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Voice-Related Quality of Life (V-RQOL) Is Associated with Postoperative Change in Subglottic Stenosis

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Short Title: V-RQOL in Subglottic Stenosis

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ABSTRACT

Objectives. To characterize the impact of subglottic stenosis (SGS) on voice-related quality of life (V-RQOL) and quantify the effect of treatment on voice outcomes.

Methods. Retrospective review of SGS patients treated from 1996 to 2018 at a single institution to assess for (1) V-RQOL association with individual patient cumulative treatment number and (2) V-RQOL correlation with treatment type, time between treatments, and degree of stenosis. Analysis included both parametric and nonparametric statistical comparison across treatment types and multivariable and univariate linear regression.

Results: Sixty-one patients, predominantly white (93%) and female (93%), were included. Etiology of SGS included idiopathic (61%), iatrogenic (16%), granulomatosis with polyangiitis (16%), and other (7%). The plurality of patients had four or more treatments (44%), with the remainder having one (28%), two (13%) or three treatments (15%). Analysis of change between pre- and post-operative V-RQOL scores was completed for 130 treatments. These included dilation with laser incision (52%), in-office injection (34%), dilation without division (8%), cricotracheal resection (1%), and all other treatment (8%). For every 10% improvement in airway caliber postoperatively, there was a 1.3-point improvement in calculated V-RQOL ($r=0.27$, $p=0.02$). After adjustment for treatment type, age, sex, and SGS etiology, this association held ($beta=1.5$, $p=0.02$). Change in V-RQOL was not associated with treatment type, treatment number, or time between treatments.

Conclusions: Patients with subglottic stenosis who have greater degree of change in airway caliber experience greater improvement in V-RQOL scores following treatment. V-RQOL scores are not associated with treatment type or time between individual treatments

Keywords: laryngology, quality of life, voice disorders, airway stenosis/reconstruction
Level of Evidence: Level 4

INTRODUCTION

Subglottic stenosis (SGS) is a rare condition characterized by a fixed narrowing of the extrathoracic airway at the junction of the cricoid ring and cervical trachea, with associated negative effects on respiration, voice, and quality of life.[1] SGS is treated by a wide variety of procedures—encompassing in-office, endoscopic, and open reconstructive procedures.[2–6] While open reconstruction such as cricotracheal resection is considered a more definitive treatment, it also carries the greatest risk of morbidity. As such, many patients opt to engage in more conservative treatments such as in-office steroid injections or endoscopic dilation procedures. While these treatments have been shown to be effective in alleviating symptoms of SGS, it is a chronic condition for many patients, with recurrences typically requiring repeated treatments over time.[7,8] These serial procedures have a significant positive impact upon clinical measures , such as pulmonary function tests, and have demonstrated cost effectiveness for the healthcare system as a whole.[6,8]

There has been some research to date on the impact of SGS treatments on quality of life.[9,10] Most patients had improvement in their score on the Voice-Related Quality of Life (V-RQOL) Measure after a single dilation.[9] However, there is no available information on how V-RQOL might change over the course of this chronic disease, and how this is impacted by the serial nature of treatments required to manage it.

In this study, we sought to better understand how both patient-reported outcomes and degree of stenosis change with serial procedures for SGS. In order to characterize patient

perceptions of voice, we measured how the patient's V-RQOL score changed over the course of their treatment period. To further evaluate the factors associated with voice outcomes, we investigated whether change in V-RQOL score was impacted by the degree of change in the stenosis associated with a procedure.

MATERIALS AND METHODS

Patient Population

This study was approved by the Institutional Review Board of the University of Michigan (HUM00150934). All patients treated at the University of Michigan from 1996 to 2018 with subglottic stenosis were reviewed. Patients records were retrieved from the electronic medical record through a combination of International Classification of Diseases, 9th edition (ICD-9) and International Classification of Diseases, 10th edition (ICD-10) codes for laryngeal stenosis and tracheostomy complications (J95.5, J95.0, J38.6, J39.8, 478.74, 997.32, 519.19, 519.1, 519.02) and Current Procedures and Techniques (CPT; American Medical Association, Chicago, IL) codes for tracheal reconstruction and dilation (31541, 31526, 31571, 31592, 31599, 31599.3, 31588, 31780).[11,12] Patients were included if they had a diagnosis of subglottic stenosis and had completed the Voice-Related Quality of Life Measure at least twice. Patients were excluded if they had current laryngeal cancer, bilateral vocal fold paralysis, posterior glottic stenosis, tracheomalacia, or tracheostomy during the treatment period.

Exposures and Outcomes

Demographic data and co-morbidities, including tobacco use, were collected for each patient. If documented, the degree of airway stenosis at the initial visit and all subsequent pre- and post-procedural visits were collected. The degree of airway stenosis was determined by the individual surgeons at the time of evaluation or treatment, either in the office or the operating room. Stenosis was quantified as percent of the airway caliber that is narrowed compared to normal (percent stenosis). Percent stenosis must have been documented within four months pre- and post-procedure to be included. Procedures included were endoscopic dilation, endoscopic incision or excision of stenosis, cricotracheal resection, or in-office steroid injection. Utilization of intra-operative steroid and mitomycin C application was noted, but was not utilized for inclusion or exclusion criteria. Other information on treatments recorded included timing relative to the patient's first treatment, length of time between procedures, and pre- and post-procedure percent stenosis (when available). If treatments at another hospital were noted, treatment number was documented for the patient's overall number of treatments, rather than the number of treatments performed at the study institution.

The primary outcome was V-RQOL score, collected before and after procedures. The V-RQOL Measure is a validated instrument with both physical functioning and social-emotional domains.[13,14] The normalized calculated score is on a scale of 0-100, as are the calculated physical functioning and social-emotional scores. For this study, the calculated total score was recorded, with sub-analysis based on physical functioning and social-emotional sub-scores. The

difference in V-RQOL was defined as the calculated post-operative score minus the calculated pre-operative score. Both pre- and post-V-RQOL measurements had to be within four months of the procedure to be included in analysis.

Data Analysis

Data were analyzed for the change in V-RQOL over each treatment. Differences in V-RQOL scores, time between treatments, and percentage change in subglottic stenosis by treatment number were determined using a non-parametric p-for-trend test, a method similar to the Wilcoxon rank-sum test to test for monotonicity across three or more groups in a series. This was done to determine whether all data are going in the same direction over time—all increasing, or all decreasing. A subgroup analysis of change in stenosis, V-RQOL, and time between treatments was performed excluding patients who received in-office steroid injections, as the intent of those procedures was to maintain airway caliber rather than to improve it. V-RQOL differences and change in percent stenosis compared by treatment type were determined using ANOVA due to the number of categories. Association of V-RQOL with pre- and post-operative percent stenosis was determined using univariate and multivariate linear regression, accounting for clustering of treatments in individual patients. Multivariable regression included treatment type, age, sex, and etiology of SGS as covariates. All data were collected and managed in REDCap (Research Electronic Data Capture) hosted at the University of Michigan.[15,16] All data analysis was performed in Stata 15.1 (StataCorp LLC, College Station, TX).

RESULTS

Study Population

Sixty-one patients were included in this study, while 127 patients initially identified for chart review were excluded from analysis due to comorbidities including current laryngeal cancer, vocal fold paralysis, glottic stenosis, tracheomalacia, or current tracheostomy. Of the 61 included patients, median age was 48 years (interquartile range [IQR] 19.5), 57 (93.4%) were women, and 57 (93.4%) were white. Black, Hispanic, and patients who declined to report their race or ethnicity comprised the other 6.6% of the sample. The majority of patients were never tobacco users (45, 70.5%). Among SGS etiologies, the most common was idiopathic (37, 60.7%), followed by granulomatosis with polyangiitis (10, 16.4%) and iatrogenic (10, 16.4%). All iatrogenic cases were intubation-related. Patients presented with a median of 60% stenosis (IQR 30). The plurality of patients had four or more treatments (27, 44.3%), with the next largest group having only one documented procedure (17, 27.9%). Further information on patient demographics and comorbidities can be found in Table 1.

Treatment Characteristics

Among 130 total documented treatments with reliable V-RQOL measurements—across all 61 patients in the study—the plurality were endoscopic dilations with sharp or laser division or excision of stenosis (64, 51.4%). Eleven of these patients received steroid injection as their

only adjunct; fifty-one (79.6%) had both mitomycin C and steroid injection at the time of endoscopic procedure. In-office injection of steroid was the next most common treatment, with 44 procedures (33.4%), followed by dilation without division of stenosis (10, 7.7%) and cricotracheal resection (1, 0.8%). All other treatments comprised the remaining 7.8% of treatments. These treatment types are shown divided by treatment number in Table 2. Patients achieved the longest inter-procedure interval between treatments one and two (315 days, IQR 602), with decreasing intervals between subsequent treatments (p-for-trend <0.001).

Airway Stenosis

There were 78 procedures across 39 patients with reliable data available to assess change in degree of airway stenosis. Comparing the initial visit with last follow-up among these patients, median initial preoperative measurement of stenosis was 60% (IQR 50-75), compared to median 20% at last post-operative measurement (IQR 10-30, p<0.001). Distribution of these values can be found in Figure 1.

Comparing by treatment type in the cohort with available stenosis data, endoscopic dilation and scar incision or excision was associated with an absolute improvement of 41% of airway caliber (95% CI -48 to -33). Dilation alone achieved a similar change (-37%, 95% CI -52 to -21), while in-office steroid injection resulted in essentially no change in stenosis (-1%, 95% CI -3 to +1.2).

Within this time period, patients had the greatest change in the degree of stenosis after the initial treatment, with an absolute increase in airway caliber of 50% (IQR 30). When patients who underwent in-office steroid injection were excluded (leaving 44 surgical procedures with reliable stenosis data), the increase in airway caliber on initial treatment was unchanged at 50% (IQR 25), with similar median improvements across all treatment groups (p-for-trend = 0.06, Table 2).

V-RQOL

Initial pre-operative total V-RQOL score was a median of 82.5, with an interquartile range of 57.5-92.5. Median last post-operative V-RQOL score was 90 (IQR 70-97.5). There was a significant difference between these two measurements using a signed-rank test (p=0.01). Full distributions of first pre-operative and last post-operative V-RQOL are in Figure 1. Comparing by treatment type, patients had no average change in V-RQOL with endoscopic dilation and scar incision or excision (+4.1, 95% CI -0.9-9.1). Mean V-RQOL was also stable on average with dilation alone (+2.7, 95% CI -16.6-22.0) and with in-office steroid injections (+2.9, 95% CI -1.3-7.1).

When evaluated across treatment numbers in all study patients, overall V-RQOL and social-emotional subscores did not demonstrate a significant change or trend (Table 2), with a median change of 0 for both across all treatments. Change in physical functioning sub-score of V-RQOL improved with the initial procedure by 16.7 points (IQR 29.2). This improvement

decreased with successive procedures, diminishing to a change of 0 points (IQR 4.2) following four or more procedures (p-for-trend = 0.01).

Excluding patients who had an in-office injection—leaving 86 procedures—physical functioning subscore of V-RQOL improved by 16.7 (IQR 29.2) after the first operative treatment, with similar improvements for subsequent operations (p-for-trend = 0.17). Total V-RQOL and social-emotional subscores showed no change across all treatments (Table 2).

Association Between Stenosis and V-RQOL

Improvement in degree of stenosis was associated with improvement in overall V-RQOL. For every 10% improvement of airway caliber postoperatively, V-RQOL improved by 1.3 points (95% CI 0.1-2.5, Figure 2). This comparison held on multivariable adjustment (including treatment type, patient age, sex, race, and etiology of SGS) with a V-RQOL improvement of 1.5 points associated with a 10% absolute increase in airway caliber (95% CI 0.2-2.9). For the univariate and multivariable models, R^2 values were 0.05 and 0.11, respectively.

DISCUSSION

In this study, we examined a population of 61 patients with SGS who underwent 130 procedures. The overwhelming majority therefore had serial procedures, most commonly endoscopic dilation and scar incision or excision with steroid injection in the operating room. However, as patients underwent more procedures, the distribution changed: patients underwent

more in-office procedures, such as steroid injections, compared to endoscopic treatments in the operating room. Patients had the greatest improvement in stenosis after their first treatment, achieving 50% increase in airway caliber. Among patients undergoing serial endoscopic procedures, improvement in stenosis continued to hover around 40-50%. Patients who underwent in-office steroid injections had little to no change in airway stenosis following these procedures, which is lower than previously reported 20-30% reduction in stenosis over many treatments in one study of patients undergoing one course of injections.[5]

The greatest improvement in V-RQOL scores occurred after the initial treatment, with little perceived improvement following subsequent treatments, as the positive change in V-RQOL scores is maintained throughout the study period. The improvement was within the physical functioning domain of the V-RQOL rather than the social-emotional items. Importantly, there was also no decrease in V-RQOL scores associated with these procedures, which is reassuring for long-term voice outcomes in patients undergoing serial procedures for SGS. Interestingly, although overall change in V-RQOL scores was small, it was associated with postoperative improvement in stenosis, with a 1.5 point improvement in V-RQOL for every 10% absolute decrease in stenosis.

These findings are consistent with extant literature on SGS. While this study includes a more diverse population of etiologies than prior studies on idiopathic SGS alone, the patient population itself—largely female and white—is comparable to previous studies that looked at V-RQOL improvement after procedures for idiopathic SGS[9]. Additionally, while the absolute

degree of improvement is slightly smaller—7.5 points in our study, compared to 11 points in the previous work—they are statistically similar. This study also demonstrates the greatest degree of improvement in V-RQOL with endoscopic dilation procedures, in line with this prior study. Other studies have shown improvement over individual procedures as well, but they used other patient reported measures, such as the Voice Handicap Index, that are not directly comparable to V-RQOL.[17,18]

A study of the broader population looking at patient treatment preferences for SGS showed that patients are most concerned about voice, avoiding surgery with a higher risk profile, and avoiding multiple procedures.[19] Notably, however, the two SGS patients included in that study were more likely to accept serial treatment than non-SGS patients. This is also reflected in a study of an online SGS community, which showed that maximizing time between procedures was prioritized, rather than having only one procedure.[20] While recurrence rates are low with single procedures such as cricotracheal resection, many patients prefer the more favorable safety profile of endoscopic and in-office treatments, given concerns about higher risk of complications and permanent voice changes associated with open reconstructive procedures.[21]

This study provides important information in counseling of these patients regarding prognosis and treatment options. Patients undergoing serial procedures experienced a decrease in the degree of change in V-RQOL with subsequent procedures—even though they achieve similar improvement in airway caliber when treatments intended only to maintain airway patency, i.e. in office injections, are excluded. There are several potential explanations for this observation.

Many patients have a relatively high degree of stenosis prior to their initial treatment due to delayed diagnosis; however, once they are aware of their condition, self-monitoring by patients and serial examinations by their surgeons lead to earlier intervention—in the operating room or the office. This is supported by our findings showing an association between degree of stenosis and V-RQOL, and is in line with previous studies looking at pulmonary function tests and broader assessments of quality of life in patients with SGS.[22] It is possible that over time patients may develop a new baseline perception of their voice quality. To determine this, further qualitative study of this patient population is needed to understand how their expectations change over time. This concept was previously demonstrated when studying longitudinal changes in V-RQOL with Botox injections for spasmodic dysphonia.[23]

These data should be interpreted carefully: this is a retrospective study, with inconsistent timing of the V-RQOL test compared to the date of the procedure itself. We had only V-RQOL as an outcome, with no other voice measure such as auditory perceptual analysis or acoustic and aerodynamic measures to compare with. Additionally, measurements of stenosis caliber were done by individual surgeons and are susceptible to confirmation bias. We also report some intermediate variables, such as the interval between procedures, that can be highly idiosyncratic—such as planned dilations for a patient undergoing a cricotracheal resection, or planned sets of injections. However, our data still represent the median experience of our institution's population. Prospective studies with standardized measurement of both objective clinical findings and patient reported outcomes are needed to more fully characterize the change

in voice perception over time. The association between V-RQOL and stenosis must also be considered carefully. As shown by the calculated R^2, stenosis does not predict much of the variance in V-RQOL, even if it is associated in both adjusted and unadjusted models. Given this, there are likely other unmeasured factors that are driving more of the V-RQOL change, such as patient expectation.

CONCLUSION

This study represents a vital step in understanding the course of patients with SGS, demonstrating that V-RQOL improves following initial dilation of stenosis, with decreased perceived improvement over serial treatments. Importantly, these data are also reassuring to patients and providers that serial SGS treatments, including in-office steroid injections, are not associated with harm to V-RQOL. Larger prospective studies are needed to better understand these associations, along with qualitative studies of the patient experience.

REFERENCES

1. Nouraei S a. R, Nouraei SM, Randhawa PS, et al. Sensitivity and responsiveness of the Medical Research Council dyspnoea scale to the presence and treatment of adult laryngotracheal stenosis. *Clin Otolaryngol Off J ENT-UK Off J Neth Soc Oto-Rhino-Laryngol Cervico-Facial Surg*. 2008;33(6):575-580. doi:10.1111/j.1749-4486.2008.01832.x

2. Gelbard A, Anderson C, Berry LD, et al. Comparative Treatment Outcomes for Patients With Idiopathic Subglottic Stenosis. *JAMA Otolaryngol-- Head Neck Surg*. Published online October 31, 2019. doi:10.1001/jamaoto.2019.3022

3. Gelbard A, Shyr Y, Berry L, et al. Treatment options in idiopathic subglottic stenosis: protocol for a prospective international multicentre pragmatic trial. *BMJ Open*. 2018;8(4). doi:10.1136/bmjopen-2018-022243

4. Axtell AL, Mathisen DJ. Idiopathic subglottic stenosis: techniques and results. *Ann Cardiothorac Surg*. 2018;7(2):299-305. doi:10.21037/acs.2018.03.02

5. Hoffman MR, Coughlin AR, Dailey SH. Serial office-based steroid injections for treatment of idiopathic subglottic stenosis. *The Laryngoscope*. 2017;127(11):2475-2481. doi:10.1002/lary.26682

6. Franco RA, Husain I, Reder L, Paddle P. Awake serial intralesional steroid injections without surgery as a novel targeted treatment for idiopathic subglottic stenosis. *The Laryngoscope*. 2018;128(3):610-617. doi:10.1002/lary.26874

7. Gartner-Schmidt JL, Shembel AC, Zullo TG, Rosen CA. Development and validation of the Dyspnea Index (DI): a severity index for upper airway-related dyspnea. *J Voice Off J Voice Found*. 2014;28(6):775-782. doi:10.1016/j.jvoice.2013.12.017

8. Yin LX, Padula WV, Gadkaree S, et al. Health Care Costs and Cost-effectiveness in Laryngotracheal Stenosis. *Otolaryngol Neck Surg*. 2019;160(4):679-686. doi:10.1177/0194599818815068

9. Hillel AT, Karatayli-Ozgursoy S, Benke JR, et al. Voice Quality in Laryngotracheal Stenosis: Impact of Dilation and Level of Stenosis. *Ann Otol Rhinol Laryngol*. 2015;124(5):413-418. doi:10.1177/0003489414564249

10. Dhillon VK, Akst LM, Best SR, Hillel AT. Voice Outcomes in Laryngotracheal Stenosis: Impact of the Montgomery T-tube. *Clin Surg*. 2018;3.

11. International Classification of Diseases, Ninth Revision. Published March 1, 2019. Accessed February 2, 2020. https://www.cdc.gov/nchs/icd/icd9.htm

12. CPT® (Current Procedural Terminology). American Medical Association. Accessed May 7, 2020. https://www.ama-assn.org/amaone/cpt-current-procedural-terminology

13. Hogikyan ND, Sethuraman G. Validation of an instrument to measure voice-related quality of life (V-RQOL). *J Voice*. 1999;13(4):557-569. doi:10.1016/S0892-1997(99)80010-1

14. Kupfer RA, Hogikyan EM, Hogikyan ND. Establishment of a normative database for the Voice-Related Quality of Life (V-RQOL) measure. *J Voice Off J Voice Found*. 2014;28(4):449-451. doi:10.1016/j.jvoice.2013.11.003

15. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)—A metadata-driven methodology and workflow process for providing

translational research informatics support. *J Biomed Inform*. 2009;42(2):377-381. doi:10.1016/j.jbi.2008.08.010

16. Harris PA, Taylor R, Minor BL, et al. The REDCap consortium: Building an international community of software platform partners. *J Biomed Inform*. 2019;95:103208. doi:10.1016/j.jbi.2019.103208

17. Hseu AF, Benninger MS, Haffey TM, Lorenz R. Subglottic stenosis: A ten-year review of treatment outcomes: Subglottic Stenosis. *The Laryngoscope*. 2014;124(3):736-741. doi:10.1002/lary.24410

18. Romak JJ, Orbelo DM, Maragos NE, Ekbom DC. Correlation of the Voice Handicap Index-10 (VHI-10) and Voice-Related Quality of Life (V-RQOL) in patients with dysphonia. *J Voice Off J Voice Found*. 2014;28(2):237-240. doi:10.1016/j.jvoice.2013.07.015

19. Naunheim MR, Naunheim ML, Rathi VK, Franco RA, Shrime MG, Song PC. Patient Preferences in Subglottic Stenosis Treatment: A Discrete Choice Experiment. *Otolaryngol Neck Surg*. 2018;158(3):520-526. doi:10.1177/0194599817742851

20. Haik D, Kashanchi K, Tajran S, et al. The Online Support Group as a Community: A Thematic Content Analysis of an Online Support Group for Idiopathic Subglottic Stenosis. *Ann Otol Rhinol Laryngol*. 2019;128(4):293-299. doi:10.1177/0003489418820348

21. Carpenter PS, Pierce JL, Smith ME. Outcomes after cricotracheal resection for idiopathic subglottic stenosis. *The Laryngoscope*. 2018;128(10):2268-2272. doi:10.1002/lary.27263

22. Naunheim MR, Paddle PM, Husain I, Wangchalabovorn P, Rosario D, Franco RA. Quality-of-Life Metrics Correlate With Disease Severity in Idiopathic Subglottic Stenosis: Quality of Life in Subglottic Stenosis. *The Laryngoscope*. 2018;128(6):1398-1402. doi:10.1002/lary.26930

23. Rubin AD, Wodchis WP, Spak C, Kileny PR, Hogikyan ND. Longitudinal effects of Botox injections on voice-related quality of life (V-RQOL) for patients with adductory spasmodic dysphonia: part II. *Arch Otolaryngol Head Neck Surg*. 2004;130(4):415-420. doi:10.1001/archotol.130.4.415

Table 1: Characteristics of Study Population

	No.	%
Gender		
Female	57	93.4%
Male	4	6.6%
Race		
Black or African American	2	3.3%
White	57	93.4%
Hispanic	1	1.6%
Unknown / Not Reported	1	1.6%
Diagnosis (SGS Type)		
Wegeners/Granulomatosis with Polyangiitis	10	16.4%
Iatrogenic	10	16.4%
Idiopathic	37	60.7%
Other	4	6.6%
Diabetes		
No	47	77.0%
Yes	13	21.3%
Missing	1	1.6%
Concurrent Cardiac Disease		
No	35	57.4%
Yes	25	41.0%
Missing	1	1.6%
Concurrent Pulmonary Disease		
No	43	70.5%
Yes	16	26.2%
Missing	2	3.3%
Tobacco Use		
No	45	73.8%
Former	11	18.0%

Current	3	4.9%
Missing	2	3.3%
Total treatment count		
1	17	27.9%
2	8	13.1%
3	9	14.8%
4+	27	44.3%

	Median	**IQR**
Age	47	18
Percent Stenosis at Baseline	60	30

Table 2: Treatment Type, Timing, and Response by Treatment Number

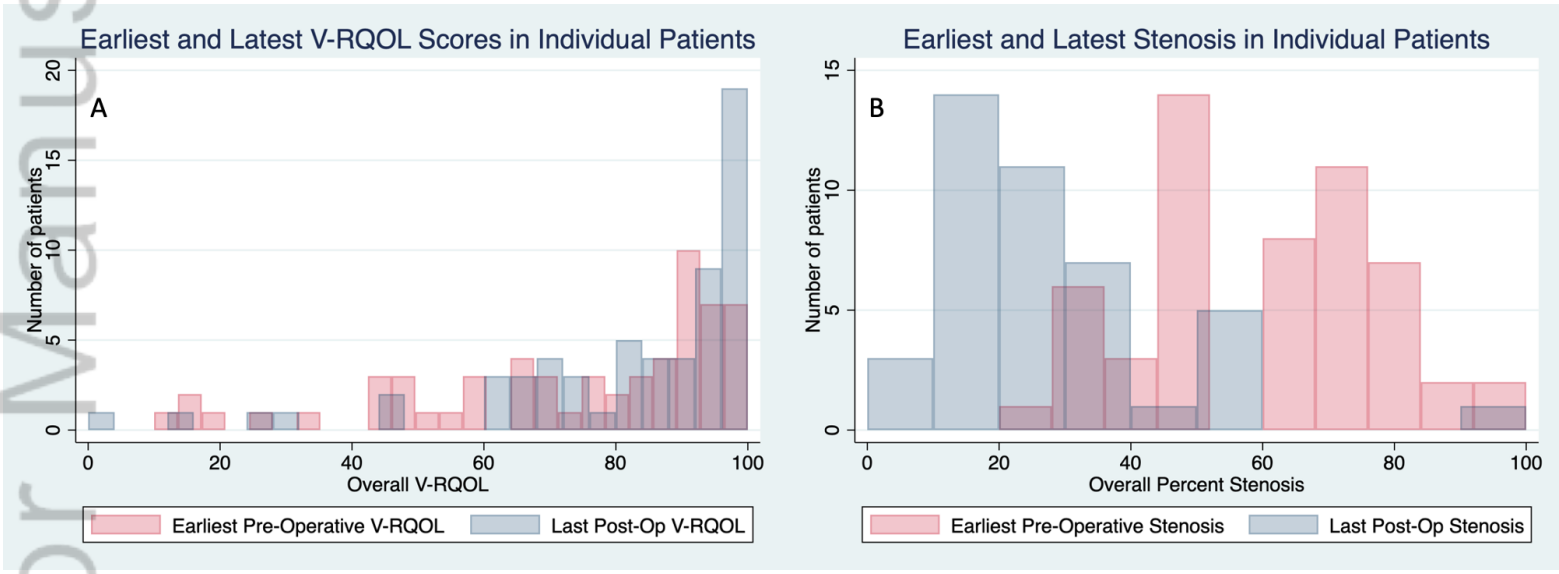
	Treatment Number				
	1	**2**	**3**	**4+**	**p-value**
Treatment Types (n, % by treatment number)					<0.001
*Dilation with division of scar, with or without adjuncts**	24 (72.7)	11 (73.3)	11 (52.4)	21 (34.4)	
*Dilation without division, with or without adjuncts**	6 (18.2)	1 (6.7)	1 (4.8)	2 (3.3)	
Cricotracheal Resection	0 (0)	0 (0)	1 (4.8)	0 (0)	
In-office injection	0 (0)	2 (13.3)	6 (28.6)	36 (59.0)	
Other	3 (9.1)	1 (6.7)	2 (9.5)	2 (3.3)	
Total Number of Treatments	33	15	21	61	
Complete Cohort Analysis					
Days from Previous Treatment	-	315 (602)	189 (622)	84 (255)	<0.001
Change in % Stenosis	-50 (30)	-30 (45)	-25 (42.5)	0 (10)	<0.001
Change in V-RQOL (Total, Calculated)	0 (15)	0 (5)	0 (12.5)	0 (10)	0.11
Change in V-RQOL (Social/Emotional, Calculated)	0 (12.5)	0 (12.5)	0 (0)	0 (6.2)	0.50
Change in V-RQOL (Physical Functioning, Calculated)	16.7 (29.2)	4.2 (8.3)	0 (16.7)	0 (4.2)	0.01
Subgroup Analysis Excluding SILSI					
Days from Previous Treatment	-	115.5 (224)	399.5 (560)	336 (314)	0.08
Change in % Stenosis	-50 (32.5)	-45 (22.5)	-40 (30)	-40 (40)	0.06
Change in V-RQOL (Total, Calculated)	0 (12.5)	0 (5)	0 (15)	2.5 (15)	0.67

Change in V-RQOL (Social/Emotional, Calculated)	0 (12.5)	3.1 (12.5)	0 (6.2)	-6.2 (0)	0.95
Change in V-RQOL (Physical Functioning, Calculated)	16.7 (29.2)	4.2 (8.3)	6.2 (14.6)	-	0.17

*Adjuncts are defined as intra-operative steroid injection or mitomycin C. P-values are calculated using Fisher's exact test for treatment type, and a nonparametric p-for-trend test for the continuous variables. **Sub-group analysis run without including in-office injections. Abbreviations: SILSI, serial intra-lesional steroid injections

Figure 1. Change in VRQOL and stenosis over course of treatment. A, earliest preoperative (red) and latest postoperative (blue) V-RQOL scores. There is a tighter distribution of high V-RQOL scores in the last post-operative visit compared to a broader distribution of scores in first preoperative visit. B, earliest preoperative (red) and latest postoperative (blue) stenosis measurements. Similarly, this shows a tighter distribution of stenosis measurements at lower degrees of stenosis at the last postoperative visit compared to a broader distribution of initial stenosis measurements.

Figure 2. Scatterplot of the difference in airway caliber (absolute difference in percent of airway remaining) compared to the difference in V-RQOL score before and after treatment. Navy line represents univariate linear regression, with 95% confidence interval shown in light grey.



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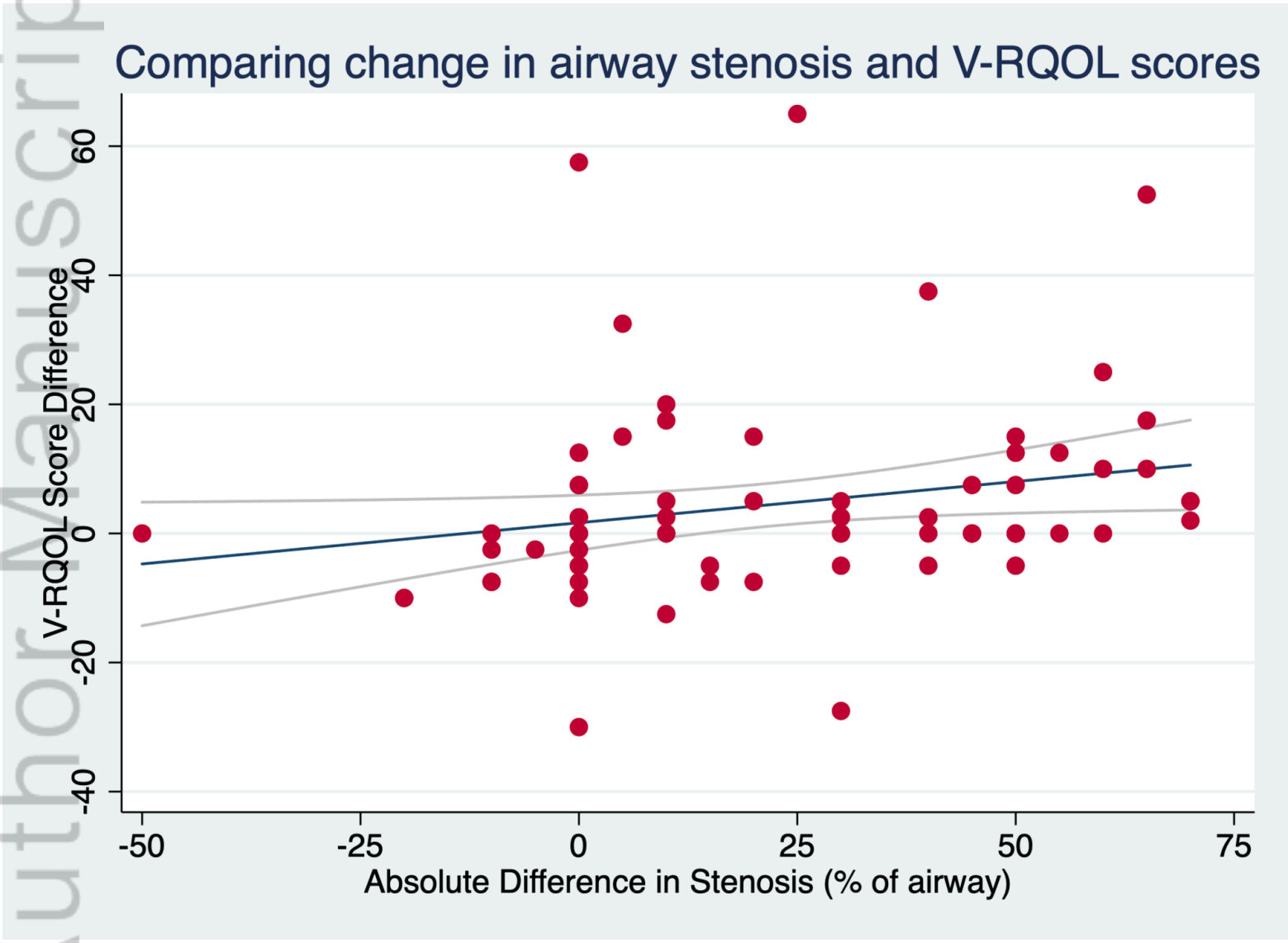

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