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REVIEW ARTICLE

Minimally invasive treatment of laryngoceles: a systematic review and pooled analysis

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Abstract

Laryngoceles are best treated with surgery. The goal of this study is to compare patient outcomes and complications in patients undergoing removal of laryngoceles with either transoral endoscopic/microlaryngoscopic or robotic approaches. A systematic review of the published literature was conducted using Pubmed, Web of Science, and the Cochrane Clinical Trials databases. A pooled analysis of individual data was used to compare outcomes between robotic and endoscopic approaches. A total of 30 studies were included. Nine studies with 95 patients were included in the final analysis. Eighty-one (85.26%) were treated with microlaryngoscopic surgery and 14 (14.74%) were treated with robotic-assisted surgery. The rates of tracheostomy (RR = 1.44, 95% CI = 0.389–5.332), complications (RR = 0.329, 95% CI = 0.047–2.294) and recurrence (RR = 0.354, 95% CI = 0.021–5.897) were not statistically different between groups. Within the endoscopic subgroup, 66 laryngoceles (78.57%) were completely excised, while 18 (21.43%) laryngoceles were treated with marsupialization. Marsupialization was associated with an increased risk of recurrence (RR = 4.889, 95% CI = 1.202–19.891). In the robotic subgroup, there was an increased risk of nasogastric tube use (RR = 103.867, 95% CI = 6.379–1619.214) and a longer mean length of hospital stay ($p = 0.0001$). Transoral treatment of laryngoceles has complication and recurrence rates of 18.95% and 7.37%, respectively. Robotic approaches are associated with higher rates of NGT use and increased hospital stay, however much of this is due to one robotic surgeon's preference for routine NGT placement and higher rates of combined laryngocele removal via robotic approach. Complete excision of combined laryngoceles is possible with transoral approaches. Marsupialization, reported in traditional endoscopic approaches, is associated with a significantly higher rate of recurrence (22.22% vs. 4.76%).

Keywords Laryngocele · Systemic review · Minimally-invasive · Endoscopic · Robotic

Introduction

Laryngoceles are rare and account for 1–3% of laryngeal lesions with a reported incidence of one per 2.5 million person-years [1]. Risk factors for laryngocele include activities that increase intralaryngeal pressure and is classically seen in glass blowers and brass musicians. Pathophysiologically, prolonged or chronic increases in intralaryngeal pressure results in saccular dilation and eventual laryngocele formation. Previous laryngeal surgery and malignancy may also lead to laryngocele development via anatomical obstruction of the ventricle. Historically, up to 29% of laryngoceles are associated with malignancy and thus require endoscopy and biopsy to rule out cancer as the cause [2].

Surgery is the treatment of choice for laryngocele, but symptomatic laryngoceles are rare. Thus, there is little consensus on the best surgical approach [3, 4]. Classically, external approaches were the preferred method for laryngocele excision due to low recurrence rates and relatively low morbidity of cervical approaches and lateral thyrotomy [3]. Since the 1990s and the development of endoscopic surgery, the management of laryngoceles has evolved. Improved phonomicrosurgical instruments and the wide availability of CO_2 lasers have led to increased experience with endoscopic approaches and outcomes showing similar recurrence rates [5]. Today, endoscopic approaches are often used for the treatment of internal laryngoceles where line of

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site instrumentation allows for complete excision, [6] while combined laryngoceles are mostly managed with external approaches [5].

The FDA approved transoral robotic surgery (TORS) for the treatment of benign and malignant head and neck tumors in 2009. Since then, there have been numerous reports of transoral robotic-assisted excision of laryngoceles [7–12]. While initial reports included internal laryngoceles, the improved surgical facility in TORS has allowed for complete transoral excision of both internal and combined laryngoceles. The goal of this study is to compare patient outcomes and complications in patients undergoing minimally invasive removal of laryngoceles with endoscopic/microlaryngoscopic and robotic approaches.

Methods

A systematic review of the published literature was conducted in accordance with the Joanna Briggs Institute methodology for systematic reviews of effectiveness. Given that all data in this study was extracted from the published literature, institutional review board approval, and informed consent were not required. The review protocol was written and registered using PROSPERO (CRD42020152501) prior to data extraction. Reporting of results will adhere to the Primary Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA-P) guidelines [13].

Search strategy and study inclusion

PubMed, Web of Science, and the Cochrane Clinical Trials databases were searched from January 1, 2000, to April 30, 2020, for English language articles using the MeSH terms "trans-oral robotic surgery," "robotic surgery," "TORS," "endoscopic surgery," "laryngoscopy," "minimally-invasive surgery," and "laryngocele" ("Appendix 1"). Studies eligible for inclusion were case reports or case series of patients with laryngoceles that underwent minimally invasive surgical treatment. The study period from 2000 to present was chosen because it includes a 10-year period during which endoscopic approaches were widely used, as well as a 10-year period after FDA-approval of TORS for removal of benign head and neck tumors. Studies were excluded if they were unavailable in English, anatomic studies, diagnostic studies, or technical reports that did not include treatment and outcomes ("Appendix 2"). The study selection process is outlined in Fig. 1.

Quality assessment

Eligible studies were critically appraised by two independent reviewers (E.H. and M.T.) using standardized critical appraisal instruments from the Joanna Briggs Institute for Critical Appraisal Checklist for Case Series and Case Reports [14]. These tools provide checklists that examine standard reporting criteria for case series and case reports. Higher-quality studies can be awarded up to eight or ten points in these tools. Disagreements on individual study quality were resolved through reassessment, conference call discussion, and the development of a consensus. All studies, regardless of quality, were used for data extraction and synthesis (where possible). The level of evidence presented in each study was determined with guidelines established by the Center for Evidence-Based Medicine [15].

Data extraction and synthesis

Data extraction was performed by two authors (E.H. and P.P.). Data was input into Excel 365 (Microsoft Corp., Redmond, WA) and included the following: study design, level of evidence, patient age, type of laryngocele, size of laryngocele (largest reported dimension in centimeters), tracheostomy tube use, nasogastric tube (NGT) use, time to oral feeding, length of hospital stay (LOHS), number and type of postoperative complications, number of recurrences, and length of follow-up. Primary outcomes were overall complications and recurrence. Secondary outcomes were tracheostomy use, NGT use, time to oral feeding, LOHS and length of follow-up. Outcome variables were both dichotomous and continuous. Disagreements about data were resolved after review by author M.T. The final dataset was used for analysis.

Statistical meta-analysis of incidence rates performed using the JBI SUMARI online tool and reported as Freeman-Tukey Proportions (FTP) and weighted using the inverse variance method [16]. Heterogeneity was calculated using the chi-squared and I^2 tests. A random-effects model was used supposing variation secondary to patient, setting, and technical variation between studies. Forest plots and funnel plots (to assess publication bias) were constructed through JBI SUMARI [17]. Meta-analysis comparing outcomes by the intervention was not possible, because no study directly compared endoscopic to robotic approaches. For that reason, the individual patient data extracted from all case series. Pooled analysis of the individual patient data from the case series was then performed. The pooled post-intervention rates (dichotomous data), of complications, recurrence, tracheostomy tube use, and nasogastric tube use were to calculate effect sizes and were reported as risk ratios along with 95% confidence intervals. Final post-intervention mean differences (continuous data) were calculated and compared using Student's t test.

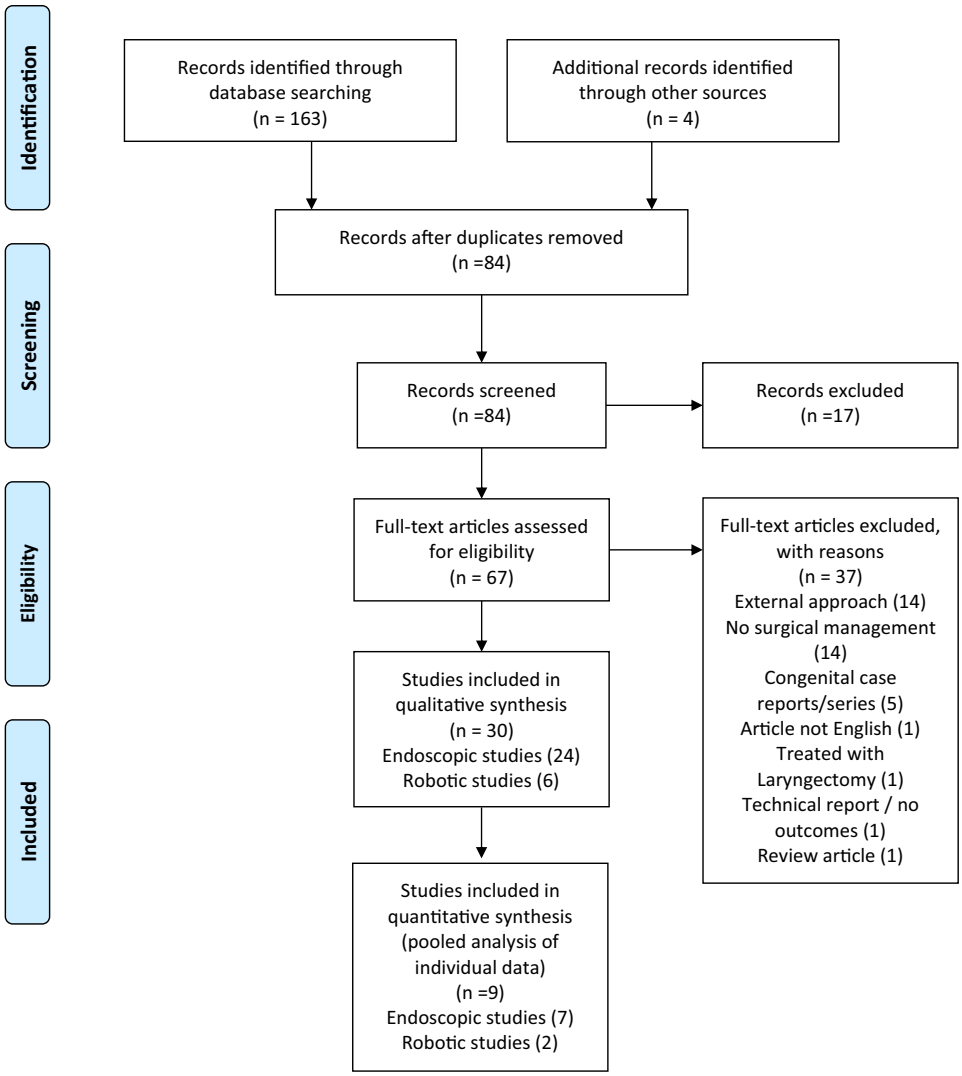

Fig. 1 Preferred Reporting Items for Systematic Reviews literature search flowchart

Results

Eighty-four studies were identified after duplicates were excluded. Four studies were identified through additional sources. Abstract screening led to the exclusion of 17 studies, and full text review led to exclusion of 37 studies, the reasons for which are detailed in the selection process. A total of 30 studies were included in the qualitative analysis. Twenty-four studies described outcomes and complications in endoscopic/microlaryngoscopic approaches [18–41]. Six studies described outcomes and complications using robotic-assisted approaches [7–12]. A total of nine case series were used in quantitative analysis. [10] The selection process is detailed in Fig. 1. Table 1 presents the summary of findings for the 30 studies selected for inclusion in the systematic review. The case–control study received nine out of ten points ("Appendix 3"). The quality was fairly homogenous with seven of the eight case series included receiving eight of ten points. For the case reports included, 18 of 21 studies received seven out of eight points. For detailed information quality (risk of bias) assessment of individual studies included in the review see "Appendix 3". Among the included studies all but one, a case–control study by Cohen et al. were Level 4 evidence. [33].

A total of 95 patients with 100 laryngoceles were included in the final analysis, of which 81 patients (85.26%) were treated with microlaryngoscopic techniques and 14 patients (14.74%) were treated with robotic-assisted techniques. The average patient age was 53.68 years. A total of eight patients had bilateral laryngoceles, one (7.14%) in the robotic subgroup and seven (8.64%) in the endoscopic subgroup. There were significantly more combined laryngoceles in the robotic subgroup (46.67%) vs. endoscopic subgroup (3.57%), (RR 13.0967, 95% CI = 3.797–44.970). There were no significant differences in average laryngocele size between subgroups, $t(21) = -0.361$, $p = 0.722$, despite the robotic subgroup ($M = 3.51$ cm, SD = 1.68) having slightly larger laryngoceles than those in the endoscopic subgroup

Table 1 Summary of demographics, level of evidence, and findings for the studies included in the systematic review

Author	Country of study	Level of evidence	*N*	Age mean/ range	Presenting symptoms	Laterality	Type	Laryngopyocele	Size (cm, range)
Robotic									
Ciabatti et al	Italy	4	1	69	Hoarseness, dysphonia, foreign body sensation	Unilateral	Combined	0	3.00
Gal et al	United States	4	1	37	Dysphonia, odynophagia, fever	Unilateral	Combined	1	6.30
Kayhan et al	Turkey	4	6	52.7/ 41–62	Hoarseness, dyspnea, globus	Unilateral	Combined (4), internal (2)	1	3.9 × 2.7
Lisan et al	France	4	1	61	Chronic cough	Unilateral	Combined	0	N/A
Patel et al	United States	4	1	43	Dysphonia	Unilateral	Internal	0	N/A
Villeneuve et al	France	4	8	61.5/ 48–84	Dysphonia, dyspnea	Unilateral (7), bilateral (1)	Combined (3), internal (6)	0	1.50–6.00
Endoscopic									
Aksoy et al	Turkey	4	1	43	Dyspnea, cough, excessive phlegm, late-onset stridor	Bilateral	internal	0	N/A
Al-yahya et al	Malaysia	4	1	59	Hoarseness, neck pain, odynophagia	Unilateral	combined	1	N/A
Andreou et al	United Kingdom	4	1	63	Stridor and dyspnea	Unilateral	internal	1	N/A
Cohen et al	Israel	3	24	60.5	Dysphonia, less commonly: dyspnea, globus, asymptomatic	Unilateral	internal	5	N/A
Devesa et al	United Kingdom	4	12	54.5/24–79	Neck mass, dysphonia, airway obstruction	Unilateral (8), bilateral (4)	Internal (10), combined (2)	0	N/A
Dursun et al	Turkey	4	7	45.4/32–80	Dysphonia, dyspnea, dysphagia, odynophagia	Unilateral	Internal	0	N/A
Fraser et al	United Kingdom	4	1	66	Dyspnea, dysphagia, stridor	Unilateral	internal	1	N/A
Fredrickson et al	United States	4	1	34	Dyspnea and stridor	Unilateral	internal	1	1.80
Harney et al	Ireland	4	1	80	Dysphagia and hoarseness	Unilateral	internal	0	N/A
Hirvonen et al	Finland	4	1	80	Dysphagia, hoarseness	Unilateral	internal	0	3.00–4.00
Kusunoki et al	Japan	4	1	64	No symptoms	Unilateral	internal	0	N/A
Lebecque et al	Belgium	4	1	31	Dysphonia	Unilateral	combined	1	N/A
Marom et al	Israel	4	2	71/67–75	Neck mass and hoarseness	Unilateral	internal	0	N/A

Table 1 (continued)

Author	Country of study	Level of evidence	*N*	Age mean/ range	Presenting symptoms	Laterality	Type	Laryngopyocele	Size (cm, range)
Mobashir et al	Egypt	4	7	53.5	Hoarseness, neck swelling	Unilateral	internal	0	N/A
Ozgursoy et al	Turkey	4	1	68	Sudden dyspnea and severe stridor	Unilateral	internal	0	1.50
Papila et al	Turkey	4	1	26	Progressive hoarseness, obstructive airway	Unilateral	Internal	1	1.70 × 1.60x1.20
Sahin et al	Turkey	4	1	51	Sudden dyspnea after uri	Unilateral	internal	0	1.70 × 2.35
Shandilya et al	Ireland	4	9	61.6/22–88	Respiratory embarrassment	Unilateral	internal	0	N/A
Spinosi et al	Italy	4	1	91	Dyspnea	Unilateral	internal	0	1.50
Szymanowski et al	United States	4	1	54	Neck mass	Unilateral	combined	0	6.00
Thabet et al	Egypt	4	17	41/24–57	Dysphonia, dyspnea, cough, neck swelling	Unilateral	internal	0	1.50 × 2.00x2.00 – 3.00 × 3.00x4.00
Upile et al	United Kingdom	4	1	77	Altered voice	Unilateral	internal	0	N/A
Vedasalam et al	United Kingdom	4	1	74	Otalgia, vertigo, bloody otorrhea	Unilateral	internal	0	N/A
Young et al	United States	4	13	52.19	Dysphonia	Unilateral	internal	0	N/A

($M = 3.28$ cm, SD = 1.09). Of those patients presenting in the outpatient setting, the most common presenting symptom was dysphonia (54.85%). Of those patients presenting emergently for treatment, the most common presenting symptoms was dyspnea and/or odynophagia. Of those patients undergoing robotic approaches, the most common presenting symptom was dysphagia (41.67%). Table 1 shows study demographics including the most common presenting symptoms in outpatient and emergency settings.

The overall rate of tracheostomy tube placement across studies was 9.47% (FTP = 0.277, 95% CI = 0.100–0.490) (Fig. 2a). Tracheostomy tubes were placed preoperatively in emergency settings to secure the airway in 94.44% of cases. Only two tracheostomy tubes were placed electively due to concern for difficult intubation: one in a patient who had another recurrence following six previously unsuccessful operations (an open approach and five marsupializations) and another in a patient with a history of prior laryngeal cancer treated with surgery and radiation [10]. The rates of tracheostomy in robotic vs. endoscopic approaches was similar between groups (RR = 1.44, 95% CI = 0.389–5.332). There was no difference in the average time to decannulation between subgroups, $t(7) = 1.104$, $p = 0.306$, despite the robotic subgroup having a shorter time to decannulation ($M = 6.33$ days, SD = 2.08) than those in the endoscopic subgroup ($M = 24.75$ days, SD = 27.90). In the endoscopic group, the meantime to decannulation was skewed by three elderly patients who remained hospitalized for other severe chronic illness that prolonged their time to decannulation [22, 41].

No patients undergoing microlaryngoscopic procedures required NGT placement and oral feeding was started either immediately postoperatively or the following day. In the robotic subgroup, 71.43% of patients had temporary NGTs (FTP = 0.731, 95% CI = 0.024–1.000) (Fig. 3). The overall heterogeneity across studies was 88.3%, and there was no evidence of publication bias as demonstrated in Figs. 3a, b. In our pooled analysis, robotic excision of laryngocele was associated with a significantly greater risk of NGT placement (RR = 103.867, 95% CI = 6.379–1619.214). Among the 14 patients undergoing robotic-assisted surgery, 10 had routine NGT placement. Kayhan et al. performed NGT placement

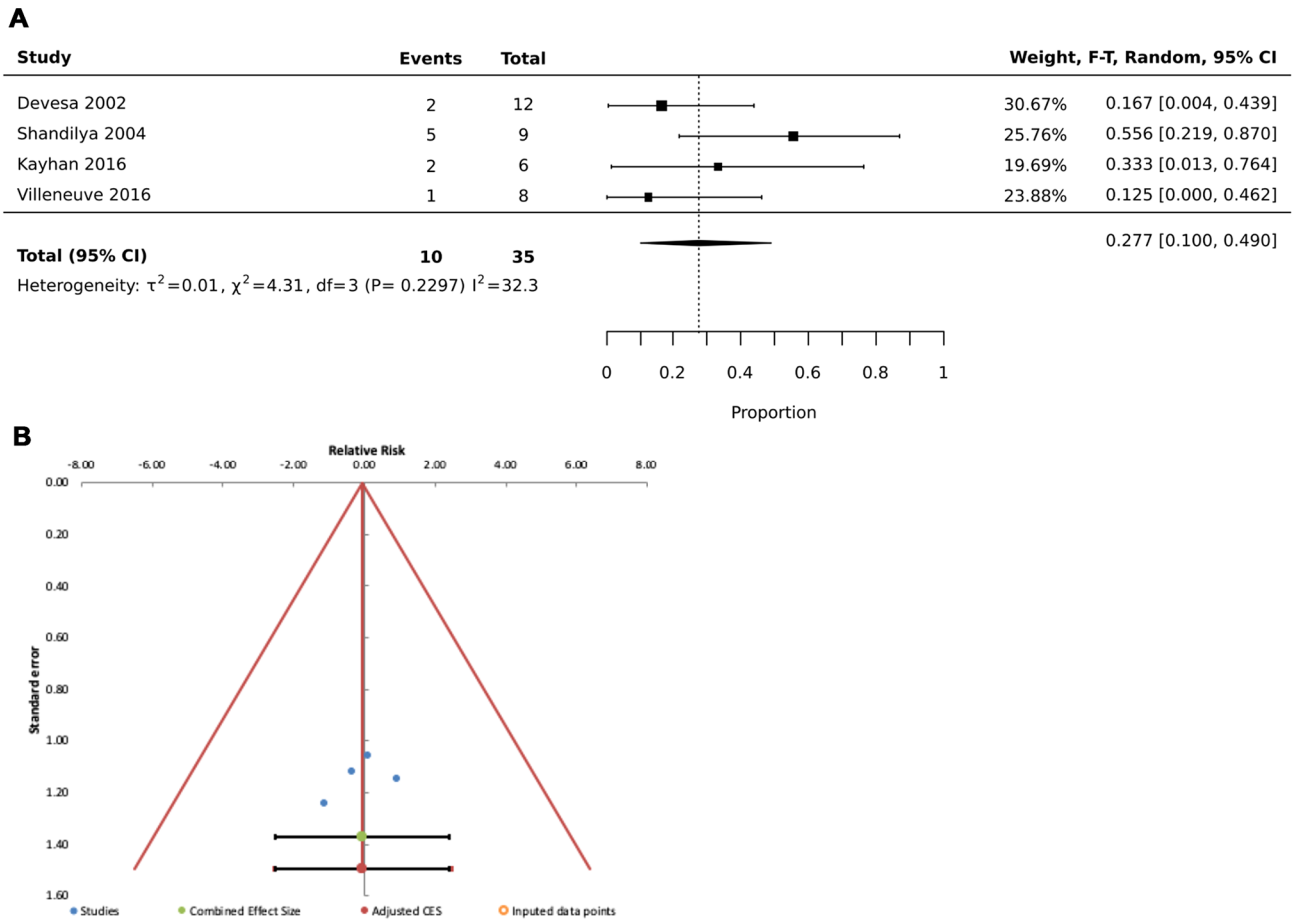

Fig. 2 **a** Forest plot of overall rate of tracheostomy tube placement. **b** Funnel plot of heterogeneity of included studies. ($Q = 8.35$, $I^2 = 36.20\%$)

routinely in all patients due to the preference of the senior surgeon [8]. Villeneuve et al.routinely used NGTs for 5 days in patients with combined laryngoceles [10]. NGT placement was therefore associated with a significantly increased time to oral feeding $t(16) = 4.377$, $p = 0.0005$ in patients with NGT placement ($M = 3.5$ days, SD = 1.58) compared to those without NGT placement ($M = 1.00$ days, SD = 0.32). All 95 patients were discharged after the initiation of oral intake. Given variation in practices around NGT use and the initiation of feeding, the mean LOHS was significantly longer $t(51) = 6.538$, $p = 0.0001$ in patients undergoing robotic approaches ($M = 5.267$ days, SD = 2.940) compared to endoscopic approaches ($M = 1.786$ days, SD = 0.982).

The overall complication rate for patients undergoing minimally invasive management of laryngoceles was 18.95% (FTP = 0.244, 95% CI = 0.099–0.421) (Fig. 4a). The overall heterogeneity across studies was 36.20%, and there was no evidence of publication bias as demonstrated in Fig. 4b. In the robotic subgroup, there was one reported complication (7.14%) in a patient that experienced postoperative hemorrhage and required emergent operative treatment [10]. In the endoscopic subgroup, there were 17 reported complications (20.99%). There were only two serious complications in the endoscopic group. One patient required emergency reoperation for recurrence that caused acute respiratory distress and was subsequently treated with an external approach [35]. Another required postoperative antibiotics for treatment of infection [3]. Sixteen patients in the endoscopic group had relatively minor complications described as symptomatic granulation tissue with prolonged dysphagia or hoarseness [33, 37]. In the pooled analysis comparing robotic vs. endoscopic approaches there was no significant difference in the relative risk of complications (RR = 0.329, 95% CI = 0.047–2.294).

The overall recurrence rate across the 9 studies including 95 patients was 7.37% (FTP = 0.117, 95% CI = 0.019–0.261) (Fig. 5a). The overall heterogeneity across studies was 44.3%, and there was no evidence of publication bias as demonstrated in Fig. 5b. All recurrences occurred in the endoscopic subgroup with a reported average follow-up of 20.88 months. Comparing robotic vs. endoscopic approaches the risk of recurrence was not statistically different between

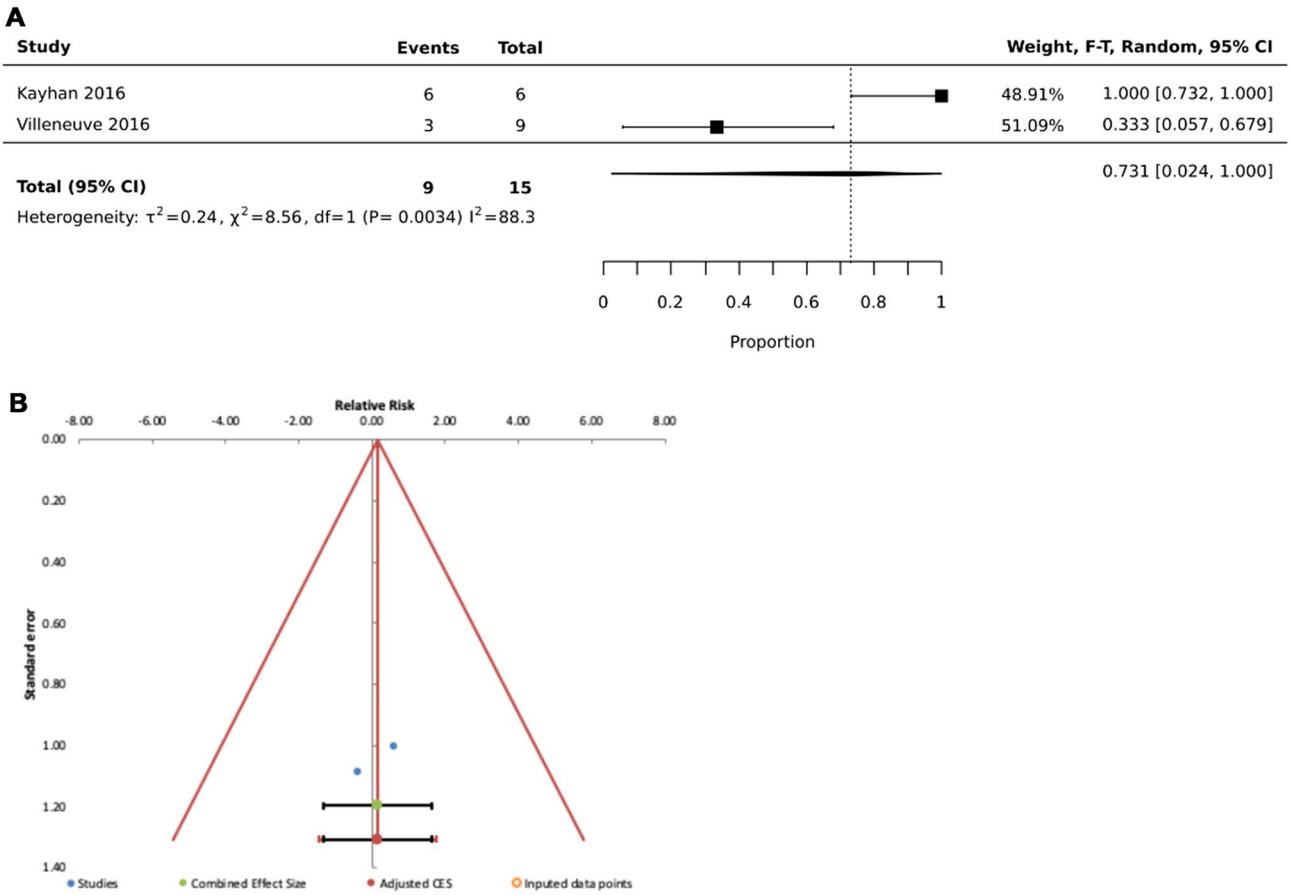

Fig. 3 **a** Forest plot of pooled risk of nasogastric tube placement. **b** Funnel plot of heterogeneity of included studies. ($Q = 8.35$, $I^2 = 36.20\%$)

approaches (RR = 0.354, 95% CI = 0.021–5.897). Similarly, the mean length of follow-up was not significantly different $t(51) = 6.538$, $p = 0.0001$ in patients undergoing robotic approaches ($M = 23.387$ months, SD = 1.625) compared to endoscopic approaches ($M = 20.88$ months, SD = 8.35). Within the endoscopic subgroup, 66 laryngoceles (78.57%) were completely excised, while 18 (21.43%) laryngoceles were treated with endoscopic marsupialization. The risk of recurrence was significantly higher in laryngoceles treated by marsupialization vs. complete excision (RR = 4.889, 95% CI = 1.202–19.891).

Discussion

The goal of this review was to understand complications and outcomes for patients undergoing "minimally invasive" treatment of laryngoceles. Examining the available literature, 30 publications, including 115 patients were identified. For the purposes of quantitative analysis, there were nine case series including 81 patients underwent traditional endoscopic approaches and 14 patients underwent robotic-assisted approaches since 2000. The average age was similar for both groups, which is in line with most other studies identifying the 6th decade as the most common age for presentation [1]. The most common presenting symptom in the outpatient setting was dysphonia (54.85%). In the robotic subgroup, the most common presenting symptom was dysphagia (41.67%) and there were significantly more combined laryngoceles. One of the advantages of robotic-assisted laryngocele excision is the use of wristed instruments and 30-degree robotic endoscope to increase the working space and visibility in the area of the vestibule and paraglottic space. Only one endoscopic series reported the size of the laryngoceles given the increased difficulty of removing such lesions with a line of sight surgery [35].

Rates of tracheostomy tube placement were not significantly different between treatment groups. In fact, the use of tracheostomy was most often dictated by patient distress at presentation (77.78%). Only two patients underwent "elective" tracheostomy prior to laryngocele excision, both of which had prior surgery and/or radiation and presented with symptomatic recurrence. In the robotic subgroup, all three tracheostomies were performed in patients

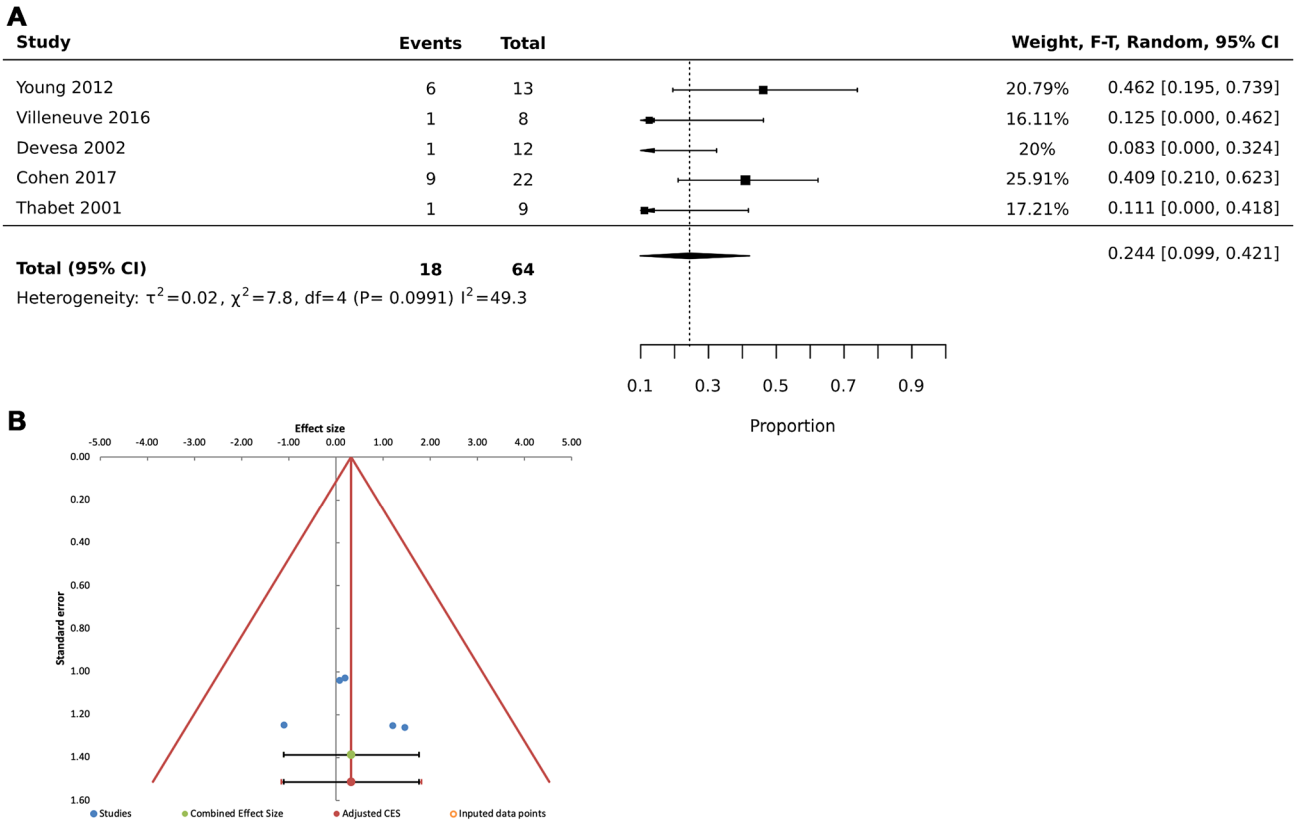

Fig. 4 **a** Forest plot of pooled risk of complications. **b** Funnel plot of heterogeneity of included studies. ($Q=8.35$, $I^2=36.20\%$)

with combined laryngoceles (3/10) presenting with airway obstruction. In endoscopic subgroup, 20% (1/5) of patients with combined laryngoceles also required tracheostomy as a treatment for airway obstruction prior to endoscopic excision of laryngocele. The time to decannulation was shorter in the robotic vs. endoscopic subgroups (6.33 vs. 22.60 days) but was not significant.

Perioperative NGT use was seen only in patients undergoing TORS, the majority of whom come from the series described by Kayhan et al. in which intraoperative NGT placement was used in all patients [8]. Villeneuve et al. placed NGT intraoperatively for patients with combined laryngoceles [10]. Given these practices, the meantime to oral feeding in the robotic subgroup was 3.5 days significantly longer than the endoscopic group. All NGTs were removed prior to discharge. The mean LOHS in patients undergoing robotic-assisted approaches was significantly longer compared to traditional endoscopic approaches (5.3 vs. 1.8), which was in part due to the increased frequency of combined laryngocele excision and routine NGT use. According to the results of this study, routine NGT use may not be necessary in transoral laryngocele excision; however, if routine NGT use is employed, longer LOHS may be expected.

The overall complication rate in this study was 18.95%. The rate of serious complications require a return to the operating room was 2.11%. Among patients undergoing TORS, there was one case of post-operative bleeding that required return to the OR for cauterization on postoperative day 11 [10]. In the endoscopic groups, one patient required emergent open laryngocele excision for recurrence with respiratory distress. The overall complication rate after traditional endoscopic surgery was higher (20.99%), but 16 patients had relatively minor complications described as symptomatic granulation tissue and prolonged dysphagia or hoarseness [33, 37]. These such complications were not reported in the TORS literature and explains the difference in overall complications rates, even if insignificant. This difference in reporting may be due to the fact that head and neck surgeons performing robotic approaches may be less likely to report dysphonia, mild dysphagia or nonobstructive granulation tissue as complications than laryngologists who study voice and swallowing outcomes in detail.

No recurrences were identified in the group undergoing TORS, which may only be due to the very small sample size. For endoscopic/microlaryngoscopic procedures the recurrence rate was 6.09%. Both the robotic and endoscopic subgroups had sufficient follow-up to suggest that these rates are

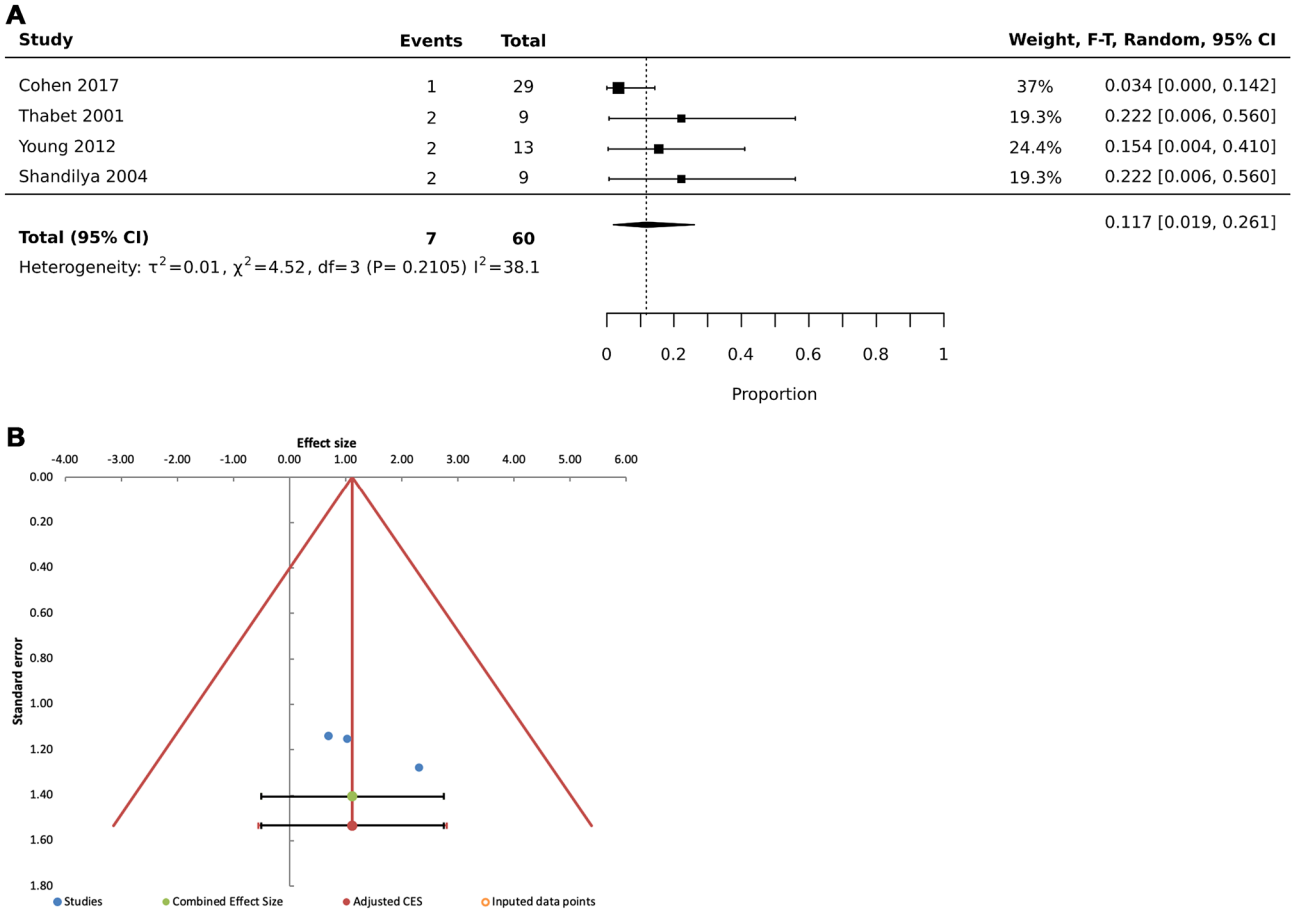

Fig. 5 **a** Forest plot of pooled risk of recurrence. **b** Funnel plot of heterogeneity of included studies. ($Q=8.44$, $I^2=44.30\%$)

accurate (23.39 vs. 20.88 months). It should be noted that 21.43% of patients in the endoscopic subgroup were treated with endoscopic marsupialization of laryngoceles, while no marsupialization procedures were performed using TORS. When comparing marsupialization procedures vs. complete excision, the recurrence rate was significantly higher (22.22% vs. 4.76%, $p=0.027$). Two TORS cases were noted to have intraoperative rupture of the laryngocele; but this was not associated with recurrence. Unintentional cyst rupture was generally not discussed in the endoscopic literature and was sometimes intentionally performed (marsupialization) or to decompress the cyst and allow easier removal given the limitations of the line of site surgery. These findings suggest that complete excision of the cyst wall should be performed when possible to prevent the recurrence of laryngoceles.

Potential advantages of robotic approaches include a binocular, three-dimensional, highly magnified view with both 0-degree and 30-degree endoscopes that are controlled by the operating surgeon. Additionally, robotic instruments allow more intuitive operative movement without inverse controls and the ability to reach around tissue curvatures. The extra reach, surgical facility and angled views increase the ability to work laterally in the paraglottic space and to dissect the internal branches of the superior laryngeal neurovascular bundle as it enters the larynx at the thyrohyoid membrane. Therefore, TORS offers the possibility of the simultaneous removal of the internal and external portions of combined laryngoceles, which is difficult and often requires multiple repositionings using traditional endoscopic approaches.

Potential advantages of endoscopic approaches include the lower cost and the wide availability of endoscopic instruments and CO_2 lasers compared to robotic systems. Furthermore, endoscopic approaches can be easily and quickly performed on short notice at the time of emergency intubation without increased operative time or need for specialized robotic staff [32]. As in the case reported by Gal et al. the patient underwent emergency endoscopic decompression and then underwent robotic excision electively at a later date, thus requiring two separate procedures [9]. Finally, endoscopic approaches are associated with overall shorter LOHS.

Limitations of the study are numerous and include overall small sample size, publication bias, and selection bias in the choice of approach. To address the issue of small sample size and publication bias, we performed a pooled analysis of all the available individual data from the case series available in the literature. Since symptomatic laryngoceles are very rare, there is a limited experience by any one institution to guide decision-making with regard to treatment; high-volume institutions may only see a small number of cases over a 10-year period [37]. We specifically examined publication bias with respect to outcomes using methods by Sterne et al. and did not find evidence of publication bias [42]. Thus, publication bias remains a factor when attempting to examine true outcomes, because authors are less likely to publish case reports or series with adverse outcomes. Finally, looking at the pooled data, it is obvious that there is inherent selection bias in the use of endoscopic approaches to treat internal laryngoceles (96.43% of reported cases), which explains the lack of need for NGT use and shorter hospital stays. In contrast, there appears to be little to no selection bias in the robotic cohort as half of the patients combined laryngoceles and some were as large as 6.3 cm.

In spite of its limitations, this study represents the best available data on outcomes of transoral treatment of laryngoceles. Symptomatic laryngoceles requiring surgical treatment are rare with only 115 cases (including case reports) treated by transoral surgery reported in the literature since 2000. Improved reporting as well as larger sample sizes will be necessary to better understand complications and recurrence rates no matter the surgical approach used.

Conclusions

Transoral treatment of laryngoceles has complication and recurrence rates of 18.95% and 7.37%, respectively. Robotic approaches are associated with high rates of NGT use and LOHS in the literature; but this is largely due to surgeon preference for routine NGT placement following removal of combined laryngoceles. Complete excision of combined laryngoceles is possible with transoral approaches. Marsupialization, reported in traditional endoscopic approaches, is associated with a significantly higher rate of recurrence (22.22% vs. 4.76%).

Appendix 1 Search Strategy

Pubmed, Web of Science, and Cochrane Databases for studies in English published from 2000-present in English

Pubmed

"transoral robotic surgery" AND "laryngocele" = 7
"robotic surgery" and "laryngocele" = 8
"TORS" AND "laryngocele" = 4
"endoscopic" AND "laryngocele" = 28
"laryngoscopy" AND "laryngocele" = 50
"microlaryngoscopy" AND "laryngocele" = 2
"minimally invasive surgery" and "laryngocele" = 1
100 References, X with removal of duplicates

Web of Science

"transoral robotic surgery" AND "laryngocele" = 6
"robotic surgery" and "laryngocele" = 7
"TORS" AND "laryngocele" = 4
"endoscopic" AND "laryngocele" = 41
"laryngoscopy" AND "laryngocele" = 50
"microlaryngoscopy" AND "laryngocele" = 3
"minimally invasive surgery" and "laryngocele" = 1
112 references, X with removal of duplicates

Searches conducted on 4/21/20

Cochrane Database:

"transoral robotic surgery" AND "laryngocele" = 0
"robotic surgery" and "laryngocele" = 0
"TORS" AND "laryngocele" = 0
"endoscopic" AND "laryngocele" = 0
"laryngoscopy" AND "laryngocele" = 0
"microlaryngoscopy" AND "laryngocele" = 0
"minimally invasive surgery" and "laryngocele" = 0
0 references

Searches conducted on 4/21/20 and repeated on 9/18/20.

Appendix 2 Excluded studies

Aidonis I, Lazaridis N, Piagkou M, Anastasopoulos N, Natsis K. A Large Laryngeal Mucocele Causing Progressive upper Airway Obstruction and Cervical Swelling. Acta Medica (Hradec Kralove). 2017;60(4):157–9.

Reason for exclusion: external approach

Akbas Y, Unal M, Pata YS. Asymptomatic bilateral mixed-type laryngocele and laryngeal carcinoma. Eur Arch Otorhinolaryngol. 2004;261(6):307–9.

Reason for exclusion: external approach

Akdogan O, Ibrahim O, Selcuk A, Dere H. The association of laryngoceles with squamous cell carcinoma of the larynx presenting as a deep neck infection. B-ENT. 2007;3(4):209–11.

Reason for exclusion: Open approach no access

Araz O, Turan A, Yoruk O, Alper F, Akgun M. Laryngocele and epiglottic cyst as rare causes of obstructive sleep apnea. Sleep Breath. 2009;13(3):285–7.

Reason for exclusion: No surgical management—just a description of laryngocele as cause of sleep apnea.

Butskiy O, Anderson DW. Upper airway obstruction due to a change in altitude: first report in fifty years. J Otolaryngol Head Neck Surg. 2016;45:9.

Reason for exclusion: external approach

Cassano L, Lombardo P, Marchese-Ragona R, Pastore A. Laryngopyocele: three new clinical cases and review of the literature. Eur Arch Otorhinolaryngol. 2000;257(9):507–11.

Reason for exclusion: external approaches

Chang CY, Furdyna JA. Bilateral pharyngoceles (branchial cleft anomalies?) and endoscopic surgical considerations. Annals of Otology Rhinology and Laryngology. 2005;114(7):529–32.

Reason for exclusion: Patient declined surgery, so no ability to assess intervention.

Ettema SL, Carothers DG, Hoffman HT. Laryngocele resection by combined external and endoscopic laser approach. Annals of Otology Rhinology and Laryngology. 2003;112(4):361–4.

Reason for exclusion: No management or surgery

Fox R, Ramdoo K, Tatla T. Endoscopic CO2 laser excision of a ruptured laryngocele: a novel "blue-dye" technique to assist dissection and avoid recurrent laryngeal nerve injury. Clin Otolaryngol. 2017;42(4):957–8.

Reason for exclusion: technical report, no case details or outcomes

Gallivan KH, Gallivan GJ. Bilateral mixed laryngoceles: simultaneous strobovideolaryngoscopy and external video examination. J Voice. 2002;16(2):258–66.

Reason for exclusion: On endoscopic video examinations and correlation with imaging. No surgical treatment evaluated.

Gomaa MA, Hammad MS, Mamdoh H, Osman N, Eissawy MG. Value of high resolution ultrasonography in assessment of laryngeal lesions. Otolaryngol Pol. 2013;67(5):252–6.

Reason for exclusion: No surgical management

Goud BU, Rao AVSH, Satyanarayana D, Gupta MK, Majeed J. LARYNGOCELE: A CASE REPORT. Journal of Evolution of Medical and Dental Sciences-Jemds. 2015;4(32):5586–91.

Reason for exclusion: open surgery

Kara I, Kokoglu K, Cagli S, Yuce I. Bilateral Laryngocele Causing Epiglottic Deformity and Upper Airway Obstruction. Turkish Archives of Otorhinolaryngology-Turk Otorinolarengoloji Arsivi. 2019;57(2):99–101.

Reason for exclusion: External approach

Keles E, Alpay HC, Orhan I, Yildirim H. Combined laryngocele: a cause of stridor and cervical swelling. Auris Nasus Larynx. 2010;37(1):117–20.

Reason for exclusion: external approach

Korampalli TS, Belloso A, Hans PS, Irion K, Sheppard IJ. Laryngeal squamous cell carcinoma presenting as a prelaryngeal, air-filled structure (pseudolaryngocoele). Journal of Laryngology and Otology. 2008;122(5):535–7.

Reason for exclusion: Prelaryngeal laryngocele and cancer—no a true laryngocele. Treated with laryngectomy.

Maweni RM, Shirazi S, Chatzoudis D, Das S. Laryngopyocoele with contralateral laryngocoele: a rare cause of respiratory distress. BMJ Case Rep. 2018;2018.

Reason for exclusion: external approach

McDonald SE, Pinder DK, Sen C, Birchall MA. Oncocytic cyst presenting as laryngocele with surgical emphysema. Eur Arch Otorhinolaryngol. 2006;263(3):237–40.

Reason for exclusion: biopsy, no definitive treatment

Nazaroglu H, Ozates M, Uyar A, Deger E, Simsek M. Laryngopyocele: signs on computed tomography. Eur J Radiol. 2000;33(1):63–5.

Reason for exclusion: Diagnostic study not interventional

Oukessou Y, Abada RL, Roubal M, Mahtar M. Laryngocele: an unusual presentation. Eur Ann Otorhinolaryngol Head Neck Dis. 2015;132(3):177–8.

Reason for exclusion: external approach

Oztdemir A, Dogruel D, Yucel A, Api A. A rare cause of stridor in infancy: congenital laryngocele. Cukurova Medical Journal. 2016;41(3):581–3.

Reason for exclusion: Not in English once searched. Abstract was in English.

Pennings RJ, van den Hoogen FJ, Marres HA. Giant laryngoceles: a cause of upper airway obstruction. Eur Arch Otorhinolaryngol. 2001;258(3):137–40.

Reason for exclusion: external approaches

Prasai A, Phillips J, Jani P. Spontaneous resolution of a traumatic laryngocele. J Otolaryngol. 2007;36(3):E5-8.

Reason for exclusion: no surgical intervention, spontaneous resolution

Raine JI, Allin D, Golding-Wood D. Laryngopyocoele presenting with acute airway obstruction. BMJ Case Rep. 2014;2014.

Reason for exclusion: No discussion of management or outcomes, seems external

Reddy MVV, Ramakrishna C, Gupta M, Babu AS, Shankar T, Singh R, et al. Laryngocele—A Case Report and Review of Literature. Indian Journal of Otolaryngology and Head & Neck Surgery. 2008;60(3):281–3.

Reason for exclusion: open surgery

Singh CA, Sakthivel P. Laryngocele. N Engl J Med. 2018;379(23):e40.

Reason for exclusion: No distinction of surgery.

Suqati AA, Alherabi AZ, Marglani OA, Alaidarous TO. Bilateral combined laryngocele. Saudi Med J. 2016;37(8):902–3.

Reason for exclusion: external

Toro K, Kardos M, Dunay G. Fatal asphyxia due to laryngomucocele. Forensic Sci Int. 2009;190(1–3):e1–4.

Reason for exclusion: No treatment, report of death due to laryngocele

Vasileiadis I, Kapetanakis S, Petousis A, Stavrianaki A, Fiska A, Karakostas E. Internal laryngopyocele as a cause of acute airway obstruction: an extremely rare case

and review of the literature. Acta Otorhinolaryngol Ital. 2012;32(1):58–62.

Reason for exclusion: no discussion of surgical management only presentation and workup

Vasileiadis I, Kapetanakis S, Petousis A, Stavrianaki A, Fiska A, Karakostas E. Internal laryngopyocele as a cause of acute airway obstruction: an extremely rare case and review of the literature. Acta Otorhinolaryngologica Italica. 2012;32(1):58–62.

Reason for exclusion: no surgical management, was drained at diagnosis and patient left the country AMA

Vengerovich G, McCoul ED, Burstein DH, Yao FB, Lim JW. Excision of laryngocele via transcervical midline approach. Laryngoscope. 2010;120 Suppl 4:S189.

Reason for exclusion: external approach

Verret DJ, DeFatta RJ, Sinard R. Combined laryngocele. Ann Otol Rhinol Laryngol. 2004;113(7):594–6.

Reason for exclusion: imaging study does include surgical treatment

Zelenik K, Stanikova L, Smatanova K, Cerny M, Kominek P. Treatment of Laryngoceles: what is the progress over the last two decades? Biomed Res Int. 2014;2014:819,453.

Reason for exclusion: Review only

Appendix 3 Quality assessment of individual studies based on the Joanna Briggs Institute Critical Appraisal tools for use in JBI Systematic Reviews [14]

See Tables 2, 3 and 4.

Table 2 Case control study

Citation	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Cohen et al. 2017 [33]	Y	Y	Y	N	Y	Y	Y	Y	Y	Y
%	100.0	100.0	100.0	0.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 3 Case reports

Citation	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Aksoy et al. 2013 [21]	Y	Y	Y	Y	Y	Y	Y	Y
Al-Yahya et al. 2016 [32]	Y	Y	Y	Y	Y	Y	U	Y
Andreou et al. 2011 [22]	Y	Y	Y	Y	Y	Y	Y	Y
Ciabatti et al. 2013 [7]	Y	Y	Y	Y	Y	N	Y	Y
Gal et al. 2017 [9]	Y	Y	Y	Y	Y	Y	Y	Y
Lisan et al. 2016 [11]	Y	Y	Y	Y	Y	Y	Y	Y
Marom et al. 2011 [27]	Y	Y	Y	Y	Y	Y	Y	Y
Papila et al. 2005 [18]	Y	Y	Y	Y	Y	Y	Y	Y
Patel et al. 2019 [12]	Y	Y	N	Y	Y	N	Y	Y
Szymanowski et al. 2019	Y	Y	Y	Y	Y	Y	Y	Y
Upile et al. 2006 [28]	Y	Y	Y	Y	Y	Y	Y	Y
Hirvonen et al. 2001 [26]	Y	Y	Y	Y	Y	Y	Y	Y
Kusunoki et al. 2016 [38]	Y	Y	Y	Y	Y	N	N	Y
Lebecque et al. 2012 [36]	Y	Y	Y	Y	N	N	N	Y
Ozgursoy et al. 2009 [39]	Y	Y	Y	Y	Y	Y	Y	Y
Sahin et al. 2019 [40]	Y	Y	Y	Y	Y	Y	Y	Y
Fraser et al. 2011 [23]	Y	Y	Y	Y	Y	Y	Y	Y
Fredrickson et al. 2007 [24]	Y	Y	Y	Y	Y	Y	Y	Y
Harney et al. 2001 [25]	Y	Y	Y	Y	Y	Y	Y	Y
Spinosi et al. 2018 [31]	Y	Y	Y	Y	Y	Y	Y	Y
Vedasalam et al. 2010 [29]	Y	Y	Y	Y	Y	Y	Y	Y
%	100.0	100.0	95.24	100.0	95.24	80.95	85.71	100.0

Table 4 Case series

Citation	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	0
Dursun et al. 2007 [19]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Kayhan et al. 2016 [8]	Y	Y	Y	Y	Y	Y	Y	Y	Y	N/A	
Mobashir et al. 2017 [34]	Y	Y	Y	Y	U	Y	Y	Y	Y	N/A	
Villeneuve et al. 2016 [10]	Y	Y	Y	Y	Y	Y	Y	Y	Y	N/A	
Devesa et al. 2002 [3]	Y	Y	Y	Y	Y	Y	Y	Y	Y	N/A	
Shandilya et al. 2004 [41]	Y	Y	Y	Y	N	Y	Y	Y	Y	N/A	
Thabet et al. 2001 [35]	N	Y	N	N	Y	Y	Y	Y	Y	N/A	
Young and Smith 2012 [37]	Y	Y	Y	Y	Y	Y	Y	Y	Y	N/A	
%	87.5	100.0	87.5	87.5	85.71	100.0	100.0	100.0	100.0	12.5	

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Declarations

Conflict of interest None of the authors have conflicts to disclose.

Ethical approval All data included in this study were obtained from previously published studies.

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