



Voice outcome indicators for unilateral vocal fold paralysis surgery: a review of the literature

G. Desuter^{1,3} · M. Dedry¹ · B. Schaar¹ · J. van Lith-Bijl^{1,2} · P. P. van Benthem³ · E. V. Sjögren³

Received: 26 October 2017 / Accepted: 8 December 2017
© Springer-Verlag GmbH Germany, part of Springer Nature 2017

Abstract

Introduction There is no consensus on which voice outcome indicators (VOIs) should be used to compare the merits of the various surgical treatments for unilateral vocal fold paralysis (UVFP). Authors performed a literature review to identify which VOIs are most frequently used and most relevant, in terms of significant change in pre- and post-operative measurements, to assess UVFP surgical treatments.

Method A Medline/Pubmed literature review was performed and the most frequently used VOIs were identified using a Pareto diagram. For these most frequently used VOIs, the number of studies that showed a statistically significant change in pre- and post-operative results were compared to the total number of studies found using that same VOI, this portion was expressed in percent. This percentage was defined as the “percentage of significance” and used to assess changes of each VOI.

Results Eleven VOIs were identified using the Pareto analysis. These were, in decreasing order of frequency of citation: maximum phonation time (MPT), jitter, Shimmer, video-stroboscopic examination, noise to harmonic ratio (NHR/HNR), mean air flow (MeAF), fundamental frequency (F0), “Infrequent Perceptual Scales”, GRBAS scale, mean subglottic pressure (MSGP). MPT, MeAF, factor G of GRBAS-I, Jitter, shimmer and VHI-30 had respective “percentage of significance” of 90, 86, 85, 74, 68 and 64%, respectively.

Conclusion The results indicate that MPT, MeAF and GRBAS-I, represent the top-three most frequently used and the most relevant VOIs in terms of “percentage of significance”. VHI-30 showed a relatively low rate of use and low “percentage of significance”. The role of Jitter and Shimmer remains unclear. Finally, MSGP and the F0 appear to be less relevant VOIs for the evaluation of UVFP surgical treatments in terms of significant change in pre- and post-operative measurements.

Keywords Unilateral vocal fold paralysis UVFP · Thyroplasty · Injection laryngoplasty · Larynx reinnervation · Outcome

Introduction

Abduction in unilateral vocal fold paralysis (UVFP) causing dysphonia, dysphagia and “phonatory” dyspnea, represents a defined pathological entity for which many different surgical treatments have been proposed over the years. Although

diverse in their approach these surgeries all primarily seek closure of the glottis during phonation. Unfortunately, there is no consensus on which voice outcome indicators (VOIs) should be used to compare the merits of these various treatments. If voice quality assessment is thought to be necessarily multidimensional, some authors have advocated, in the recent literature, the need for disease-specific sets of VOIs. This paper is a Medline/Pubmed-based review and evaluation of the literature focusing on VOIs that have been utilized for the assessment of UVFP surgical treatments.

The primary aim of this review was to determine the frequency of use of every VOI that has been utilized to assess patient’s voice, after surgical treatment for UVFP, using a Pareto diagram. Having determined the most frequently used VOIs according to the Pareto diagram, the secondary aim of this review was to report their pre- and post-intervention results. The ultimate goal of the review was to identify which

✉ G. Desuter
gauthier.desuter@uclouvain.be; gdesuter@post.harvard.edu

¹ Otolaryngology, Head and Neck Surgery Department, Voice and Swallowing Clinic, Cliniques Universitaires Saint-Luc, Université catholique de Louvain, 10 avenue Hippocrate, suite 407, 1200 Brussels, Belgium

² Otolaryngology Department, Flevoziekenhuis, Almere, The Netherlands

³ Otolaryngology, Head and Neck Surgery Department, LUMC, University of Leiden, Leiden, The Netherlands

VOIs are most frequently used and most relevant in terms of significant change in pre- and post-operative measurements when it comes to assess UVFP surgical treatments.

Methods

In October 2016, a systematic search was performed in Medline/Pubmed to identify articles published after 1990 on assessment of UVFP surgical treatments. Using the following medical subject heading (MeSH) and subheadings, “Vocal Cord Paralysis/Diagnosis” [MeSH] OR “Vocal Cord Paralysis/Surgery” [MeSH] OR “Vocal Cord Paralysis/

Therapy” [MeSH], a total of 3052 articles were found. Two thousand two-hundred ninety-five articles (2295) were published after 1990. The first selection was based on the exclusion criteria. Seven hundred sixty articles (760) were selected after title reading. Abstracts of these 760 were reviewed. One hundred and fifty-six (156) of these articles were selected for extensive reading. Eventually, 72 of these 156 articles met the inclusions criteria and were analyzed [1–72].

Exclusion and inclusion criteria are listed in Table 1. Figure 1 shows the flowchart of article selection.

An extensive data bank was set up. Type of study, type of surgical intervention(s), type of VOI used and their values,

Table 1 Exclusion criteria are listed on the left column, Inclusion criteria are listed on the right column

Exclusion criteria	Inclusion criteria
Meta-analysis	
Studies published before 1990 referenced in the « PubMed » database	Studies published after 1990 referenced in the « PubMed » database
Other pathologies than unilateral vocal fold paralysis	Unilateral vocal fold paralysis
No intervention or unspecified intervention	Intervention (medialization thyroplasty, injection, arytenoid adduction, reinnervation)
Post-surgery outcomes non available or reported in correlation	Voice outcome indicator before and after surgery
Outcomes in dead subjects	Studies on human living subjects
Studies about surgical complications	
Case studies	
Animal studies	

Fig. 1 Flowchart of article selection

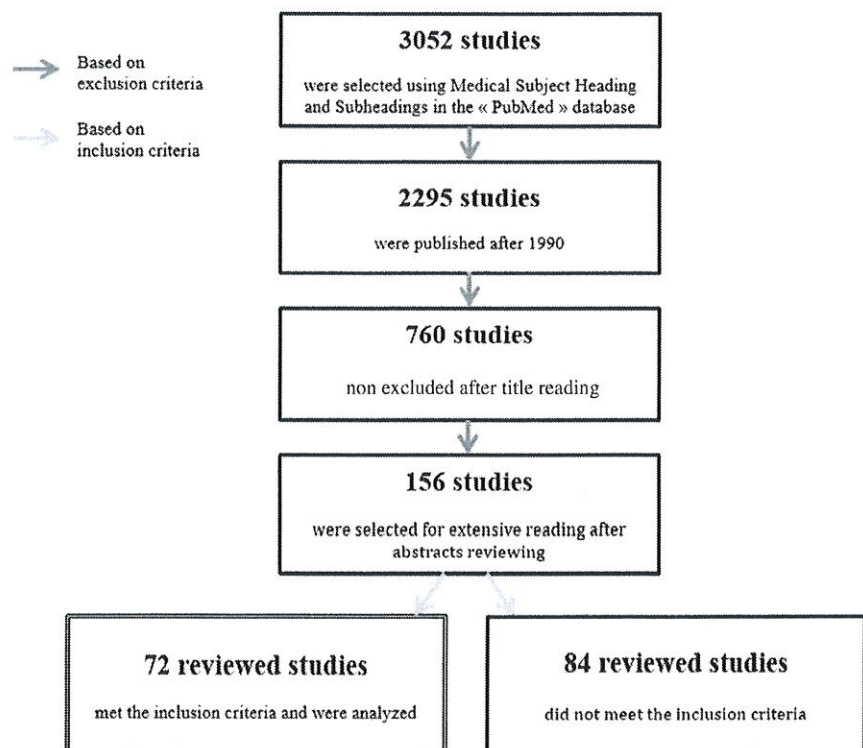


Table 2 Frequency of use of the different VOIs utilized in the literature, their overall percentages of use and the cumulative percentage of all VOIs

	Frequency	Percent- age (%)	Cumulative percent- age (%)
MPT	45	13.5	13.6
Jitter	33	9.9	23.5
Shimmer	32	9.6	33.1
Videostroboscopy	30	9.0	42.2
NHR	27	8.1	50.3
Mean air flow	22	6.6	56.9
Fundamental frequency	22	6.6	63.6
Homemade perceptual scales	17	5.1	68.7
GRBAS-I	16	4.8	73.5
Mean subglottic pressure	10	3.0	76.5
VHI-30	9	2.7	79.2
Intensity	8	2.4	81.6
Glottal flow rate	6	1.8	83.4
NNE	6	1.8	85.2
CAPE-V	4	1.2	86.4
VHI-10	3	0.9	87.3
V-RQOL	3	0.9	88.3
Laryngeal airway resistance	3	0.9	89.2
Pitch range	3	0.9	90.1
Frequency range	3	0.9	91.0
Pitch perturbation quotient	3	0.9	91.9
Amplitude perturbation quotient	3	0.9	92.8
Phrase grouping	2	0.6	93.4
Word per minute	2	0.6	94.0
Maximum intensity range	2	0.6	94.6
Sound pressure level	2	0.6	95.2
Standard deviation of F0	2	0.6	95.8
Phonetogram	2	0.6	96.4
Vocal performance questionnaire score	1	0.3	96.7
NHP	1	0.3	97.0
Voice symptoms scale	1	0.3	97.3
Voice outcomes survey	1	0.3	97.6
SR-36	1	0.3	97.9
Forced vital capacity	1	0.3	98.2
Intra-abdominal pressure	1	0.3	98.5
Peak expiratory flow	1	0.3	98.8
Forced expiratory volume in 1 s	1	0.3	99.1
Peak inspiratory flow	1	0.3	99.4
Volume O2 maximum	1	0.3	99.7
S/Z ratio	1	0.3	100.0
Total	332	100.0	

along with the time interval from the intervention date to the moment of assessment, were collected. The total frequency of use of each VOI was classified in descending order. A

Pareto diagram that combines bars showing individual values by descending order and a line graph showing the cumulative percentage of data was drawn. Using the Pareto diagram, the most frequently used VOIs, accounting for 80% of the total VOIs, were identified. Once the most frequently used VOIs had been identified, their pre- and post-intervention mean values were compared.

Two choices regarding VOI grouping were made by the authors. (a) The number of citations of noise to harmonic ratio and harmonic to noise ratio (NHR and HNR) VOIs were merged. Authors postulate that NHR and HNR represented the same VOI differing only by a software setting swapping the numerator and denominator of the same ratio. (b) Inversely, the number of citations of VHI-30 and VHI-10 was not merged. Authors postulated that they represented two different—although similar—VOIs that were based on different validation studies in different languages.

Concerning the GRBAS-I score, only the general score (G) will be considered.

The pre- and post-intervention mean values of the VOIs selected using the Pareto diagram were compared. One post-intervention VOI result was considered for each surgical technique and each time interval of post-intervention assessment. The same pre-intervention data were used in case of studies comparing (1) multiple techniques and (2) post-intervention at multiple time points. This explains why post-intervention data were more numerous than pre-intervention data.

Boxplot graphs were used to display pre- and post-intervention means. Line graphs were preferred to boxplot graphs when no clear post-operative trends in the voice outcome could be found.

Finally, for these most frequently used VOIs, the number of studies that showed a statistically significant change in pre- and post-operative results (≤ 0.05) was compared to the total number of studies found using that same VOI, this portion was expressed in percent. This percentage was defined as the “percentage of significance” and used to assess changes of each VOI.

Results

Fifty-three (73.6%) out of 72 studies were prospective. Some of these 72 studies evaluated more than one type of procedure. In total, 107 procedures were reported. Some articles did compare the outcomes of combined procedures. Surgeries of UVFP that were reported were, respectively, medialization or type 1 thyroplasty (ML) (56.1%), arytenoid adduction (AA), usually combined with ML (18.7%), injection laryngoplasty (IL) (17.8%), larynx reinnervation (LR) (6.5%) and arytenoidopexy (AP), usually combined with ML (0.9%).

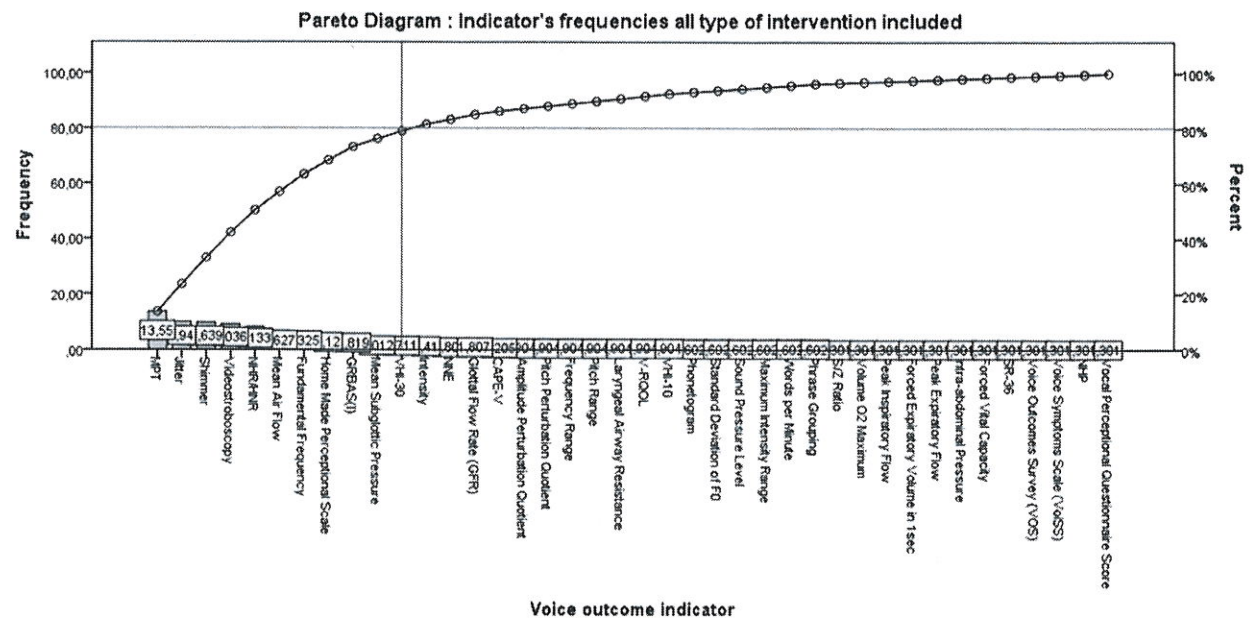


Table 4 Proportion of studies showing significant results ($p \leq 0.05$) between pre-operative and the first post-operative assessments, for each VOI

Voice outcome indicators	P -values ≤ 0.05	% Significance
MPT (s)	47/52 (0 NS; 5 NA)	90.38
Mean airflow (ml/s)	24/28 (2 NS; 2 NA)	85.71
GRBAS-I (factor G)	11/13 (0 NS; 2 NA)	84.61
HNR(dB)	8/10 (0 NS; 2 NA)	80
Jitter (%)	26/35 (5 NS; 4 NA)	74.29
Shimmer (%)	21/31 (6 NS; 4 NA)	67.74
VHI-30	9/14 (2 NS; 3 NA)	64.29
NHR(dB)	7/15 (5 NS; 3 NA)	46.67
Mean subglottic pressure (cm H ₂ O)	5/11 (3 NS; 3 NA)	45.45
F0 (Hz)	8/24 (6 NS; 10 NA)	33.33

The last column translates this proportion into a “percentage of significance”

NS not significant, NA not available

of studies showing “ P -values ≤ 0.05 ” versus studies with “ P -values > 0.05 and no P -values available”, for each VOI. For this table, only the first post-operative assessment was considered, no matter how many post-operative assessments were provided by the study. This percentage was defined as the percentage of significance.

In seven out of the nine VOIs, we found that a high percentage of the studies showed a significant difference in the pre- and post- measurements. The pre- and post-intervention means of these seven studies are displayed in Fig. 3. Figure 4 displays the pre- and post-interventions means of the remaining two VOIs, MSGP and the F0. Here no clear post-operative trends in the voice outcome could be found.

Discussion

This study is a literature review performed to reveal the most frequently cited VOIs used for UVFP surgical treatment assessment. Using the Pareto technique, eleven VOIs were found to account for 80% of the total number of indicators cited. Although the frequency of use of these VOIs may indirectly reflect their accessibility and/or facility to measure, it does not mean per se, that these VOIs are the most appropriate or accurate for the specific purpose of UVFP surgical treatments assessment. Nevertheless, if one could propose a standardized set of VOIs, its implementation could be made easier if they are already frequently used by surgeons. Very recently, Siu et al. performed a systematic review of the literature comparing outcomes of interventions for unilateral vocal fold paralysis. They concluded that “*lack of standardization in outcome measures and differences in reporting outcome*

data make generalizability between studies difficult” [74]. Hypothetically, an ideal standardized set of VOIs should be significant as well as accessible.

A notable effort has been made by the European Laryngological Society to standardize the description of vocal fold motion impairment as well as to propose a basic protocol for functional assessment of all voice pathologies, especially for investigating the efficacy of treatments [75, 76]. No data is available about the use of such standardizations of protocols. A survey performed in 2010 among U.S. board certified otolaryngologists conducted by Young et al., reported that only 50% of respondents performing medialization thyroplasties report collecting pre-operative voice recordings [77]. This suggests an underuse of pre- and post-intervention voice assessment, which is probably not only restricted to the US.

In an attempt to simplify but also make the voice assessment more accurate and significant, some authors looked at tailoring the voice assessment to the disease that is under scrutiny. Dastolfo et al. followed this strategy and demonstrated that pre- and post-operative changes in aerodynamic measurements were shown to be very significant in UVFP treatment evaluations. They specifically advocate airflow in the “all-voiced sentence” as a routine voice laboratory measure for UVFP patients [78].

Of the nine VOIs that were selected using the Pareto analysis, three VOIs have a “percentage of significance” of more than 80%, Table 4. Maximum phonation time (MPT) appears to be the most used and the second most significant VOI in terms of pre- and post-operative change. Its use for UVFP treatment assessment has been frequently advocated since an initial article by Lundy et al., published in 2004, stated that “*the intra-operative measure of MPT appears to be an adequate predictor of the postoperative-thyroplasty-outcome*” [36]. Determination of MPT is easy to perform and does not require specific equipment. There are, however, still some recording conditions and patient collaboration issues concerning the MPT. Likewise, MPT has been reported as less sensitive than MeAF to characterize laryngeal dysfunction [79].

GRBAS-I general score (G), for grade of dysphonia, represents a widely used perceptual scale. Overall voice quality is scored from 0 to 3 by listener. Inter- as well as intra-rater reliability is satisfactory [36] and there should be no obstacle to its widespread use. Nevertheless, the GRBAS-I scale has its drawbacks. It has been recently demonstrated that the GRBAS evaluation should be blind [80] and that a particular attention should be paid to task design when it comes to perceptual analysis [81].

MeAF represents a more complex VOI than the previous ones. The MeAF is a similar VOI to airflow in the “all-voiced sentence”, which was shown by Dastolfo’s team to be very significant in measuring the pre-post UVFP

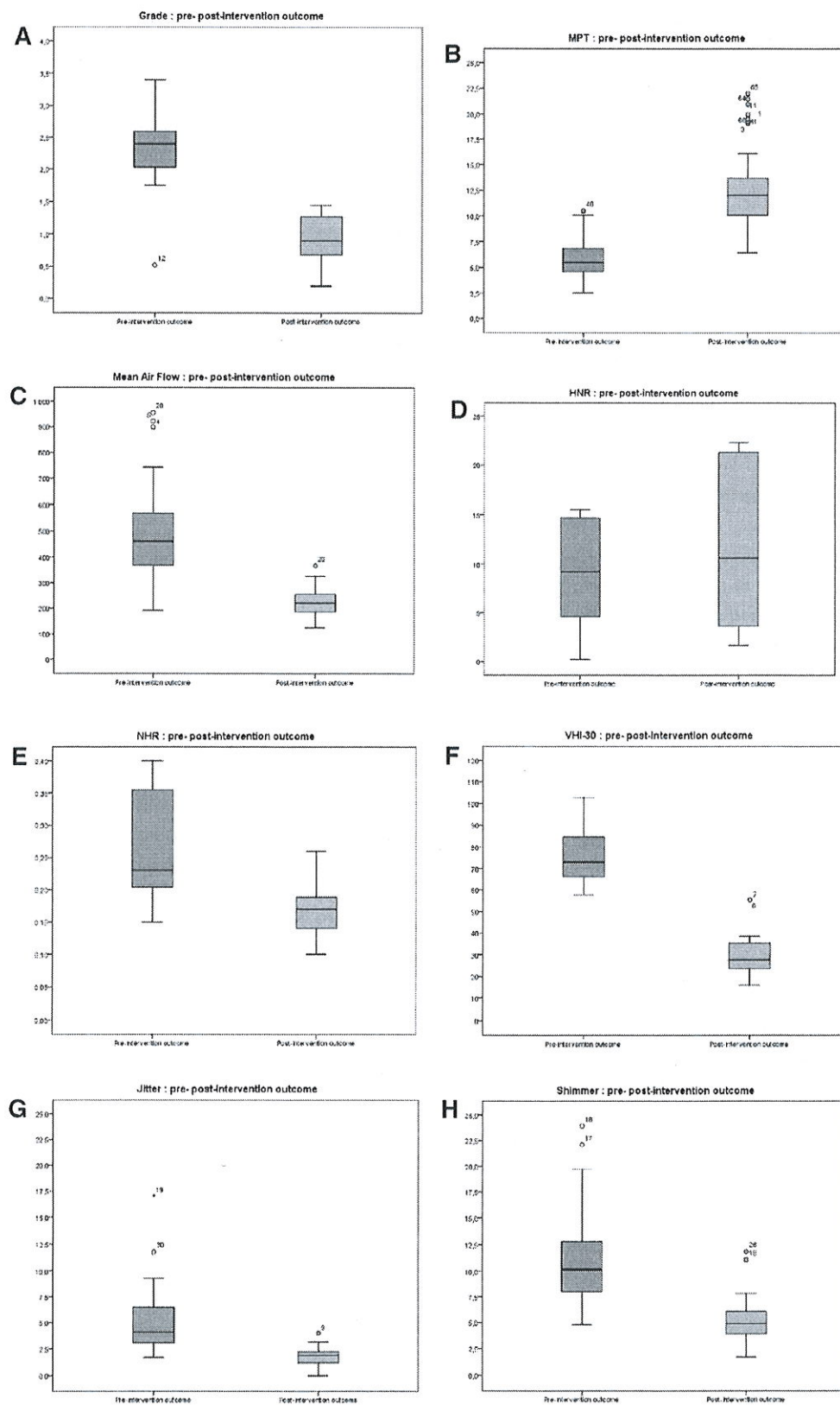


Fig. 3 Pre- and post-interventions results of G score of GRBAS-I (a), MPT (b), McAF (c), HNR (d), NHR (e), VHI-30 (f), Jitter (g) and Shimmer (h)

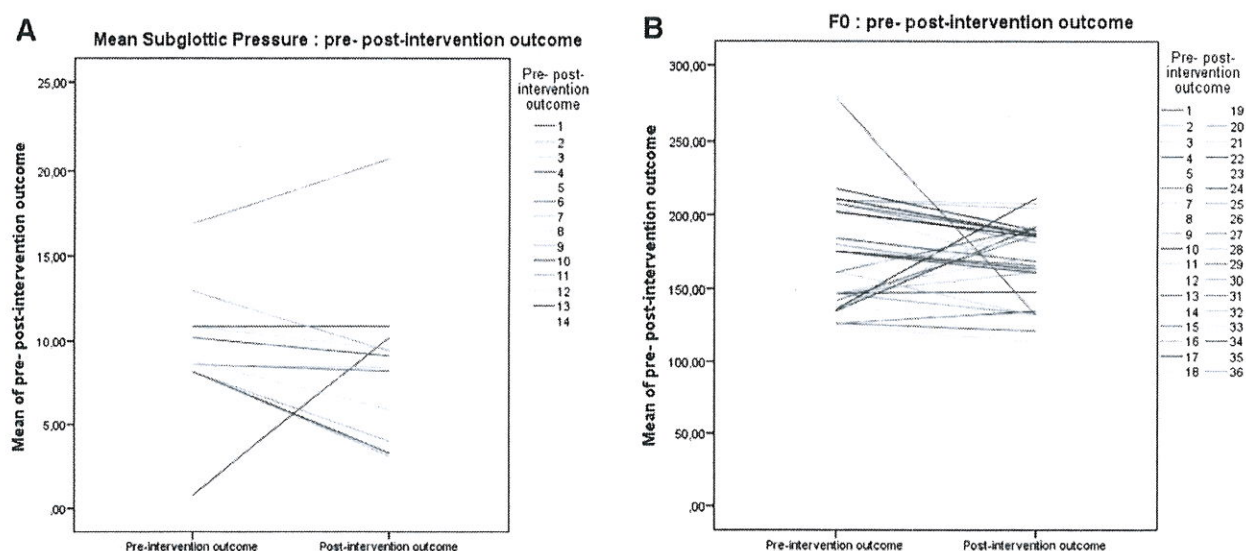


Fig. 4 Pre- and post-interventions results of MSGP (a) and F0 (b)

surgical treatment. Access to this VOI can be an issue considering the need of a pneumotachograph to be able to measure it, it is therefore somewhat reassuring to find the MeAF in our short list. Phonatory Quotient (PQ), a ratio between Vital Capacity and MPT that correlates with MeAF, could represent a valid surrogate.

Jitter and Shimmer are, respectively, ranked at fifth and sixth places in terms “percentage of significance” (Table 4). They are usually provided systematically by most voice laboratory software tools available on the market. This may explain their frequency of use, even though, their respective usefulness is questionable. As a matter of fact, Shimmer has a “percentage of significance” of only 68% and Jitter of 74%. Also, Jitter is calculated with the f0, which is in itself a VOI with low significance. VHI-30 ranking is low in terms of frequency of use and significance ratio. Merging of the VHI-30 and VHI-10 would not have changed these results significantly. Mean subglottic pressure and the Fundamental Frequency do not show clear outcome tendencies after UVFP treatment, and thus, despite being widely reported, do not seem to have much added value.

The limits of this review must certainly be underscored. First, this review has been done using exclusively the PubMed research tool. Nevertheless, we believe that the majority of the articles published on the subject, have been included although some publications might have not been considered. The sole published review on the specific topic of VOIs to assess UVFP treatments—all-together—is the recently published article by Siu et al. mentioned above.

Second, ML interventions are over-represented in comparison to IL interventions. This does not reflect the reality of practice. The main reason of this discrepancy lies in the

selection and inclusion criteria of the studies that favored ML interventions. Many publications concerning IL did not exclusively deal with UVFP patients and did not systematically present pre- and post-op results data.

Third, the extensive databank—more than 150 excel sheets—that has been created, may have been subject to coding errors or bias.

Fourth, raw data of these numerous studies could not be collected, limiting the validity of our conclusions. The presented outcome results are means of means. Likewise, the percentage of significance represents a ratio between studies showing statistical differences and studies showing no statistical differences or no statistical data at all. Furthermore, the fact that authors are more likely to publish significant results rather than non-significant results represents a clear bias.

Finally, this study may overlook VOIs that might be very relevant but not widely reported in the literature. Also, a statistical difference in pre- and post-operative VOI may not necessarily correspond to a clinically relevant change for the patient and the surgeon and for many VOIs there is still some uncertainty as to what the normal value and a clinically significant difference should be.

Conclusion

The goal of this review was to crossmatch frequency of use and relevance in terms of significant change in pre- and post-operative measurements of VOIs used in the evaluation of treatments of UVFP. The results indicate that MPT, MeAF and GRBAS-I represent the top-three VOIs in terms of significance within the most frequently used VOI's. The

VHI-30 showed a relatively low rate of use and low “percentage of significance”. The role of the Jitter and Shimmer remains unclear. Finally, MSGP and the F0 appear to be less relevant VOIs for the evaluation of UVFP surgical treatments in terms of significant change in pre- and post-operative measurements.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Human and animal rights statement This article does not contain any studies with human or animals performed by any of the authors.

Informed consent Informed consent collection is not applicable to this study.

References

- Abdel-Aziz MF, El-Hak NG, Carding PN (1998) Thyroplasty for functional rehabilitation of the incompetent larynx. *J Laryngol Otol* 112(12):1172–1175
- Adams SG, Irish JC, Durkin LC, Wong DL, Brown DH (1996) Evaluation of vocal function in unilateral vocal fold paralysis following thyroplastic surgery. *J Otolaryngol* 25(3):165–170
- Alghonaim Y, Roskies M, Kost K, Young J (2013) Evaluating the timing of injection laryngoplasty for vocal fold paralysis in an attempt to avoid future type I thyroplasty. *J Otolaryngol Head Neck Surg* 42(1):1
- Almeida AAFD., Fernandes LR, Azevedo EHM, Pinheiro RSDA., Lopes LW (2015) Characteristics of voice and personality of patients with vocal fold immobility. *CoDAS* 27(2):178–185
- Asik MB, Karasimav O, Birkent H, Merati AL, Gerek M, Yildiz Y (2015) Airway and respiration parameters improve following vocal fold medialization a prospective study. *Ann Otol Rhinol Laryngol* 124(12):972–977
- Bielamowicz S, Berke GS, Gerratt BR (1995) A comparison of type I thyroplasty and arytenoid adduction. *J Voice* 9(4):466–472
- Billante CR, Clary J, Childs P, Netterville JL (2002) Voice gains following thyroplasty may improve over time. *Clin Otolaryngol Allied Sci* 27(2):89–94
- Borel S, Crevier-Buchman L, Tessier C, Hans S, Laccourreye O, Brasnu D (2004) Quality of life before and after thyroplasty for vocal fold paralysis. *Revue de laryngologie-otologie-rhinologie* 125(5):287–290
- Bryant NJ, Gracco LC, Sasaki CT, Vining E (1996) MRI evaluation of vocal fold paralysis before and after type I thyroplasty. *Laryngoscope* 106(11):1386–1392
- Cantillo-Baños E, Jurado-Ramos A, Gutiérrez-Jódas J, Ariza-Vargas L (2013) Vocal fold insufficiency: medialization laryngoplasty vs calcium hydroxylapatite microspheres (Radiess Voice®). *Acta Oto-laryngol* 133(3):270–275
- Choi HS, Chung SM, Lim JY, Kim HS (2008) Increasing the closed quotient improves voice quality after type I thyroplasty in patients with unilateral vocal cord paralysis: analysis using SPEAD program. *J Voice* 22(6):751–755
- Chowdhury K, Saha S, Saha VP, Pal S, Chatterjee I (2013) Pre and post operative voice analysis after medialization thyroplasty in cases of unilateral vocal fold paralysis. *Indian J Otolaryngol Head Neck Surg* 65(4):354–357
- Chhetri DK, Gerratt BR, Kreiman J, Berke GS (1999) Combined arytenoid adduction and laryngeal reinnervation in the treatment of vocal fold paralysis. *Laryngoscope* 109(12):1928–1936
- Dastolfo C, Gartner-Schmidt J, Yu L, Carnes O, Gillespie AI (2015) Aerodynamic outcomes of four common voice disorders: moving toward disorder-specific assessment. *J Voice* 30(3):301–307
- Desuter G, Henrard S, Boucquoy D, Van Boven M, Gardiner Q, Remacle M (2015 Feb) Learning curve of medialization thyroplasty using a Montgomery™ implant. *Eur Arch Otorhinolaryngol* 272(2):385–390
- Devos M, Schultz P, Guilleré F, Debry C (2010) Thyroplasty for unilateral vocal fold paralysis using an adjustable implant in porous titanium. *Eur Ann Otorhinolaryngol Head Neck Dis* 127(6):204–212
- Elnashar I, El-Anwar M, Amer H, Quriba A (2015) Voice outcome after gore-tex medialization thyroplasty. *Int Arch Otorhinolaryngol* 19(3):248–254
- Gliklich RE, Glovsky RM, Montgomery WM (1999) Validation of a voice outcome survey for unilateral vocal cord paralysis. *Otolaryngol Head Neck Surg* 120(2):153–158
- Gray SD, Barkmeier J, Jones D, Titze I, Druker D (1992) Vocal evaluation of thyroplastic surgery in the treatment of unilateral vocal fold paralysis. *Laryngoscope* 102(4):415–421
- Guerrero J, Cobeta I, García-Díaz JD, Vegas A, Montojo J, Lorenzo F, Mate A (1998) Surgery of the laryngeal framework: type I thyroplasty. *Acta Otorrinolaringol Esp* 49(1):45–49
- Hajioff D, Rattenbury H, Carrie S, Carding P, Wilson J (2000) The effect of Isshiki type I thyroplasty on quality of life and vocal performance. *Clin Otolaryngol Allied Sci* 25(5):418–422
- Harries ML, Morrison M (1995) Short-term results of laryngeal framework surgery—thyroplasty type I: a pilot study. *J Otolaryngol* 24(5):281–287
- Havas TE, Priestley KJ (2003) Autologous fat injection laryngoplasty for unilateral vocal fold paralysis. *ANZ J Surg* 73(11):938–943
- Hogikyan ND, Wodchis WP, Terrell JE, Bradford CR, Esclamado RM (2000) Voice-related quality of life (V-RQOL) following type I thyroplasty for unilateral vocal fold paralysis. *J Voice* 14(3):378–386
- Jang JY, Lee G, Ahn J, Son YI (2015) Early voice rehabilitation with injection laryngoplasty in patients with unilateral vocal cord palsy after thyroidectomy. *Eur Arch Otorhinolaryngol* 272(12):3745–3750
- Konomi U, Watanabe Y, Komazawa D (2014) Application of pitch range evaluation subsequent to arytenoid adduction and thyroplasty. *J Voice* 28(3):394–395
- Kraus DH, Orlikoff RF, Rizk SS, Rosenberg DB (1999) Arytenoid adduction as an adjunct to type I thyroplasty for unilateral vocal cord paralysis. *Head neck* 21(1):52–59
- Laccourreye O, Sharkawy E, Holsinger L, Hans FC, Ménard S, M., & Brasnu D (2005) Thyroplasty type I with montgomery implant among native French language speakers with unilateral laryngeal nerve paralysis. *Laryngoscope* 115(8):1411–1417
- Leder SB, Sasaki CT (1994) Long-term changes in vocal quality following isshiki thyroplasty type I. *Laryngoscope* 104(3):275–277
- Lee WT, Milstein C, Hicks D, Akst LM, Esclamado RM (2007) Results of ansa to recurrent laryngeal nerve reinnervation. *Otolaryngol Head Neck Surg* 136(3):450–454
- Li AJ, Johns MM, Jackson-Menaldi C, Dailey S, Heman-Ackah Y, Merati A, Rubin AD (2011) Glottic closure patterns: type I thyroplasty versus type I thyroplasty with arytenoid adduction. *J Voice* 25(3):259–264
- Lorenz RR, Esclamado RM, Teker AM, Strome M, Scharpf J, Hicks D, & Lee WT (2008) Ansa cervicalis-to-recurrent laryngeal

- nerve anastomosis for unilateral vocal fold paralysis: experience of a single institution. *Ann Otol Rhinol Laryngol* 117(1):40–45
33. Lu FL, Casiano RR, Lundy DS, Xue JW (1996) Longitudinal evaluation of vocal function after thyroplasty type I in the treatment of unilateral vocal paralysis. *Laryngoscope* 106(5):573–577
 34. Lu FL, Lundy DS, Casiano RR, Xue JW (1998) Vocal evaluation of thyroplasty type I in the treatment of nonparalytic glottic incompetence. *Ann Otol Rhinol Laryngol* 107(2):113–119
 35. Lundy DS, Casiano RR, Mc Clinton ME, & Xue JW (2003) Early results of transcutaneous injection laryngoplasty with micronized acellular dermis versus type-I thyroplasty for glottic incompetence dysphonia due to unilateral vocal fold paralysis. *J Voice* 17(4):589–595
 36. Lundy DS, Casiano RR, Xue JW (2004) Can maximum phonation time predict voice outcome after thyroplasty type I? *Laryngoscope* 114(8):1447–1454
 37. Lundy DS, Casiano RR, Xue JW, Lu FL (2000) Thyroplasty type I: short- versus long-term results. *Otolaryngol Head Neck Surg* 122(4):533–536
 38. Mahieu H, Norbart TH, Snel F (1996) Laryngeal framework surgery for voice improvement. *Revue de laryngologie-otologie-rhinologie* 117(3):189–197
 39. Malik A, Ramalingam WVBS., Nilakantan A, Nair S, Ramesh AV, Raj P (2014) Comparison of the use of silastic with titanium prefabricated implant in type I thyroplasty. *Braz J Otorhinolaryngol* 80(2):156–160
 40. Manfredi C, Peretti G (2006) A new insight into postsurgical objective voice quality evaluation: application to thyroplastic medialization. *IEEE Trans Biomed Eng* 53(3):442–451
 41. Matar N, Remacle M, Bachy V, Lawson G, Giovanni A, Lejoly-Devuyst V, Legou T (2012) Objective measurement of real time subglottic pressure during medialization thyroplasty: a feasibility study. *Eur Arch Otorhinolaryngol* 269(4):1171–1175
 42. McLean-Muse A, Montgomery WW, Bunting G, Hillman RE, Doyle P, Varvares M, Eng J (2000) Montgomery® thyroplasty implant for vocal fold immobility: phonatory outcomes. *Ann Otol Rhinol Laryngol* 109(4):393–400
 43. Mohammed H, Masterson L, Gendy S, Nassif R (2016) Outpatient based injection laryngoplasty for the management of unilateral vocal fold paralysis-clinical outcomes from a UK centre. *Clin Otolaryngol* 41(4):341–346
 44. Morgan JE, Zraick RI, Griffin AW, Bowen TL, Johnson FL (2007) Injection versus medialization laryngoplasty for the treatment of unilateral vocal fold paralysis. *Laryngoscope* 117(11):2068–2074
 45. Mortensen M, Carroll L, Woo P (2009) Arytenoid adduction with medialization laryngoplasty versus injection or medialization laryngoplasty: the role of the arytenoidopexy. *Laryngoscope* 119(4):827–831
 46. Murata T, Yasuoka Y, Shimada T, Shino M, Iida H, Takahashi K, Furuya N (2011) A new and less invasive procedure for arytenoid adduction surgery. *Laryngoscope* 121(6):1274–1280
 47. Nouwen J, Hans S, De Mones E, Brasnu D, Crevier-Buchman L, Laccourreye O (2004) Thyroplasty type I without arytenoid adduction in patients with unilateral laryngeal nerve paralysis: the Montgomery implant versus the Gore-Tex implant. *Acta otolaryngol* 124(6):732–738
 48. Omori K, Slavit DH, Kacker A, Blaugrund SM (1996) Quantitative criteria for predicting thyroplasty type I outcome. *Laryngoscope* 106(6):689–693
 49. Paniello RC, Edgar JD, Kallogjeri D, Piccirillo JF (2011) Medialization versus reinnervation for unilateral vocal fold paralysis: a multicenter randomized clinical trial. *Laryngoscope* 121(10):2172–2179
 50. Parker NP, Barbu AM, Hillman RE, Zeitel SM, Burnas JA (2015) Revision transcervical medialization laryngoplasty for unilateral vocal fold paralysis. *Otolaryngol Head Neck Surg* 153(4):593–598
 51. Peretti G, Provenzano L, Piazza G, Giudice M, Antonelli AR (2001). Risultati funzionali dopo tiroplastica di I tipo con protesi di Montgomery. *Acta Otorhinolaryngol Ital*, 21, 156–161
 52. Prendes BL, Yung KC, Likhterov I, Schneider SL, Al-Jurf SA, Courey MS (2012) Long-term effects of injection laryngoplasty with a temporary agent on voice quality and vocal fold position. *Laryngoscope* 122(10):2227–2233
 53. Ryu IS, Nam SY, Han MW, Choi SH, Kim SY, Roh JL (2012) Long-term voice outcomes after thyroplasty for unilateral vocal fold paralysis. *Arch Otolaryngol Head Neck Surg* 138(4):347–351
 54. Sakai N, Nishizawa N, Matsushima JJ, Kurihara H, Kokubun T, Koichi KI, ... & Inuyama Y (1996) Thyroplasty type I with ceramic shim. *Artif Organs* 20(8):951–954
 55. Sasaki CT, Leder SB, Petcu L, Friedman CD (1990). Longitudinal voice quality changes following Isshiki thyroplasty type I: the Yale experience. *Laryngoscope* 100(8), 849–852
 56. Schwarz K, Cielo CA, Steffen N, Becker J, Jotz GP (2011) Voice and laryngeal configuration of men with unilateral vocal fold paralysis before and after medialization. *J Voice* 25(5):611–618
 57. Shin JE, Nam SY, Yoo SJ, Kim SY (2002) Analysis of voice and quantitative measurement of glottal gap after thyroplasty type I in the treatment of unilateral vocal paralysis. *J Voice* 16(1):136–142
 58. Smith ME, Houtz DR (2016) Outcomes of laryngeal reinnervation for unilateral vocal fold paralysis in children: associations with age and time since injury. *Ann Otol Rhinol Laryngol* 125(5):433–438
 59. Sonoda S, Kataoka H, Inoue T (2005) Traction of lateral cricoarytenoid muscle for unilateral vocal fold paralysis: comparison with Isshiki's original technique of arytenoid adduction. *Ann Otol Rhinol Laryngol* 114(2):132–138
 60. Sridhara SR, Ashok KG, Raghunathan M, Mann SBS (2003) To study voice quality before and after thyroplasty type I in patients with symptomatic unilateral vocal cord paralysis. *Am J Otolaryngol* 24(6):361–365
 61. Stuut M, Gi RETP., Dikkers FG (2014) Change of voice handicap index after treatment of benign laryngeal disorders. *Eur Arch Otorhinolaryngol* 271(5):1157–1162
 62. Suehiro A, Hirano S, Kishimoto Y, Tanaka S, Ford CN (2009). Comparative study of vocal outcomes with silicone versus Gore-Tex thyroplasty. *Ann Otol Rhinol Laryngol* 118(6):405–408
 63. Thompson DM, Maragos NE, Edwards BW (1995) The study of vocal fold vibratory patterns in patients with unilateral vocal fold paralysis before and after type I thyroplasty with or without arytenoid adduction. *Laryngoscope* 105(5):481–486
 64. Tokashiki R, Hiramatsu H, Shinada E, Motohashi R, Nomoto M, Toyomura F, Suzuki M (2012) Analysis of pitch range after arytenoid adduction by fenestration approach combined with type I thyroplasty for unilateral vocal fold paralysis. *J Voice* 26(6):792–796
 65. Tokashiki R, Hiramatsu H, Tsukahara K, Kanabayashi H, Nakamura M, Motohashi R, Yamada T, Suzuki M (2007) A “fenestration approach” for arytenoid adduction through the thyroid ala combined with type I thyroplasty. *Laryngoscope* 117(10):1882–1887
 66. Tucker HM (1999) Long-term preservation of voice improvement following surgical medialization and reinnervation for unilateral vocal fold paralysis. *J Voice* 13(2):251–256
 67. Umeno H, Chitose S, Sato K, Nakashima T (2009) Comparative study of framework surgery and fat injection laryngoplasty. *J Laryngol Otol* 123(S31):35–41
 68. Umeno H, Chitose SI, Sato K, Nakashima T (2008) Efficacy of additional injection laryngoplasty after framework surgery. *Ann Otol Rhinol Laryngol* 117(1):5–10
 69. Umeno H, Chitose SI, Sato K, Ueda Y, Nakashima T (2012) Long-term postoperative vocal function after thyroplasty type

- I and fat injection laryngoplasty. *Ann Otol Rhinol Laryngol* 121(3):185–191
70. Vinson KN, Zraick RI, Ragland FJ (2010). Injection versus medialization laryngoplasty for the treatment of unilateral vocal fold paralysis. *Laryngoscope* 120(9):1802–1807.
 71. Wen MH, Cheng PW, Liao LJ, Chou HW, Wang CT (2013) Treatment outcomes of injection laryngoplasty using cross-linked porcine collagen and hyaluronic acid. *Otolaryngol Head Neck Surg*. <https://doi.org/10.1177/0194599813508082>.
 72. Zur KB, Carroll LM (2015) Recurrent laryngeal nerve reinnervation in children: acoustic and endoscopic characteristics pre-intervention and post-intervention. A comparison of treatment options. *Laryngoscope* 125(S11):S1–S15
 73. Jacobson BH, Johnson A, Silbergerit GrywalskiC, Jacobson A, Benninger G, Newman MS; C.W (1997))The voice handicap index (VHI): development and validation. *Am J Speech Lang Pathol* 6:66–70
 74. Siu J, Tam S, Fung K (2016) A comparison of outcomes in interventions for unilateral vocal fold paralysis: a systematic review. *Laryngoscope* 126(7):1616–1624
 75. Dejonckere PH, Bradley P, Clemente P, Cornut G, Crevier-Buchman L, FriedrichG, Van De Heyning P, Remacle M, Woisard V; Committee on Phoniatrics of the European Laryngological Society (ELS) (2001) A basic protocol for functional assessment of voice pathology, especially for investigating the efficacy of (phonosurgical) treatments and evaluating new assessment techniques. Guideline elaborated by the Committee on Phoniatrics of the European Laryngological Society (ELS). *Eur Arch Otorhinolaryngol* 258(2):77–82
 76. Rosen CA, Mau T, Remacle M, Hess M, Eckel HE, Young VN, Hantzakos A, Yung KC, Dikkers FG (2016) Nomenclature proposal to describe vocal fold motion impairment. *Eur Arch Otorhinolaryngol* 273(8):1995–1999
 77. Young VN, Zullo TG, Rosen CA (2010) Analysis of laryngeal framework surgery: 10-year follow-up to a national survey. *Laryngoscope* 120(8):1602–1608
 78. Dastolfo C, Gartner-Schmidt J, Yu L, Carnes O, Gillespie AI (2016) Aerodynamic outcomes of four common voice disorders: moving toward disorder-specific assessment. *J Voice* 30(3):301–307
 79. Woo P, Casper J, Colton R, Brewer D (1994) Aerodynamic and stroboscopic findings before and after microlaryngeal surgery. *J Voice* 8(2):186–194
 80. Webb AL, Carding PN, Deary IJ, MacKenzie K, Steen N, Wilson JA (2004) The reliability of three perceptual evaluation scales for dysphonia. *Eur Arch Otorhinolaryngol* 261(8):429–434
 81. Ghio A, Revis J, Merienne S, Giovanni A (2013) Top-down mechanisms in dysphonia perception: the need for blind tests. *J Voice* 27(4):481–485