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Conflict of interest: None declared.

Funding: No funding sources

## Abstract

Unilateral vocal fold paralysis (UVFP) is a condition characterized by impaired vocal fold movement, leading to significant voice, breathing, and swallowing difficulties. Transoral injection laryngoplasty (TIL) with hyaluronic acid (HA) has emerged as a minimally invasive and effective intervention for restoring vocal fold closure and improving phonatory outcomes in patients with UVFP. This review article examines the current evidence on the use of HA for TIL, highlighting its biomechanical properties, safety profile, and efficacy in achieving durable vocal fold medialization. Key clinical outcomes, including voice quality improvements, procedural techniques, and patient-reported satisfaction, are critically analyzed. Additionally, this review explores the limitations of HA-based laryngoplasty, such as variability in resorption rates, and compares its performance to other injectable materials. Future directions for optimizing HA formulations and integrating advanced imaging techniques for precise injection are also discussed. Injection laryngoplasty is a widely used procedure for managing unilateral vocal fold paralysis (UVFP), aiming to improve voice quality, glottal competence, and airway protection. Despite its efficacy, the procedure is associated with a range of complications that can affect outcomes and patient satisfaction. This review explores the complications of injection laryngoplasty, including procedural risks, material-related issues, and long-term effects. Common procedural complications include pain, bleeding, and vocal fold overinjection, leading to airway obstruction or phonatory instability. Material-related issues such as granuloma formation, foreign body reactions, and migration of injectable materials are significant concerns. Long-term complications include scarring, recurrent paralysis, and diminished effectiveness, necessitating repeat interventions. Additionally, rare but severe risks like infection and allergic reactions have been documented. Factors contributing to complications include the choice of injectable material, injection technique, and patient-specific variables such as comorbidities and vocal fold anatomy. Strategies to minimize these risks include the use of advanced imaging for precise delivery, selecting biocompatible materials, and individualized patient assessment. By synthesizing current evidence, this review highlights

the importance of a multidisciplinary approach to optimize outcomes and mitigate complications in injection laryngoplasty. Future research should focus on novel materials and techniques to enhance procedural safety and effectiveness.

**Keywords:** Injection Laryngoplasty, Complications

Regul Sci.™ 2023; 9(1): 8789 - 8796

DOI: [doi.org/10.18001/TRS.9.1.624](https://doi.org/10.18001/TRS.9.1.624)

## Introduction

Unilateral vocal fold paralysis (UVFP) is a common laryngeal disorder characterized by immobility of one vocal fold due to nerve injury or dysfunction. The condition leads to significant voice, breathing, and swallowing impairments, adversely affecting the patient's quality of life (1). Various treatment options exist, but injection laryngoplasty has emerged as a minimally invasive and effective therapeutic approach.

Hyaluronic acid (HA) is a biocompatible and biodegradable substance that has gained prominence as an injectable material for vocal fold augmentation. Its unique viscoelastic properties make it well-suited for restoring glottic closure and improving voice outcomes (2). The application of HA in injection laryngoplasty has demonstrated considerable efficacy in addressing UVFP-related symptoms.

The primary goal of HA injection laryngoplasty is to reposition the paralyzed vocal fold closer to the midline, thereby improving glottal closure during phonation (3). This approach is particularly beneficial for patients with mild to moderate glottal insufficiency who wish to avoid more invasive surgical interventions.

HA injection is typically performed under local anesthesia in an outpatient setting, offering several advantages over open surgical techniques. The procedure is quick, requires minimal recovery time, and has a low complication rate (4). Moreover, HA's ability to integrate seamlessly into vocal fold tissues contributes to its effectiveness and durability.

The efficacy of HA injection laryngoplasty has been supported by multiple clinical studies. Patients often report significant improvements in voice quality, vocal intensity, and reduced vocal fatigue post-procedure (5). These outcomes underscore the utility of HA as a preferred material for injection laryngoplasty in UVFP.

While HA injection provides immediate benefits, it is also associated with certain limitations. The resorption of HA over time necessitates repeat injections for sustained results, which may increase overall treatment costs (6). Additionally, precise injection techniques are required to avoid overcorrection or undercorrection, which could adversely impact voice quality.

Advancements in imaging and delivery systems have enhanced the precision and safety of HA injection laryngoplasty. Ultrasound and electromyography-guided techniques enable real-time visualization and localization of the injection site, reducing procedural risks and optimizing outcomes (7).

## Injection Laryngoplasty for Unilateral Vocal Fold Paralysis: A Comprehensive Review of Complications

The role of HA injection laryngoplasty extends beyond primary treatment. It is also employed as a diagnostic tool to predict the potential success of permanent medialization procedures, such as thyroplasty (8). This predictive capability adds to the versatility of HA in the management of UVFP.

Patient selection remains a critical factor in achieving optimal outcomes with HA injection laryngoplasty. Individuals with severe glottal insufficiency or longstanding UVFP may require alternative or adjunctive therapies, such as surgical augmentation or reinnervation techniques (9). A comprehensive evaluation is essential to tailor the treatment approach to individual patient needs.

The cost-effectiveness of HA injection laryngoplasty has been a subject of debate. While the initial cost of the procedure is relatively low, the need for repeated treatments can accumulate over time. However, the minimally invasive nature and immediate symptom relief provided by the procedure often justify its use as a first-line treatment (10).

The potential for allergic reactions or adverse effects with HA injection is minimal due to its biocompatibility. Most complications, such as mild discomfort or temporary voice changes, are transient and resolve without intervention (11). This safety profile further supports the widespread adoption of HA injection laryngoplasty.

Emerging evidence suggests that HA formulations can be modified to enhance their longevity and effectiveness. Cross-linking techniques and other advancements in HA technology may reduce the frequency of repeat injections, addressing one of the main limitations of the procedure (12).

Comparison studies between HA and other injectable materials, such as collagen or calcium hydroxylapatite, have highlighted HA's superior performance in terms of biocompatibility and patient outcomes. These findings reinforce its role as a preferred option for injection laryngoplasty (13).

The integration of HA injection laryngoplasty into multidisciplinary care models for UVFP has improved patient management. Collaboration among otolaryngologists, speech therapists, and other specialists ensures comprehensive care and optimal outcomes (14).

### Approaches of Injection Laryngoplasty

Injection laryngoplasty (IL) is a minimally invasive procedure commonly used to treat unilateral vocal fold paralysis (UVFP) and glottic insufficiency. By injecting biocompatible materials into the vocal folds, the procedure aims to improve glottal closure, enhance vocal quality, and prevent aspiration. The effectiveness of IL depends significantly on the approach used, which varies based on patient anatomy, clinical goals, and the surgeon's expertise.

The transoral approach is a traditional method for IL. Utilizing a rigid laryngoscope, the injection is performed under direct visualization. This technique provides excellent visibility and precision in material placement but often requires general anesthesia and may not be suitable for patients with limited neck mobility or other contraindications to anesthesia (1).

The transcutaneous approach involves injecting through the neck skin. It is performed under local anesthesia and can be done in-office, reducing the need for general anesthesia. Common routes

## Injection Laryngoplasty for Unilateral Vocal Fold Paralysis: A Comprehensive Review of Complications

include cricothyroid, thyrohyoid, and lateral approaches. The thyrohyoid approach offers direct access to the vocal folds, making it particularly popular among clinicians (2).

Advancements in flexible endoscopic techniques have introduced a more patient-friendly option for IL. The flexible transnasal approach uses a nasopharyngoscope for visualization and allows injections under topical anesthesia. This method minimizes patient discomfort and is ideal for outpatient settings (3).

Another innovative approach is the use of robotics and computer-assisted navigation for IL. Robotic-assisted IL improves precision and reduces variability in injection placement. Although not widely adopted, this technique holds potential for future clinical applications, particularly in complex cases (4).

The choice of approach is influenced by the patient's condition and procedural goals. For instance, in cases of bilateral vocal fold paralysis, careful consideration of the injection route is critical to avoid airway obstruction. Similarly, post-thyroidectomy paralysis may benefit from the transcutaneous approach due to its minimally invasive nature (5).

Injection materials also play a crucial role in determining the approach. Temporary materials like hyaluronic acid are often injected using flexible or transcutaneous methods, while permanent materials such as calcium hydroxylapatite might necessitate more precise placement using the transoral approach (6).

The efficacy of different approaches has been compared in numerous studies. Research suggests that the flexible transnasal and thyrohyoid techniques offer comparable outcomes, with shorter recovery times and less procedural discomfort than the traditional transoral approach (7).

Complications associated with each approach must also be considered. The transoral route carries a risk of mucosal injury due to the use of rigid instruments. The transcutaneous approach, while minimally invasive, may result in temporary bruising or hematoma. Flexible endoscopic methods are associated with minimal complications, primarily transient discomfort during the procedure (8).

Advances in imaging techniques, such as ultrasound-guided injections, have enhanced the accuracy of transcutaneous approaches. Ultrasound guidance provides real-time visualization, ensuring proper placement of the injectable material and reducing the likelihood of complications (9).

Training and surgeon experience significantly impact the choice and success of the approach. Studies emphasize the need for adequate training in flexible and transcutaneous methods to achieve optimal results. Simulation-based training has been shown to improve the precision and confidence of clinicians performing IL (10).

Patient preference is an increasingly important consideration in selecting the approach. Flexible endoscopic methods are generally favored due to their reduced invasiveness and the ability to perform the procedure without general anesthesia, leading to improved patient satisfaction (11).

Cost-effectiveness is another factor in determining the approach. Office-based techniques like the flexible transnasal and transcutaneous methods are more economical compared to operating room-based procedures, making them accessible to a broader patient population (12).

## Injection Laryngoplasty for Unilateral Vocal Fold Paralysis: A Comprehensive Review of Complications

The future of IL approaches includes the integration of artificial intelligence (AI) and augmented reality (AR) to enhance precision and reduce procedural errors. Preliminary studies suggest that AI-assisted techniques could optimize injection site selection and improve long-term outcomes (13).

Future research in HA injection laryngoplasty should focus on long-term outcomes, cost-effectiveness analyses, and innovations in material science. These efforts will further establish its role as a cornerstone in the minimally invasive treatment of UVFP (15).

### Complications of Injection Laryngoplasty

Injection laryngoplasty is a widely utilized treatment for glottal insufficiency, particularly in cases of vocal fold paralysis or atrophy. While effective, the procedure is not without risks and potential complications, which vary depending on the material used, the injection technique, and patient-specific factors (16). Understanding these complications is critical to optimizing patient outcomes and minimizing risks.

One of the most commonly reported complications is overcorrection or undercorrection of glottal closure. Overcorrection can result in excessive medialization, leading to strain or impaired vocal fold vibration, while undercorrection may fail to achieve adequate glottal closure, leaving symptoms unresolved (17). These issues often arise from inaccurate injection or miscalculation of the required volume.

Injection site complications, such as granuloma formation or tissue irritation, can also occur. Granulomas are inflammatory responses to the injected material, particularly with non-biocompatible or poorly absorbed substances. These lesions can cause persistent hoarseness or airway obstruction in severe cases (18).

Infection is a rare but serious complication of injection laryngoplasty. Proper sterilization protocols and aseptic techniques significantly reduce the risk, but patients with immunocompromised conditions or pre-existing infections are at a higher risk (19). Post-procedural symptoms such as fever, swelling, or increasing pain may indicate an infection and warrant immediate intervention (20).

Vocal fold scarring is another potential adverse effect, particularly with certain injectable materials. Scarring can lead to stiffness of the vocal fold tissue and long-term changes in voice quality (21). The choice of material plays a significant role in mitigating this risk, with hyaluronic acid being favored for its biocompatibility and minimal tissue reactivity (22).

Material migration or displacement is an uncommon but possible complication. Injected substances may shift from the intended site, particularly in dynamic regions like the larynx. This migration can result in uneven vocal fold contours or loss of the intended therapeutic effect (23).

Airway obstruction, though rare, is a critical complication requiring immediate attention. Excessive injection volume or misplaced material can encroach on the airway, causing respiratory distress. Emergency management, such as endoscopic intervention or tracheostomy, may be necessary in severe cases (24).

## Injection Laryngoplasty for Unilateral Vocal Fold Paralysis: A Comprehensive Review of Complications

Patients may also experience transient side effects, including soreness, mild edema, or temporary voice changes following the procedure. These effects usually resolve spontaneously within days to weeks (25). However, persistent or worsening symptoms may indicate underlying complications (26).

The use of imaging guidance, such as ultrasound or videoendoscopy, has been shown to reduce the incidence of complications by ensuring precise placement of the injectable material (27). Additionally, pre-procedural evaluation of vocal fold anatomy and function is essential for individualized treatment planning (28).

Allergic reactions to injectable materials, although rare, are possible. Symptoms may range from mild localized reactions to severe anaphylaxis. Pre-procedural screening for allergies and using highly purified, biocompatible materials can mitigate this risk (29).

The longevity of injectable materials varies, influencing the need for repeat procedures and associated risks. Materials that degrade rapidly may necessitate frequent reinjections, increasing the cumulative risk of complications (30). Conversely, long-lasting materials carry the risk of persistent adverse effects if complications arise (31).

Injection laryngoplasty may be complicated by technical difficulties, particularly in cases with challenging anatomy or severe glottal insufficiency. Expertise in laryngoscopic techniques and familiarity with different injection approaches are critical to overcoming these challenges (32).

Voice changes following injection laryngoplasty are often intended but can sometimes be undesirable. Dysphonia, breathiness, or changes in pitch may occur, particularly if the injection is not optimally placed. These changes can impact professional voice users more significantly (33).

Patient factors, such as age, comorbidities, and previous laryngeal surgeries, can influence the risk of complications. Older patients or those with complex medical histories may require additional precautions and tailored approaches to minimize risks (34).

Cost and accessibility of materials also play a role in procedural complications. Inferior-quality or poorly sourced materials may increase the likelihood of adverse reactions. Standardizing the quality of materials used in injection laryngoplasty is essential to ensuring safety and effectiveness (35).

In cases where complications arise, prompt identification and management are crucial. Interventions may range from conservative measures, such as observation and voice therapy, to surgical correction in severe cases (36). Follow-up care and monitoring are essential components of successful treatment (37).

Emerging technologies and techniques, such as 3D imaging and robotic-assisted injections, hold promise for reducing complications and improving outcomes in injection laryngoplasty (38). These advancements may offer greater precision and control in the future (39).

Clinical guidelines and training programs for injection laryngoplasty emphasize the importance of technique, material selection, and patient education in minimizing complications. Adherence to these best practices can significantly improve procedural safety (40).

## Injection Laryngoplasty for Unilateral Vocal Fold Paralysis: A Comprehensive Review of Complications

Research into novel materials and delivery systems continues to expand the field of injection laryngoplasty. Innovations aim to enhance material durability, biocompatibility, and ease of use while minimizing complications (41). Future studies should also focus on long-term outcomes and patient satisfaction (42).

Patient education is a critical aspect of managing expectations and recognizing potential complications. Informing patients about the risks, benefits, and signs of complications ensures they can seek timely care if needed, contributing to overall procedural success (43).

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