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Injection Pharyngoplasty With a Hyaluronic Acid and Dextranomer Copolymer to Treat Velopharyngeal Insufficiency in Adults

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Abstract

Objective: To describe the treatment of adult velopharyngeal insufficiency (VPI) with injection of a hyaluronic acid and dextranomer copolymer (Dx/HA).

Patients and Methods: This was a retrospective case series of 25 consecutively treated adults with VPI who underwent Dx/HA injection pharyngoplasty in a multidisciplinary clinic from January 1, 2011, to December 31, 2014. Data recorded included etiology of VPI, perceptual analysis of resonance, nasalance scores, and estimation of velopharyngeal gap characteristics on video nasendoscopy before and after the intervention. Statistical comparisons were made using a 2-tailed Wilcoxon signed rank test and the Kruskal-Wallis test.

Results: Patients had VPI due to a neurologic etiology, due to a benign anatomic etiology, or acquired after treatment for a head and neck malignancy. Injections were performed with local anesthesia, monitored anesthesia care, or general anesthesia. There were statistically significant improvements in speech resonance, nasalance, and velopharyngeal gap size after treatment. Patients with neurologic or benign anatomic etiologies of their VPI had more significant improvement than those with VPI after treatment of malignancy. Nineteen of the 25 patients required only 1 injection to achieve their final result.

Conclusion: Injection pharyngoplasty with a readily available Dx/HA is an effective treatment for VPI that allows for titration to complete velopharyngeal closure under local anesthesia or light sedation. It is most effective in patients with nonmalignant etiologies of VPI and in those with good lateral wall motion. Complications experienced were postoperative neck pain and occult retropharyngeal fluid collection, highlighting the importance of follow-up.

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The velopharyngeal sphincter is formed from the muscles of the soft palate and the lateral and posterior pharyngeal walls. Its proper function separates the oral and nasal cavities during speech and swallowing. Incomplete closure, known as velopharyngeal insufficiency (VPI), can manifest with hypernasality, perceptual speech errors, or nasal regurgitation during swallowing.[1] In children, VPI is most commonly related to craniofacial abnormalities, including cleft palate and neuromuscular hypotonia, or is acquired after adenoidectomy. In adults, VPI most commonly is a consequence of neurologic disease or loss of functional tissue after treatment of benign or malignant lesions.

Nonsurgical treatment of VPI can include speech or swallowing therapy or a palatal lift obturator, but it most often requires surgical intervention. Traditionally, procedures such as posterior pharyngeal flap, sphincter pharyngoplasty, or double-opposing Z-palatoplasty have been used to reduce the size of the velopharyngeal gap.[1-5] These surgical procedures have proved to be successful in most patients but also carry substantial perioperative morbidity, including pain, reduced oral intake, bleeding, hospitalization, and risk of postoperative obstructive sleep apnea.[6] Another technique is injection pharyngoplasty, whereby materials are injected into the posterior velopharynx to add bulk and reduce a velopharyngeal gap. Many types of injected material have been used, including autologous fat[7] and exogenous fillers such as hyaluronic acid and calcium hydroxyapatite.[8]

Results of injection pharyngoplasty are promising, with improvement in patients' VPI and with less morbidity than traditional surgical repairs.[9,10] However, optimal patient selection and the ideal injection material have yet to be determined. A copolymer gel consisting of hyaluronic acid and dextran polymer microspheres (Dx/HA) has been used with success in the treatment of vesicoureteral reflux,[11,12] an anatomic deficiency of a sphincter similar to that in VPI. Herein, we report the first series of adult patients treated for VPI with injection pharyngoplasty using Dx/HA. We also discuss the indications, complications, efficacy, and durability of this minimally invasive technique.

PATIENTS AND METHODS

A single-center, retrospective review of 25 consecutively treated adult patients who underwent injection pharyngoplasty for VPI from January 1, 2011, through December 30, 2014, was completed. This study was approved by the Mayo Clinic Institutional Review Board. The study patients represented the initial 25 adult patients who were offered injection pharyngoplasty with Dx/HA. There were no inclusion or exclusion criteria applied, and patients were offered injection pharyngoplasty if they had symptomatic VPI. Before treatment, patients were informed that the use of Dx/HA in the pharynx was off-label, and all the patients agreed to proceed. All the procedures were performed by the senior author (S.A.C.).

Patients were evaluated in a multidisciplinary clinic with an otolaryngologist and a speech-language pathologist. A thorough evaluation of the etiology of each patient's VPI was undertaken before treatment because VPI can be the presenting symptom of a more serious condition. A standardized multidisciplinary evaluation performed during each clinic visit consisted of a speech evaluation to determine perceptual judgment of nasality, presence of nasal grimace and nasal emission, and instrumental assessment of nasalance. This evaluation was followed by flexible nasopharyngoscopy, with a standardized speech sample elicited during direct visualization of velopharyngeal function. Data recorded included the perceptual rating of nasality as scored by a speech-language pathologist according to a subjective scale of normal resonance, or mild, moderate, or severe hypernasality. Nasalance was recorded using a Nasometer II (model 6450; KayPENTAX) while reading the zoo passage. The zoo passage is a standardized sample of connected speech with a mean ± SD nasalance of 11.25%± 5.63% in normal English-speaking adults.[13] Nasalance data were not available for every patient because we began obtaining this objective value of nasal resonance in 2012. Velopharyngeal gap size and velopharyngeal closure pattern were recorded during flexible nasopharyngoscopy. Gap sizes were scored according to a standardized scale[14]: small gaps as less than 20% of the resting velopharynx, moderate gaps as 20% to 50%, and large gaps as greater than 50%. Closure was described as a circular or coronal pattern with no, poor, or full lateral wall motion.

After injection pharyngoplasty, patients were requested to return to the VPI clinic for follow-up 4 to 6 weeks postoperatively and again every 6 months, or sooner if recurrent symptoms of VPI developed. At each visit, the standardized multidisciplinary evaluation described previously herein was repeated. If patients were deemed to have VPI limiting speech intelligibility or swallowing, repeated injection was offered. All the patients attended at least 1 follow-up appointment.

Statistical Analyses

Presurgical and postsurgical measures of perceptual speech nasality, nasalance, and estimated velopharyngeal gap size were analyzed. Categorical variables (speech nasality and gap size) are presented in contingency tables, and the continuous variable (nasalance) is presented as median (range). Although this is largely a descriptive report of our initial experiences with a novel surgical method of treating adults with VPI, limited statistical analyses were performed on these paired measures using a 2-tailed Wilcoxon signed rank test and the Kruskal-Wallis test. A Kruskal-Wallis test was also used to assess for a difference in response to injection pharyngoplasty with Dx/HA based on the etiology of a patient's VPI. Statistical comparisons were made between the preoperative values and data obtained at the patient's initial follow-up visit. Data obtained during any subsequent follow-up evaluations,

including responses to repeated injections, were not included in the statistical analysis due to the wide variety in follow-up times in the study cohort. Statistical analysis was performed using SAS software, version 9.4 (SAS Institute Inc).

Operative Technique

Early in the series, patients underwent injection pharyngoplasty either in the office under local anesthesia or in the operating room under general anesthesia. With local anesthesia, an assistant performing flexible nasopharyngoscopy allowed direct visualization of a transoral injection into the precise location of a velopharyngeal gap noted on a video screen, and real-time speech samples allowed titration of the amount of filler injected for closure of the gap. Under general anesthesia, the patient was suspended with a McIvor mouth gag, and injection was performed transorally into the location of the velopharyngeal gap identified during presurgical evaluation, which was saved in video format and reviewed at the time of the operation. With time, our preferred technique evolved to a combination of local anesthesia and light sedation under monitored anesthesia care. The final 15 patients underwent injection pharyngoplasty with this light sedation that also allows real-time speech samples and titration of injection similar to the process with an awake injection with local anesthesia but with improved patient comfort.

Every patient underwent injection pharyngoplasty with Dx/HA (Deflux; Salix Pharmaceuticals). Patients were informed that Dx/HA is approved by the Food and Drug Administration for human use in urologic practice and for treatment of anal incompetence (Solesta; Salix Pharmaceuticals) but that its use in the pharynx is considered off-label.

RESULTS

The mean ± SD age of the 25 patients was 43.0±18.8 years, and there were 13 men (52%) and 12 women (48%) in the group. Hypernasality, the most common symptom of VPI, ranged from mild to severe hypernasal resonance. The most common size of a velopharyngeal gap was small, but moderate and large gaps were also treated (Table 1). Of 33 total injections in 25 patients, 8 were performed under general anesthesia, 10 under local anesthesia in the office, and 15 under monitored anesthesia care with light sedation in the operating room. The amount of Dx/HA injected increased with increasing velopharyngeal gap size: small gaps were injected with a mean of 2.5 mL compared with 3.5 and 4.1 mL for moderate and large gaps, respectively.

TABLE 1. Preoperative Characteristics of the 25 Study Patients

Characteristic	Patients (No. [%])
Age	
18-30 y	9 (36)
31-60 y	11 (44)
≥61 y	5 (20)
Sex	
Male	13 (52)
Female	12 (48)
Preoperative hypernasality	
Mild	6 (24)
Moderate	10 (40)
Severe	9 (36)
Preoperative gap size	
Small (<20%)	12 (48)
Moderate (20%-50%)	10 (40)
Large (>50%)	3 (12)
Closure pattern	
Coronal	17 (68)
Circular	8 (32)
Etiology of VPI	
Neurologic	13 (52)
Anatomic, benign	8 (32)
Anatomic, malignant	4 (16)

VPI = velopharyngeal insufficiency.

Efficacy

Overall, 19 of the 25 patients had an improvement in their perceptual nasal resonance after their first injection pharyngoplasty with Dx/HA, 5 patients had stable resonance, and 1 patient was noted to have increased hypernasality (Table 2). Due to the retrospective nature of this analysis, the time to the first follow-up visit was variable, with a median time of 2.6 months (range, 0.5-23 months). In comparing across all patients, there was a significant improvement in speech hypernasality after Dx/HA injection pharyngoplasty ($P \leq .001$, Wilcoxon signed rank test). In 18 patients with nasometry data available, there was also a significant improvement in

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nasalance, with median preoperative nasalance of 46% (range, 16%-73%) improving to 36% (range, 8%-70%) postoperatively (P=.008, Wilcoxon signed rank test). The median difference between preoperative and postoperative nasalance was −6.0% (range, −44% to 4%). Injection pharyngoplasty with Dx/HA was also effective in reducing the size of a velopharyngeal gap (P<.001, Wilcoxon signed rank test).

Velopharyngeal insufficiency can also manifest as nasal regurgitation during swallowing. In this series, 12 of the 25 patients endorsed nasal regurgitation at initial presentation. Six of these patients had an improvement in nasal regurgitation after injection pharyngoplasty, 2 patients did not, and data were not available for 4 patients.

Overall, median total follow-up was 7.4 months, with a range of 0.9 to 36.7 months. Most patients (19 of 25) needed just 1 injection. In the 6 patients who did require a second injection, the median follow-up time until they requested a second intervention was 6.5 months (range, 1.2-26.0 months). There were 33 injections given in this series among the 25 patients.

TABLE 2. Contingency Table Showing Preoperative and Postoperative Perceptual Nasal Resonance and Velopharyngeal Gap Size

Preoperative hypernasality	Postoperative hypernasality				
	Normal	Mild	Moderate	Severe	Total
Mild	3	2	1	0	6
Moderate	5	3	2	0	10
Severe	2	5	1	1	9
Total	10	10	4	1	25

Preoperative gap size	Postoperative gap size[a]				
	None	Small	Moderate	Large	Total
Small (<20%)	7	5	0	0	12
Moderate (20%-50%)	4	5	1	0	10
Large (>50%)	0	0	2	1	3
Total	11	10	3	1	25

[a]Gap size scale: small (<20% of the resting velopharynx), moderate (20%-50%), large (>50%).

Etiology of VPI

It was noted during data analysis that there may be a difference in how patients respond to injection pharyngoplasty with Dx/HA based on the etiology of their VPI. Patients were identified as falling into 1 of 3 categories: 13 with neurologic pathology, 8 with a benign anatomic process causing VPI, and 4 with an anatomic deficiency after treatment for malignancy of the palate or nasopharynx (Table 3). Patients with a neurologic etiology of their VPI most commonly had iatrogenic vagal paralysis after resection of a vagal paraganglioma or schwannoma, but several patients also experienced cranial neuropathies as a consequence of stroke, progressive neurologic disease, or neuromuscular disease. Patients with a benign anatomic cause of their VPI most commonly had a history of cleft palate and had undergone previous palate surgery but had persistent velopharyngeal gaps. Patients with VPI after treatment of malignancy had received multimodality treatment for oropharyngeal or nasopharyngeal malignancy, including radiotherapy in each of these patients. When comparing outcomes across these 3 groups, there was a significant difference in how speech hypernasality improved after Dx/HA injection (P=.008, Kruskal-Wallis test) but not nasalance (P=.35, Kruskal-Wallis test).

It was noted that patients with anatomic deficiencies after treatment of a nasopharyngeal or oropharyngeal malignancy tended to have less favorable outcomes after injection pharyngoplasty with Dx/HA. Three of the 4 patients in this category had an improvement in their symptoms for 1 to 3 weeks but had early recurrence of symptoms and velopharyngeal gap by the first follow-up appointment (Table 3). One of these patients opted for a palatal lift prosthesis, and the other 2 underwent a repeated injection. Patients with a neurologic etiology or benign anatomical deficiency seemed to have a more predictable and durable response.

Subgroups based on patterns of velopharyngeal closure and lateral wall motion were also considered. Statistical evaluation was not performed because of small sample size, but comparing patients with coronal or circular patterns of velopharyngeal closure, there did not seem to be a difference in their preoperative perceptual speech resonance, nasalance, or postoperative outcomes. The gap size and degree of lateral wall motion did seem to play a small role in the response to injection pharyngoplasty, although not tested statistically. Small gaps seemed to be easier to close

with Dx/HA than moderate gaps, and large gaps tended to be difficult to close even with repeated injections. In addition, patients with full lateral wall motion seemed to be more responsive to Dx/HA injection than those with poor motion of the lateral pharyngeal walls. Patients with no lateral wall motion had a poor response to treatment, although there were only 2 patients in this group.

Complications

No patients had postoperative bleeding complications and no patients experienced symptoms of obstructive sleep apnea, although no objective measure of sleep apnea was used. Complications that were noted tended to arise in 2 categories: postoperative pain and retropharyngeal fluid collection. Most patients found that postoperative pain was manageable with nonsteroidal anti-inflammatory medication. Three patients had substantial difficulty with postoperative odynophagia (Table 3). One patient had a history of muscle spasms, which flared after injection and improved with use of outpatient muscle relaxants. The other 2 patients required admission to the hospital for intravenous rehydration and pain control. One of these patients experienced an aspiration event, thought to be related to nausea with opiate therapy, and required treatment for pneumonia. Anecdotally, it did seem that patients with a malignant etiology of their VPI had more postoperative pain than those with other etiologies.

Two patients had development of retropharyngeal fluid collections: 1 that was asymptomatic and noted as pharyngeal fullness during follow-up examination 8 months postoperatively, and 1 that manifested as malaise and dysphagia 1 month postoperatively. Both patients required transoral incision and drainage with long-term resolution of the fluid collections. Neither patient had fever, pain, or airway compromise associated with the fluid collections. Representative images from one of these patients' nasopharyngoscopy and computed tomographic scan are shown in the Figure.

DISCUSSION

Hyaluronic acid and dextranomer copolymer has a proven track record of safety, efficacy, and durability in the treatment of vesicoureteral reflux in urologic practice.[11,12] It has also been used to treat vocal cord paresis and bowing, with promising results.[15] Histologic studies have demonstrated that the hyaluronic acid portion acts as a transport medium and dissipates from the site of injection within several weeks. The tissue bulking effect is primarily driven by an immunologic reaction to the dextranomer microspheres, which stimulate collagen synthesis and influx of fibroblasts and myofibroblasts to create a consolidated bulking of tissue.[16-18]

Many different materials have been used for injection pharyngoplasty in the past, such as Teflon, paraffin, silicone, collagen, cartilage, fat, and calcium hydroxyapatite.[7,8] All have certain shortcomings, including migration and foreign-body granulomatous reactions (Teflon), resorption (fat), or requirement of donor site morbidity (autologous fat and cartilage). In this case series, we demonstrate promising clinical results in using Dx/HA for the treatment of VPI in adults caused by a wide range of etiologies. Although there have not been any trials to directly compare the 2, we find that Dx/HA has more reliable and predictable results than autologous fat injection. If performed in an operating room setting, we would posit that injection with Dx/HA results in reduced operative time and, therefore, health care costs. In addition, injection pharyngoplasty with Dx/HA performed in awake patients or under a light sedation allows real-time speech samples to guide precise placement and volume of injection, an option not available when injecting autologous fat.

As in any surgical procedure, correct patient selection is just as important as operative technique. This series suggests that injection pharyngoplasty with Dx/HA is most effective in patients with small to moderate-sized velopharyngeal gaps and a neurologic or benign anatomic etiology of their VPI. In addition, those with a better degree of lateral pharyngeal wall motion seemed to have improved results after injection pharyngoplasty. Although there were only 2 such patients, those with absent lateral wall motion had poor outcomes in terms of perceptual speech resonance. This is consistent with previous knowledge of the contribution of lateral wall motion to successful correction of VPI.[19]

Patients with a history of malignancy tended to have less durable results, with

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TABLE 3. Outcomes of Initial Injection Pharyngoplasty With Dx/HA, by Etiology[a]

Patient No.[b]	Etiology	Age (y)	Preoperative Gap size[c]	Preoperative Nasality[d]	Preoperative Nasalance (%)	Postoperative Gap size[c]	Postoperative Nasality[d]	Postoperative Nasalance (%)	First follow-up (mo)	Injections (No.)	Anesthesia[e]	Total follow-up (mo)	Complications
Neurologic etiology													
4	Vagal paraganglioma, resected	58	Small	3	-	Small	1	-	2.6	3	G, L, M	36.7	None
5	Collett-Sicard syndrome	66	Moderate	3	-	None	0	-	7.6	1	G	8.2	Retropharyngeal fluid
7	Bulbar neuropathy (CNS vasculitis)	47	Small	2	73	Small	1	33	3.0	2	L, G	22.9	None
9	Vagal schwannoma, resected	77	Small	2	25	None	0	-	9.2	1	L	9.2	None
10	Brain stem stroke, vagal paralysis	46	Small	2	-	None	0	30	4.8	1	G	4.8	None
12	Idiopathic myopathy	50	Small	1	22	Small	0	26	21.4	1	L	21.4	None
14	Multiple sclerosis	27	Moderate	3	62	Small	0	42	3.0	2	G, M	4.0	None
17	Idiopathic	29	Small	1	16	None	0	33	8.6	1	M	8.6	None
18	Iatrogenic vagal sacrifice	68	Small	2	56	None	0	50	3.0	1	M	12.0	None
19	Vagal paraganglioma, resected	47	Moderate	1	29	Small	1	31	3.2	1	M	3.9	Retropharyngeal fluid
20	Hereditary ataxia syndrome	52	Moderate	3	52	None	1	37	0.9	1	M	0.9	None
22	Vagal paraganglioma, resected	67	Small	2	35	None	0	19	1.1	1	M	1.1	None
24	Myasthenia gravis	22	Moderate	3	69	None	1	61	1.2	1	M	7.6	None
Anatomic, benign etiology													
3	Cleft palate, maxillary advancement	19	Large	3	-	Moderate	2	-	0.5	1	L	27.5	Pain
6	Cleft palate, pharyngeal flap	22	Small	2	42	Small	1	43	1.6	1	G	1.6	None
11	Velocardiofacial syndrome	18	Moderate	3	69	None	1	70	2.2	1	G	23.0	None
13	Cleft palate, pharyngeal flap	46	Moderate	2	52	Small	1	39	23.2	2	L, M	23.3	None
15	Cleft palate, pharyngeal flap	18	Small	2	32	None	0	27	1.0	1	G	1.0	None
16	Transpalatal Chiari decompression	42	Small	3	70	Small	1	70	1.2	1	M	1.2	Neck spasms
23	Submucous cleft palate, Teflon injection	48	Small	1	35	None	0	28	0.7	1	M	6.7	None
25	Hemifacial microsomia, free flap reconstruction	19	Moderate	1	49	Small	1	22	1.4	1	M	1.4	None
Anatomic, malignant etiology													
1	Palate carcinoma, oronasal fistula	51	Large	2	-	Large	2	-	1.9	1	L	1.9	None
2	Nasopharyngeal carcinoma	50	Moderate	2	-	Small	2	-	3.5	1	L	7.4	Pain, aspiration
8	Nasopharyngeal sarcoma	18	Large	3	53	Moderate	3	53	10.8	3	L, L, M	14.4	None
21	Oropharyngeal carcinoma	69	Moderate	1	40	Moderate	2	42	1.2	2	M, M	7.2	None

[a]CNS = central nervous system; Dx/HA = hyaluronic acid and dextranomer copolymer; - = indicates no data is available.

[b]Patient number refers to the chronologic order of patients treated.

[c]Gap size scale: small, less than 20% of the resting velopharynx; moderate, 20% to 50%; and large, greater than 50%.

[d]Hypernasality scale: 0, normal; 1, mild; 2, moderate; and 3, severe.

[e]Anesthetic type key: L, local; M, monitored anesthesia care with light sedation; and G, general.

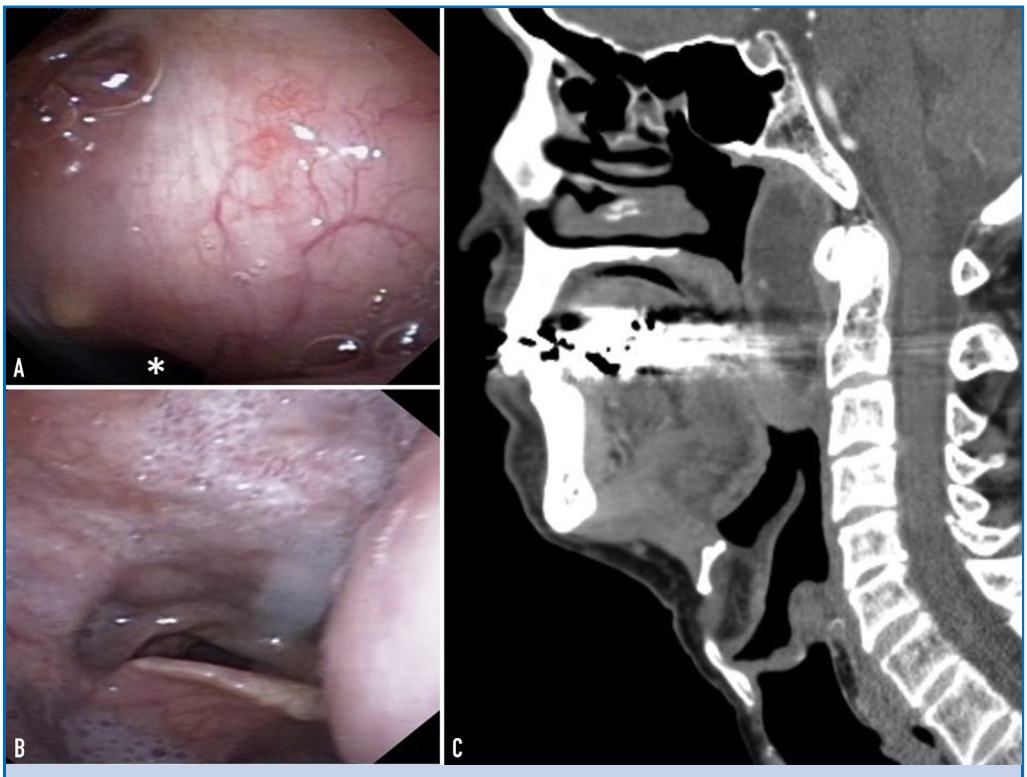

FIGURE. A and B, Nasopharyngoscopy of a patient with postoperative retropharyngeal fluid collection. The asterisk represents the midline of the velopharyngeal port. C, A representative sagittal computed tomographic scan.

several patients experiencing return of their VPI after only a few weeks. Notably, these patients also had a history of head and neck irradiation and chemotherapy. It is important to note that there were a small number of these patients in the present series (n=4). Although we did find statistically significant differences in outcomes across the 3 classes of VPI etiology in this analysis, the low number of patients with a history of malignancy made it difficult to compare this group with all other etiologies. Further investigation and observation of injection pharyngoplasty in this group of patients is necessary. If there were a notable difference in this population, we surmise that worse outcomes in this group would be multifactorial, but likely in part due to poor local blood flow and alteration of tissue planes after radiation and chemotherapy. With reduced perfusion and impaired immunologic reaction, the stimulation of collagen synthesis and fibroblast influx by the dextranomer component may not have occurred to the same degree as in nonradiated patients. If this were true, the bulking effect would dissipate as the hyaluronic acid component was absorbed. Also, tissue planes may be distorted in a radiated field, making injection into the submucosal plane more difficult and allowing dispersion of the injected material rather than localized bulking.

In the present series, 6 patients received repeated injections. Some patients received repeated injections after their symptoms gradually returned and gap size increased, and others received repeated injections soon after the first injection, likely because an insufficient amount of material was injected. Because our institution is a tertiary referral center, many of the present patients come from long distances and follow up with local providers if they are doing well or delay follow-up until they need to travel again for other health issues. Therefore, the follow-up data in this cohort were too variable to estimate the expected durability of Dx/HA injections in the

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velopharynx. In the urologic literature, some patients required several injections to achieve successful treatment of their vesicoureteral reflux, but more than 95% of those patients continued to be reflux free 2 to 5 years later, indicating that Dx/HA has the potential for long-lasting effect in a similar anatomic scenario.[20] The same may hold true with injection pharyngoplasty, and several patients in this series did have good results lasting more than 2 years. However, this series is unable to statistically validate that possibility.

Among the 33 injections in the series, there were 2 major complications (6.1%) and 3 minor complications (9.1%). The most severe were 2 cases of a delayed and asymptomatic retropharyngeal fluid collection identified during routine follow-up examination. These seemed to be inflammatory fluid collections rather than infections because of the absence of pain, fever, or leukocytosis. Neither of these patients had recurrence of the fluid collection after transoral incision and drainage. A search of the urologic literature did not identify a report of similar fluid collections. The 3 minor complications were related to postoperative pain. One patient experienced an exacerbation of neck spasms that required muscle relaxant therapy as an outpatient. Two patients were admitted to the hospital for pain control, and 1 of these experienced nausea, vomiting, and aspiration likely as a result of opiate use. These events led to the use of oral ketorolac as a stronger alternative to over-the-counter nonsteroidal anti-inflammatory drugs. Reports of severe postoperative pain were much reduced with this practice, and there were no bleeding-related complications.

Another shift in our treatment was that initially, most patients underwent injection under local anesthesia in the office or general anesthesia. As our experience grew, the preferred method of injection became a combination of local anesthesia and light sedation in the operating room. This allowed the patient to provide speech samples to titrate the volume of injection required to achieve complete closure in a more comfortable setting than awake injections in the office.

This study primarily investigated voice-related manifestations of VPI using a subjective scale of patient nasal resonance commonly used in the literature: mild, moderate, or severe hypernasality. Objective nasometry data were obtained on most patients in this cohort. However, nasometry data must be analyzed carefully in this population, which often has concomitant dysarthrias and speech distortions that make comparing nasalance scores between patients challenging. It is likely that the reduction in nasalance scores in patients did not always match the perceptual resonance improvements due to these additional speech disorders. Although no quantitative measurement of patient satisfaction was obtained, our experience is that satisfaction aligned more with perceptual resonance than with nasalance scores.

It is important to note some limitations of this study. Because of the novel use of Dx/HA in the treatment of VPI, this study was not powered to perform robust statistical analyses and evaluate subgroups or perform multivariate analysis, although we identified areas for future investigation. Follow-up of these patients was variable, and the longevity of the injection is not completely understood, although some patients had excellent results for more than 2 years. In the future, these patients will continue to be followed up with an eye toward the longevity of their symptom improvement and what factors may predispose a patient to needing repeated injections. Furthermore, we have begun to use patient quality-of-life surveys, such as the VPI Effects on Life Outcomes instrument,[21] to better understand patient satisfaction and perceptions. In addition, this study did not analyze non–speech-related manifestations of VPI, such as nasal regurgitation and associated dysphagia. We hope to collect more detailed data on these aspects to more completely define quality-of-life outcomes in the future. Finally, we hope that this study spurs controlled comparisons of Dx/HA with other materials used in injection pharyngoplasty, such as autologous fat, which would be extremely beneficial to the literature.

CONCLUSION

The Dx/HA has been used with success in the treatment of vesicoureteral reflux for many years and has demonstrated safety and efficacy in that setting. In this initial series of patients, we found improved speech hypernasality,

nasalance, and velopharyngeal gap size after injection pharyngoplasty with Dx/HA in adults. Patients with a neurologic etiology or benign anatomic deficiency, adequate lateral wall motion, and a small to medium-sized velopharyngeal gap seem to be the best candidates for this treatment. Patients with VPI after treatment of malignancy and those with absent lateral wall motion had poorer results in this small series. Complications after injection included postoperative pain and 2 patients with fluid collections in the retropharynx. The preferred method of injection was under local anesthesia or light sedation, which allowed the patient to provide real-time speech samples and facilitated precise placement of Dx/HA to achieve complete velopharyngeal closure.

Abbreviations and Acronyms: **Dx/HA** = hyaluronic acid and dextranomer copolymer; **VPI** = velopharyngeal insufficiency

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