when treatment and control groups were pooled together, multilevel operations resulted in a significantly higher rate of vocal cord paralysis compared to single-level operations—4.4% versus 1.7%, respectively ($p < 0.05$).[5] Of note, this relationship was only significant when comparing 1- to 2-level operations. On the contrary, In 't Veld et al. did not find any significant differences regarding the relationship between number of levels operated on or corpectomy operation and dysphagia presence at 2 months.[14] Similarly, Jung and Schramm found no relationship between single-level or multilevel fusion and recurrent laryngeal nerve paralysis.[19] Although matching of these characteristics may make studies more meaningful, we chose not to focus on these factors because many of them, such as patient sex or cervical level operated on, cannot be adjusted in a meta-analysis. Despite the aforementioned limitations, whose impact remains unclear, the present analysis detected significant findings and represents the most comprehensive synthesis of literature on this topic to date. Future meta-analyses and randomized studies should seek to corroborate these findings.

Conclusions

Deflation and reinflation of the ETT cuff after retraction to maintain a just-seal pressure is practiced as a protective measure during anterior cervical spine surgery and reduces the likelihood of postoperative laryngeal dysfunction. In the present meta-analysis, we combined the results from 9 studies comparing the incidence and severity of laryngeal dysfunction in intervention (reduced ETTCP) and control (unadjusted ETTCP) groups. All findings trended toward favoring reduction of ETTCP after retraction to reduce the odds or severity of signs and symptoms. Variation in sample size and follow-up time points limited the number of studies that could be used for comparisons. Based on the current best available evidence, reduction of ETTCP after retractor placement in anterior cervical surgery is a protective measure that will decrease the severity of dysphagia and the odds of developing RLNP or dysphonia.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

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